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CHANGES IN CARDIAC RATE DURING COMPLEX MENTAL ACTIVITY

by

Robert A. Meyer

A Dissertation Submitted to the Faculty of the Graduate School
of Loyola University in Partial Fulfillment of
the Requirements for the Degree of
Doctor of Philosophy

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LIFE

Robert A. Meyer was born on July 2, 1931 in Chicago, Illinois, and he enrolled in September, 1949 in the College of Arts and Sciences, Loyola University, Chicago.

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CHAPTER I

STATEMENT OF THE PROBLEM

The purpose of this study is twofold: first, to describe and analyze the sequential organization of complex mental processes (problem solving) in efficient and inefficient problem solvers, and secondly, to investigate the relationship between a specific physiological factor and the psychological variables that are operating during the problem solving situation. Two pilot studies already have been completed with these general goals in mind, and their results have given specific direction to this study (Rimoldi, Meyer, Meyer and Fogliatto, 1962; Rimoldi and Meyer, 1963). In general, this study has concerned itself with two distinct problems and a sub-problem relating the two of them, that is, the problem solving tasks and the problem of autonomic arousal to a specific stimulus. These two problems then are related in terms of the construct of efficiency in that efficiency can be related to problem solving and it can be related to autonomic arousal.

Historically, these two problems and the related problem of efficiency have been approached in many different ways. For example, the construct efficiency has been defined by many people from different points of view. Efficiency on a task has been defined in terms of accuracy, speed, redundant behavior and correct solution on a task or problem. Then again this construct has been handled by attempts to get at the underlying variables or factors that enhance or inhibit it. Buswell (1956) states that efficient problem solvers are distinguished from inefficient problem

solvers not in terms of their mental ability but in terms of their self-confidence. Brunner, Goodnow and Austing (1956) in their study also believed that lack of confidence in subjects led to inefficiency on a concept formation task. John (1957) found several personality factors such as self-confidence, anxiety and compulsiveness that contributed to a subject's efficiency on a complex problem solving task. Blatt (1961) operationally defined efficiency in his group of subjects in terms of redundancy of behavior, that is, the more redundant questions a subject asked in solving a problem, the less efficient he was. Wertheimer (1959) also recognized that the "right mood" (p.64) of the subject will influence his efficiency on an intellectual task. Luchins (1942) and Frenkel-Brunswik (1949) suspected that anxiety, fear, threat, rigidity, etc., all influenced the efficiency of a subject on a task. There are also numerous experiments, one of which was Beier's (1951), that demonstrated the effects of induced stress or anxiety on the efficiency of subjects in tasks of abstract reasoning.

Again the problems of cognition and problem solving have been approached historically from different points of view. The most rigid, behavioristic approach would be through the analysis of responses to a task or problem. However Rimoldi has pointed out that if it is true that most psychologists are interested in only analyzing responses

then we are at a loss to interpret most of the psychological literature in which either explicitly or implicitly an effort is made to infer, from test scores, or test answers, the kind of mental processes in relation to which the given answers are, in all likelihood, a final product. (1960)

Historically the importance of analyzing process and product rather than product alone in problem solving behavior has been demonstrated. Although Wertheimer (1959) and Dunker (1945) essentially worked with the products of problem solving behavior, by resorting to introspection and retrospection they made certain inferences about the process of problem solving. Bloom and Broder (1950) also believed that the product and the process of problem solving complement one another in giving an accurate evaluation of a subject, and they attempted to get at this process by the same method as Dunker, that is, they had their subjects introspect or "think aloud" while solving the problems. Glaser, Damrin and Gardner (1954) have attempted to quantify the process a subject goes through in a task concerning electronic trouble shooting. Basically the subjects ask questions and receive answers to these questions which they must integrate and assimilate in order to arrive at the solution to the problem. For the purpose of this study, the task of quantifying the process of problem solving has been described by Rimoldi and Haley where they say that

a process is experimentally characterized by the sequence of questions asked by the subject. Any characterization of the process should include at least number of choices (of questions) made, type of choices and their order. The same questions may have an entirely different meaning according to the questions previously asked. It is assumed that at every successive step the problem changes, and that what the subject knows and what he may still want to know is not a fixed property of the problem but varies as the solution develops. (1962)

Thus for the purpose of this study, the Rimoldi technique will be employed to analyze the process the subjects go through in order to solve a problem. (see Chapter III, Procedure).

It is interesting to note that although psychology in the Soviet Union appears to be extremely behavioristic due to Pavlovian influences, Zhinkin (1958) severely criticizes several American scientists who attempt to simulate human thinking through the use of computers. He criticizes them because they attempt to evade a specific issue by reserving for the machine the function of responses whereas a thinking person is capable also of asking questions. He continues to say that if this element of asking questions were to be deleted from the process of thinking, there wouldn't be any thinking.

The second part of this study is related to autonomic arousal and its relationship to efficient problem solving. Heart rate was selected as the response measure of autonomic arousal because previous research indicates that it is sensitive to a variety of stimuli. For example, Ford (1953) demonstrated that lying supine on a cot and performing arithmetical computations which required no speech or bodily movements increased the electrical output of the heart and in the majority of the subjects produced a more rapid heart rate. During work on a clerical test, heart rate was higher during work periods than during rest periods, and higher when the individual was working under distracting stimuli than when he was working under conditions of quiet --- in spite of the fact that there was no decrease in efficiency of the performance under distraction (Bitterman and Soloway, 1946). According to a review by Altshule (1953), "startle, anxiety, tension and apprehension may increase cardiac output by two-thirds and occasionally by more."

The hypothesis that efficiency in certain tasks is functionally related to autonomic arousal has been repeatedly reported in several studies. Freeman (1940) demonstrated that efficiency in reaction time and its relationship to G.S.R. produced an inverted U-shaped curve. As efficiency in reaction time increases, autonomic arousal increased. Malmö (1957) describes "several experiments that demonstrate significant relationships between muscle-potential gradients and level of palmar skin conductance and excellence of performance on various motor tasks, such as mirror tracing and tracking." Duffy (1957) also reports that the curve which expresses the relationship between autonomic arousal and quality of performance takes the form of an inverted U. A similar functional relationship between reaction time and E.E.G. was reported by Lansing, Schwartz and Lindsley (1956). Blatt (1961) also found a highly significant increase in heart rate in efficient subjects while they were attempting to solve a complex, abstract problem.

Thus in summary, it has been demonstrated that the problem of efficiency on a task such as problem solving can be approached from several different perspectives, that is, the process of problem solving can be analyzed rather than just analyzing the correctness or incorrectness of the response to a problem. Also previous research has indicated that efficiency on a task may be related to autonomic arousal.

The purpose of this study is to analyze and characterize the process that a group of efficient and inefficient subjects go through in solving a problem. (See Chapter III for the criterion of efficiency in this study.) Another purpose of this study is to see how autonomic

arousal, measured in terms of heart rate, is related to the efficiency or inefficiency of the subjects in the problem solving situation, and also what variable in the problem solving task contributes to the change in heart rate in the subjects. On this basis, several general hypotheses will be tested in this study: 1) problem solving as a task will produce an increment in heart rate in both groups of problem solvers when compared to their baseline periods, and that there will be more of an increment in heart rate in the efficient problem solvers than in the inefficient problem solvers, 2) the increment in heart rate will take place while the subject is trying to integrate and assimilate the information he has requested in solving the problem, that is, during the "question period" (see Chapter III, Procedure), and 3) in analyzing the problem solving process, the efficient subjects will do better and significantly so in solving the experimental problem than the inefficient subjects.

CHAPTER II

REVIEW OF THE LITERATURE

This review of related research is divided into two separate areas; first, the historical and contemporary research that has been conducted in the field of problem solving, especially that research that attempted to get at the process underlying problem solving behavior; secondly, the historical and contemporary research that has investigated the relationship between efficiency on a task and autonomic arousal.

Cognition and problem solving behavior has been a field of interest to psychologists from the beginning of their scientific history. More complete reviews of this field has been done by Chaplin and Krawiec, (1960), Johnson, (1955), and Vinacke, (1952).

The early period in the study of problem solving was characterized by observing problem solving behavior, describing it, and making inferences based usually upon the solution of the problem. This approach can be exemplified best by the early studies of James (1890), Thorndike (1911), Dewey (1933), Köhler (1927), Dunker (1945) and Wertheimer (1959). For example, Dunker's (1926; 1945) contributions to the area of problem solving are classical, yet it is clear that his primary concern was less with classical experimentation in this field rather than a broader, empirical approach to the problem through observation of problem solving behavior. In his research he presented special problems to his subjects and requested that they "think aloud" while solving the problems. It is important to note that this method differs from classical introspection

in that his subjects were not trained to search and analyze their "mental content", but that they were required to verbalize what they were doing.

Dunker concluded from his observations that the process of solving a problem has two basic aspects: first, the solution must be analyzed, and secondly, the goal must be analyzed. In order to arrive at a solution to a problem, the subject must discover the conflicting elements of the situation because the relationship between certain elements in the problem will have to be manipulated. The subject must also analyze the goal of the problem in that he must consider what tactics must be employed in order to arrive at this goal.

Solutions obtained by this analytic method were interpreted by Dunker as being rational, whereas solutions obtained by "resonance" were considered less rational. He defines cognitive resonance as a perceptual-cognitive manner by which the present problem is related to the tactics learned in past experience, and apparently he feels that the resonance due to past experiences of problem solving hinders the subject in arriving at an appropriate solution to the problem.

There is little doubt about the importance of Dunker's contribution to the area of problem solving and cognition if it is understood that his particular problems were constructed specifically to illustrate some of his contentions about the process of problem solving. One criticism of Dunker's methodology is that asking his subjects to "think aloud" or verbalize what they were thinking while solving the problem may really inhibit or slow down the subject's thought processes. The subjects' verbalizations were not classical introspections in the sense

that they would seek out or search for specific "mental content", and he may have made more precise observations if he employed trained subjects to introspect while they were solving the problems. Also the inferences made by Dunker concerning the efficiency of problem solving should be put to a more rigidly, controlled experimental test.

Wertheimer (1959), like Dunker explored the area of problem solving from a broad, empirical approach rather than confine himself to a rigid experimental design. From his observations, he concluded that productive thinking primarily depends upon an understanding of the structural and functional relationships of the problem solving situation. However valid his conclusions are, based upon observation, his principles or postulates of problem solving should be subjected to a more highly controlled experimental design.

In their book, A Study of Thinking, Bruner, Goodnow and Austin (1956) went through an elaborate description of the process of concept formation. They explicitly stated that their aim was "to externalize for observation as many of the decisions as could possibly be brought into the open in the hope that regularities in these decisions might provide the basis for making inferences about the processes involved in learning or attaining a concept. These regularities in decision-making we shall call strategies."

The primary method used by the authors was to present a concept attainment task to each subject where they were to develop a specific concept by employing four attributes each with three values specifically illustrated in an array of eighty-one cards each varying in shape

of figure, number of figures, color of figure, and number of borders. On the basis of the observations made on their subjects, they concluded that their subjects employed various combinations of four strategies: simultaneous scanning, successive scanning, conservative focusing and focus gambling. On this basis, they arrived at a major conclusion that their subjects usually adhered to particular patterns of approach and that their behavior was not random but they behaved in a highly rational manner.

The method of observing the process of concept formation developed by the authors is certainly unique and promising, however in spite of the fact that the authors state in the second part of their book that they have presented twenty experiments on concept attainment under a variety of conditions, it is hardly true that these experiments are more than observations of subjects solving problems with little mention of any variables they had attempted to control. For example, little is known about the subjects except that they were Harvard or Wellesley undergraduate students. While some of their results were interesting, the almost complete lack of statistical analysis leaves them open to further experimental analysis.

In their monograph on problem solving, Bloom and Broder (1950) explicitly state as their aim that they wish to understand more about the nature of problems and the cognitive processes involved in problem solving. In a series of studies, they were interested in exploring the nature of the problem solving process, in comparing successful and non-successful problem solvers and in developing and improving problem

solving behavior in poor problem solvers.

Their method was similar to Dunker's, in that they would have their subjects "think aloud" or verbalize their thoughts while working on a problem. They then analyzed the verbatim records of each subject's verbalization, plus the results of several check lists and also the final solution to the problems.

The results of their studies indicated that they could accurately describe the different approaches employed by various subjects, and that they could distinguish successful from non-successful problem solvers on the basis of their approach. One major observation they made concerning the efficiency of problem solvers was that their attitude toward the problem solving tasks greatly influenced their efficiency. These attitudes were directed primarily toward their reasoning ability and their confidence in problem solving situations. They also found that they could improve the problem solving ability of the unsuccessful subjects by helping them individually and in small groups where the subjects could handle these problems, see the different approaches of different people and observe and compare their inadequate approaches with those that were more successful.

Bloom and Broder's contribution to psychology in the area of problem solving has been valuable especially where they emphasized process and product rather than product alone as important factors in problem solving. Since their analysis of their data was primarily descriptive in nature, it would be interesting to see the results of some highly controlled experiments based upon their observations.

In another study that tries to get at the underlying process of problem solving behavior, Glaser, Damrin and Gardner (1954) developed the Tab Item technique which was designed specifically to measure a mechanics proficiency in solving problems of a "trouble-shooting" type that were related to the maintenance of a radar-computer system. The materials presented in the Tab Item consisted of the following: 1) the symptoms of the set malfunctioning, 2) the check procedures, 3) the results of the check procedures, and 4) the possible defective components. The subjects to be evaluated then go through the items selecting those they feel pertinent to the problem and select as many items as they feel necessary to arrive at a specific solution. The types of items available to subjects were classified into various categories: relevant, additional, redundant, inadequate and irrelevant. A variety of scoring procedures can be employed in analyzing their results, for example, a straight frequency count of the number of items pulled or a weighted error count wherein the procedures and units which can be selected are weighted in inverse relation to their relevance in isolating the defective unit.

Because the article was only descriptive of this particular method, no analysis of available data was presented, hence it is impossible to ascertain the validity or reliability of this particular method of assessment regardless of how unique or interesting the technique appears to be.

In Buswell's (1956) study on problem solving, process again was emphasized rather than product alone. His main purpose was to see if there

were specific patterns or tactics used by problem solvers or whether problem solving approaches were so specific to each individual that only an idiographic description of each subject can be made.

He administered arithmetical problems to 499 subjects on a group and individual basis --- four group problems and two individually administered problems. His tests consisted of 38 items or cards that contained the essential information necessary to solve the problems. This information was divided into two types: algebraic information or information based upon logical reasoning. The subjects were then allowed to choose the type of information they wished in order to solve the specific problem, and the amount and type of information chosen allowed Buswell to quantify the subjects' processes while solving the problems. These results led him to confirm objectively what others had said descriptively in other studies, that is, that the process of problem solving is directly related to efficiency in problem solving. He also found that there were no clear-cut uniform approaches to the problem but rather than individual tactics overlapped and that there were a variety of approaches to the specific problem, however, some tactics proved to be more effective than others.

Zhinkin (1958) attempted to use information theory as a method of analysis for problem solving data, however his research has been more or less theoretical, and no experimental application of his idea was made. It is interesting that Soviet psychologists have not emphasized an empirical or experimental approach to the area of cognition and problem solving, but rather they try to explain cognition in a philosophical framework.

Georgiyev (1955) tries at great length to get at the underlying basis of sensory and rational cognition. What he calls sensory cognition, he interprets neurologically, and what he calls rational cognition, he interprets by philosophical speculation. A comprehensive study on cognition in the Soviet Union was made by Anan'ev, Vekker, Lomov and Yarmolenko (1959), yet even here cognition was treated as an epistemological problem rather than investigated from an experimental approach.

The Development and Application of the Rimoldi Technique

The early history of this technique was established when Rimoldi (1955) developed an objective method of analyzing problem solving behavior by observing the "number, type and sequence of questions asked by a subject in solving a problem, the main purpose being to analyze the process of thinking rather than its end product as indicated by a certain answer." Using this study as a point of origin, it can be seen that the Rimoldi technique has gone through an extensive period of evolution in terms of application of the method and the theoretical assumptions and methods of quantifying the observed data.

One of the first applications of this technique was made by Rimoldi, Haley, and Fogliatto (1962) in their study on the Test of Diagnostic Skills which was developed in order to provide "instruments to be used for evaluation, and if possible, training of medical students."

In this study, the authors explicitly stated that

an approach to the study of diagnostic ability could be made by studying the sequences of questions asked by a physician to solve a clinical problem. This could give cues as to the use of the information obtained, hypotheses made, their verification, their acceptance or rejection, conditions and situations under which they are changed, etc.

For this purpose, seven medical tests were constructed, two of which were thoroughly analyzed. These tests were administered to 41 physicians, 127 senior medical students and 89 junior medical students. The subjects were obtained from five different medical schools. A general description of the tests and technique is as follows

The subject receives, for a specified clinical case, the type of information usually available to the physicians from the hospital admission chart, from the patient's complaints, and from other aspects of his clinical history. Removable cards contained in flat pockets which partially overlap are evenly arranged on a display folder. On the top edge of the numbered cards -- we shall call them items -- the questions that the examiner may ask are indicated. These include questions that he might wish to ask of a patient, the manipulative techniques he might wish to use, the diagnostic tests he might order and so forth. By drawing a card and looking at the reverse side the subject gets information that is given in the form of verbal reports, laboratory analysis, X-ray films, etc.

As each item is selected, the experimenter or the subject records the number of the item in numerical sequence.

The data of this study were analyzed in a variety of ways; in terms of the number of items selected, the utility indices, utility scores, agreement scores, pattern analysis and performance curves.

Each of the tests were subdivided into three separate categories: 1) clinical interview, 2) physical examination, and 3) laboratory procedures. In terms of analyzing the number of items selected, it was seen that in comparing the three groups of subjects, junior medical school students selected more cards than senior students who in turn selected more cards than physicians. This provided further evidence that

the most striking change in the diagnostic process with clinical experience was in the interview phase of the process.

The utility score is the average of the sum of the utility indices for the items selected by a given subject, and the utility index is defined as the ratio between the number of subjects who asked a question and the total number of subjects who took the test. The utility score can be interpreted as an estimation of agreement of a subject with the group used for the determination of the utility indices. In analyzing the utility scores of each group, it seems

that seniors apply the strict approach taught in medical school and thus are in more agreement as to which items are useful. The juniors, having had a more limited training tend to agree less among themselves as to which items are useful. The lower mean utility scores for physicians could reflect a certain flexibility of approach or possible concentration on a particular area in their specialized fields.

A pattern analysis of the data indicated that patterns manifested by seniors agreed more with the physicians' patterns than did the patterns of the junior students. This specific technique of pattern analysis was developed by Rimoldi and Grib (1960a; 1960b). An analysis of the performance curves generated by each group showed that physicians obtained more information at each step of the diagnostic process than senior students, and seniors more than juniors.

In evaluating the Test of Diagnostic Skills, there are two important implications stemming from the results of this research, one being the training of medical students and the other being the selection of medical students. It seems that this test could be used as a training device in that a set of problems could be developed whose nature

could be dictated by the specific medical school using this technique. The individual student's performance on the tests could be discussed by student and instructor in that the teacher could use this performance to point out to the student certain pitfalls in his clinical reasoning, etc. Again this test may be used in selecting medical students, and it would be up to each school to decide what the admission criterion should be. On the basis of this criterion, problems could be developed that may be incorporated into an admissions test battery. As it was indicated by the authors, perfect validity is not claimed for this test, and it would be almost impossible to develop a set of predictors to accomplish this. Thus, even though forty-one physicians were used as a criterion group for this study, any application of this test to the actual screening of medical students would have to be made only after more suitable standardized norms were developed on the basis of the admissions criterion of each specific school.

Haley (1960) conducted a study with the Test of Diagnostic Skills where he compared a group of medical students' performances in their junior year with their performances in their senior year. His main interest was focused primarily on changes in performance after a training period.

His subjects were 36 medical students to whom tests numbers 2 and 4 were administered at the end of their junior year. About a year later, the same students were administered the same tests again.

By employing an analysis of variance of tests, administrations and subjects for the number of items selected, he found that the "learning period that took place between the first and second administration is a real source of variation for the number of items selected." In using the utility scores of 40 physicians who took these tests as norms, he also found that his subjects were more in agreement with these physicians' norms in their senior year than they were in their junior year, and that this group of subjects were more in agreement with themselves as to the utility of items selected in their senior year than they were in their junior year. On the basis of these results, he concluded that the Test of Diagnostic Skills is capable of measuring change during a learning period.

Some may criticize this study because a memory factor was not controlled, that is, both tests were given to the same group of subjects on two different occasions, and there is a possibility that the subjects remembered the items from one occasion to the next, however, this is doubtful because of the intensity of the total testing program in a medical school environment. The subjects may have remembered that they took the tests, but it seems doubtful that they would remember the specific items on the tests to any significant degree.

Another application of the Rimoldi technique was made in a study involving training in problem solving (Rimoldi and Devane, 1961). The purpose of this study was "to explore 1) individual characteristics of problem solving behavior and 2) the extent to which high school students may be trained in problem solving procedures."

Twenty-five pairs of subjects were selected and were matched for intelligence and educational level. One subject from each pair was selected at random to compose the experimental group.

Each member of the experimental group met individually with an investigator every two weeks for a forty-minute training session. The subject was presented with a problem and a number of questions he might employ in working toward a solution. A record was kept of the order in which he chose questions. When he felt he had arrived at a solution, he and the investigator reviewed his performance step by step, while the subject reconsidered his successive decisions. The investigator encouraged the subject to question his own thinking, and to propose alternate methods that he might have employed. The investigator was careful not to evaluate the solution offered. The only criticisms or revisions were those of the subject. The subject's reasoning as he proceeded through the problem and his questioning of his own thinking after reaching a solution were recorded in order to relate his thinking to more objective measures.

The control group received no training between pre and post-testing.

In analyzing the ellipsoids (Rimoldi and Devane, 1961) generated by the experimental and control groups, it was shown that the experimental group after training showed more agreement as to the importance of certain items in the tests than did the control group. "The increased agreement evident here is taken as a reflection of an increased capacity to grasp the salient features of the problem, to delineate its outlines prior to solution, as opposed to a relatively unplanned and less clear delimitation." Also, there was a significant increase in mathematics grades for the experimental group and no change in the control group after training.

One criticism of this study is that the subjects were scored on the basis of norms generated by group performances. However this problem was apparent to the authors because a new technique was developed by which they could control both content and structure of the problem (Rimoldi, Haley, Fogliatto and Erdmann, 1963). This then allows norms to be generated from the intrinsic properties of each specific problem.

A continuation of the study of training in problem solving (Rimoldi, Fogliatto, Haley, Reyes, Erdmann and Zacharia, 1962) and the new development in norms based upon the properties of the problem produced a new method of analyzing problem solving data. Again the purpose of this study was to see the effects of training on problem solving behavior.

One hundred subjects were selected, 52 high school students and 48 college freshmen, and they were divided into experimental and control groups matched on the basis of intelligence and problem solving ability. Forty-one problems were prepared for this study and analyzed by the Rimoldi Technique.

A major finding of the study was that by analyzing

the plateaux (from the curves based on schemata norms), it is clear that both schemata and content contribute significantly to performance, and that training affects both differentially. This seems to follow the same pattern in both high school and college freshmen, though the latter are consistently superior to the former. Since plateaux can be interpreted as indicating defective planning, this may have important connotations in terms of training, and how this training may be expected to be effective in terms of increasing the subject's ability to deal with progressively more complicated sets of logical relationships and/or dealing with material of decreasing familiarity.

The results also indicated that the analysis of the ellipsoids shows that the experimental subjects agree among themselves better than the controls. Also, that college graduate students are, on the whole, better than high school students. The norms used here are based on group performances, and thus cloud individual differences. The importance of this finding is then in showing how training may increase agreement.

In evaluating the results of this study, one important implication is that through training, the problem solving ability of students can be made more effective and that this increment in problem solving ability has had significant effect on improving the students grades especially in the area of mathematics. A major development in the scoring technique was also made in that an objective criterion of efficiency was defined in terms of the intrinsic properties of the problems. However, before future research is conducted with these problems, it is necessary to evaluate the specific difficulty these problems present to subjects of different ages and educational level. This can be done by administering a battery of these problems ranging in degree of difficulty based upon their properties to different age groups from very young children through middle-aged adults to a geriatric sample.

A series of studies has been completed in which the Rimoldi technique has been used to investigate certain clinical problem. One such study was done by Tabor (1959) working with the Rorschach. He states clearly that the purpose of his study was not to validate the Rorschach test or its underlying principles but rather to explore how the Rorschach analyst utilizes this instrument in arriving at a diagnosis.

The primary role of this study was to analyze group patterns of Rorschach analysts and to describe their approach to a diagnostic problem by using the Rimoldi technique.

Tabor selected 30 Rorschach analysts based upon specific criteria of competency. Each subject was asked to analyze three Rorschach protocols, two of which were psychiatric cases and one normal college student. By using Kendall's coefficient of concordance, he interpreted the number of cards selected in terms of the communality of judgments of the analysts, and he felt the W_s that he derived expressed a "definite lawfulness in the order of accumulating diagnostic Rorschach evidence" by his subjects. One interesting finding was that the utility indices of the items of the tests had a "direct relationship with the sequential positioning of the item", especially in that the items that were selected earlier in the sequence tended to have high utility indices.

If Tabor would have employed other groups of Rorschach analysts, such as experts or unsophisticated analysts and made a comparative study such as Rimoldi, Haley and Fogliatto (1962), his study may have been much more meaningful. It is somewhat difficult to understand the significance of his results since he really didn't have an experimentally adequate criterion with which he could compare his group of subjects. Even the ideal sequence that he used may not have provided much meaning to his results since this ideal sequence was based upon his own group's performance, so that he was comparing his subjects with themselves. The study would have been much more fruitful if he could have

obtained protocols from expert Rorschach analysts and then used these protocols as his criterion group.

Mohrbacher (1961) in using the Rimoldi technique stated that his general purpose was to determine the type of clinical information members of three different disciplines that is, psychiatry, psychology and social work, request in forming a diagnosis of organic brain disorder or some alternative diagnosis. Basically the study was an exploratory one rather than a hypothesis-testing experiment.

From a pool of 118 cases, he selected four cases of children having a minimal of intracranial pathology. These four cases served as the basis for developing four tests similar in structure to the Test of Diagnostic Skills (Rimoldi, et al., 1962), and each subject selected items from each test in order to arrive at a diagnosis. The subjects were 20 psychiatrists, 20 psychologists and 20 social workers varying in degree of clinical experience.

Mohrbacher found that the members of each group were quite consistent and homogeneous in terms of selecting specific items in order to arrive at a diagnosis and that the group of psychologists "consistently differed from both psychiatrists and social workers, although the differences were generally of greater statistical significance between psychologists and social workers than the differences between psychologists and psychiatrists. Social workers and psychiatrists, on the other hand, interestingly disclosed a number of similarities in theoretical orientation." This trend indicated that psychologists proceeded to reach a diagnosis in each case with less repetition of overlapping

items and corresponding economy in acquiring information in arriving at a diagnosis. Although the author did not explicitly state this, it seems that the group of psychologists appeared to be more efficient in their problem solving behavior at least in terms of the reduction in using redundant information in developing their diagnoses.

On the basis of Mohrbacher's results, several important implications should be considered. One is that shouldn't it be expected that subjects from three different disciplines would differ in their approach to a diagnostic problem. It seems logical that psychologists would emphasize the importance of testing, social workers would emphasize social case history data and the psychiatrists would be especially interested in medical data, so that the author's results are not too surprising. Another important implication is that the group of psychologists arrived at a diagnosis by using less redundant information than the other two groups, and if these items were analyzed appropriately, this analysis would then provide cues that may be incorporated into the diagnostic training program which then might improve the training program itself. As the author explicitly stated, this study was primarily exploratory in nature, and his results have provided a sound basis for future research with this approach employing a more highly controlled experimental setting.

In another clinical study, Gunn (1962) states that the purpose of his research was to attempt to validate the Rimoldi technique. His general aim was to see if the processes employed by those who were

diagnosed as suffering from emotional disturbances were different from those used by apparently undisturbed persons. He also wanted to determine if highly trained clinicians employed a different approach in solving a diagnostic problem than the less trained clinicians.

Gunn selected 6 trained and 6 untrained psychologists, 10 trained and 10 untrained social workers, 10 bright, 10 uneducated and 10 neurotic subjects for his sample. Each subject attempted each of the three clinical cases developed specifically for this study.

His results suggest that this technique can discriminate between trained and untrained clinicians and between groups of clinicians and subjects not working in the clinical field. Homogeneity of card selection and order of selection was observed in different degrees for each group of subjects, psychologists being the most homogeneous, next social workers, then bright lay people and last uneducated lay people. On this basis, Gunn states that education and level of training does influence a subject's performance on his problems. The neurotic group's performance was so different that they couldn't be analyzed quantitatively.

A major criticism of this study is that the author presents the analysis of his data but he fails to adequately interpret the psychological significance of these results. It is not clear of what importance his results are when considering the original purpose of the study. It isn't clear what Gunn meant when he purported this to be a validity study, but it seems that it was more or less a comparative study of different groups. Also the complexity and length of each test, 130 items,

would prove to present a problem to the subjects in their handling of all the data available to them. It seems that so many items would make it difficult for the subject to select the most important items and assimilate and integrate them. Because of the wealth of clinical information available to the subjects, it might have been more fruitful to allow each subject to generate his own questions about the cases, and analyze these questions asked by the same method.

A unique application of the Rimoldi technique was produced by Meyer (1963) where he investigated the effects of psychotherapy on problem solving behavior. He wanted to "explore the way an individual's approach to a simulated real-life problem is affected by a course of psychotherapy. The emphasis in this investigation is not primarily on the final solution an individual offers, but rather the emphasis is on the particular manner in which he approaches the problem." By the construction of real-life problems and analyzing them by the Rimoldi technique, Meyer hoped to explore whether the approaches to the problems change as a result of psychotherapy and whether there were significant differences between certain problem solvers and judgments of change resulting from treatment.

He stated three null hypotheses that he wished to test: 1) there shouldn't be any differences in approach to a real-life problem by a patient at the beginning of therapy and after therapy has been completed, 2) there shouldn't be any differences between a patient's way of approaching real-life problems and judgments of therapeutically observed change, and 3) if change is measured on the real-life problems,

this change will not be in the direction of his therapist, but rather in the direction of effectiveness, that is, he will become more similar to community subjects.

Meyer's sample of subjects consisted of 33 patients receiving out-patient treatment for a period of 24 weeks on a once a week basis. The final sample consisted of 22 patients. He used a group of 50 subjects not receiving psychotherapy that acted as a quasi-control group. His therapist group was composed of 14 psychotherapists of varying degrees of qualification. The subjects of each group were given three real-life problems and a therapist post-therapy check list. The real-life problems were analyzed with the Rimoldi technique on three different levels; number of cards selected by the subjects, utility scores, and a sequence score. The sequence score for each subject was arrived at by adding the weights for each card chosen when the order of selection was considered and dividing by the number of cards selected. Weights for each question when order of selection was considered were obtained by dividing the frequency with which a card was chosen in a particular order by the sum total number of selections made by the group.

Meyer found that there were no significant changes between pre- and post-therapy problems for the patients in terms of the number of cards selected or the utility scores so that his first hypothesis had to be accepted. The second null hypothesis was rejected in that the patients rated by their therapist as changed did actually change in their approach to the problem in terms of selecting more questions for the problems than the unchanged patients. The third null hypothesis was rejected yet

the alternative hypothesis was accepted with caution in that it wasn't clear whether the change was due possible to identification with the therapists or some other unknown learning process.

It is believed that this was a very carefully planned and well thought out piece of research. The problems researchers encounter when dealing with the variables involved in psychotherapy are multifold and extremely complex. The author went to great lengths to criticize his own study and brought forth an abundant amount of supporting research for his experimental design. He also went to great length to describe the principle of identification of patient to therapist as an important variable in psychotherapy, yet he states that his results are not clear whether they were produced by the patients identifying with their therapists or whether they were artifacts or products of some other uncontrolled variable. Because of the exploratory nature of this study, it is difficult to conclude whether this type of methodology and instrument can effectively be used to discriminate any change taking place in patients in psychotherapy.

Efficiency on Experimental Tasks and Autonomic Arousal

A thorough review on autonomic arousal in its relationship to activating human behavior has recently been published by Duffy (1962), and more theoretical research regarding the underlying assumptions involved in efficiency on a task and autonomic arousal has been presented by Duffy (1957) and Malmo (1957).

One of the earliest studies in this area was conducted by Freeman (1940) where he published the results of three separate experiments illustrating the relationship between performance level and bodily activity level. Specifically he was concerned with the level of palmar skin resistance when individuals are performing above, below, and at their normal 'congenial' pace such as on tasks of finger oscillation and reaction time.

In his first experiment, he made observations upon 20 undergraduates under two conditions: 1) where the individual subject set his own standard of performance, and 2) where the standard of performance was set an arbitrary number of points higher than the individual's averages for the first condition, with failure in meeting the raised standard called to his attention. Both conditions were preceded by a period of relaxation until a measure of palmar skin resistance showed no marked change for five minutes.

His results indicated that the instructions given to the subjects the second time generally were successful in motivating the subjects to increased effort or reactivity.

During the second experiment, Freeman conducted an intensive study on one subject where reaction time and palmar skin resistance were recorded simultaneously in a series of one hundred and five trial observations. The observations were made at various times with the subject in various states of alertness. When the subject's performance was plotted against reactivity, an inverted U-shaped curve was produced, that is, autonomic arousal increased in the subject as his performance

increased up to a point where the subject felt an optimal amount of tension that seemed to facilitate his performance. After that point, the subject experienced more tension and his performance began to drop.

In his third experiment, Freeman was interested in increasing or decreasing motivational effort in reference to the subject's 'normal' or 'congenial' pace. Measures of skin resistance and reaction time or finger oscillation performances were taken under three conditions, that is, where each subject was instructed to work at a comfortable working pace, where he should work above his pace, and where he should work below his pace. Fifteen subjects were observed under these three levels and a relaxation period. His results suggested that changes in skin resistance are more related to subjective effort rather than performance levels per se.

It is interesting to note that research conducted during this period in psychology is almost totally lacking in the analysis of data by inferential statistics, but rather heavy emphasis has been placed upon descriptive analysis through the use of measures of central tendency, correlations and the analysis of curve functions. However, regardless of the lack of statistical sophistication in these experiments by Freeman, his analysis of the relationship between performance on a task and autonomic activity is clearly demonstrated in his second experiment. Perhaps in his first and second observations it is more difficult to arrive at clear conclusions from his results because of a lack of more sophisticated methodology.

Beckman and Stein (1961) investigated the relationship of autonomic arousal and efficiency in problem solving. They explored this relationship by employing the problem solving apparatus developed by John and Rimoldi (John, 1957) with thirty-three subjects. Efficiency was defined in terms of the number of unnecessary questions asked by the subjects. A sample of electroencephalographic recording was taken ten minutes after beginning of the problem solving situation in order to estimate the per cent of alpha time manifested as a measure of autonomic arousal. The rank-order correlation between problem solving efficiency and per cent alpha time was $-.47$, that is, the more efficient problem solvers tended to have less alpha in their resting E.E.G.'s than did the less efficient subjects. On the basis of these results the authors speculate that the more efficient problem solvers may be operating with a generally higher level of "cortical excitation" and are consequently in a state of readiness to integrate external information.

The results of their study may have been more significant if they would have dicotomized their subjects into two groups of efficient and inefficient problem solvers, and then they could have statistically tested to see if the two groups differed significantly in the amount of alpha time they manifested.

A recent study relating autonomic arousal to performance level was conducted by Blatt (1961) in which he investigated the relationship of cardiac arousal to complex problem solving behavior. The following hypotheses were tested in this study: "1) Efficient problem solvers have a higher level of cardiac rate and a greater variability of

of cardiac rate than inefficient ones during complex mental activity.

2) Among efficient problem solvers, elevations in the cardiac rate occur at those points in the thought process at which necessary and sufficient information for solution has become available, at which the predominant activity has changed from analysis to synthesis, and at solution."

Blatt obtained concurrent recordings of heart rate while his subjects attempted to solve problems on the John-Rimoldi Problem Solving Apparatus (PSI). A more detailed description of this electronic problem solving instrument was made in a former research article (Blatt and Stein, 1959). As he specifically states in his second hypothesis, three crucial points in the problem solving process can be identified; the period where sufficient information has been obtained in order to reach a solution, the period where the subject shifts from analytic questions to synthetic questions, and the solution to the problem. Eighteen subjects, first and second year graduate students, were tested on the PSI, and on the basis of their performance on the experimental problem, they were separated in two groups of problem solvers - - nine efficient and nine inefficient problem solvers. The criterion for determining efficiency was the number of unnecessary questions asked by the subjects on the experimental problem. Cardiac rate was then recorded by chest leads throughout the entire experimental session; during the instruction period, the practice problem, the experimental problem and during four interposed rest periods of ten minutes each.

The results of this study supported the first hypothesis stated, that is, efficient problem solvers are significantly more rapid

and variable than inefficient problem solvers in cardiac rate while attempting to cope with a complex cognitive problem. Concerning the second hypothesis, by using "t" tests for correlated distributions, the cardiac rate at the point of necessary and sufficient information, analysis-synthesis shift and solution were compared with the mean cardiac rate of the phase before and after each of these points. Efficient subjects had elevations in cardiac rate at all three points, which were significantly greater than the mean heart rate of the phase that preceded and followed each point. For the inefficient subjects, only one significant difference was noted, between the point of necessary and sufficient information and the mean value of the lag phase. These results then support the hypothesis that elevations in cardiac rate do accompany crucial periods in their problem solving processes.

There is little doubt that Blatt has made a contribution in clarifying some of the problems involved with autonomic arousal and problem solving behavior, yet his study did lack some desirable features, one of which is more rigid control. For example, there was no control for the effects of bodily movement on heart rate increment. At the risk of seeming overly critical, bodily movement does increase heart rate when comparing this period with a period when the subject is at complete rest, that is, how much did listening to instructions or the physical movements employed in solving the problems contribute to increments in heart rate rather than just the cognitive activity of the subjects. Also the problems themselves seemed to be extremely complex and abstract,

and they certainly take much too long to solve considering the one hour time limit and that two of the subjects could not solve the problem during this allotted time limit. The complexity of the problems and the time needed to solve them possibly had produced a good deal of fatigue in the subjects which may have been a variable that confounded the results of the heart rate estimates.

It is experimentally sound to operationally define crucial points in the problem solving process, and it seems logical to consider the points at which a solution is reached and at which sufficient information has been obtained to reach a solution to be crucial periods in the problem. However the period of analysis-synthesis shift seems to be very complex, and results pertinent to this period has not been presented. This period as stated by Blatt is actually a ratio that is determined by the number of analytic questions asked first in the process and the number of synthetic questions asked later. This ratio will then fluctuate in the size of value for each subject, and become "less clear" as the value gets smaller. Thus it seems that as a crucial period, it is quite difficult to identify in a reliable manner.

In presenting research, it is important to describe the methodology clearly enough so that the study could possibly be replicated, however, Blatt does not describe the type of equipment he used which is important when considering the reliability and accuracy of his measurements. Also, it was not clearly stated whether he worked with all of the heart rate data that he obtained by continuous recording

or whether he used only thirty second estimates at the crucial points of the problem. This would be important in terms of knowing what was happening throughout the entire experimental session.

In an exploratory study, Rimoldi, Mayer, Meyer and Fogliatto (1962) investigated the relationship between autonomic arousal and complex mental processes. Five problems were administered to seventeen adults whose ages ranged from twenty-three to forty years. Heart rate was recorded continuously with an electrocardiograph while the subjects were solving the problems as well as for five minute baseline periods before and after the problem solving sessions. The results indicated that heart rate variability for the most part remained constant throughout the seven experimental sessions. Because the study was primarily exploratory in nature, more definite conclusions were not reached.

A major criticism of this study is that it is difficult to see with any degree of certainty the effects of problem solving on heart rate changes. Any change in heart rate may have been due to the different type of problems administered, and because of the extensive number of problems used, fatigue in the subjects may have been an important variable that wasn't controlled. Also the difficulty of the problem for these specific subjects was not known before they were administered so that if they proved to be too difficult, the frustration the subjects may have experienced may have been another factor that would make these results inconclusive.

In another study, Rimoldi and Meyer (1963) present the results of their investigation of the effects of problem solving as a

stimulus on autonomic arousal. Sixteen geriatric subjects over seventy years of age were tested on four different experimental occasions. During the second and third experimental occasions, two problems were administered to the subjects, the first problem being very concrete and the second being more abstract. Experimental occasions I and IV were baseline periods in which each subject went through a "simulated" problem. During all four experimental periods, heart rate was continuously measured by an electrocardiograph. Cardiac response measurements and their relationship to the four experimental occasions were analyzed in the following manner.

An event marker noted the beginning of each problem solving session, whenever the subject selected a question in the problem and the point when the problem was completed. From the moment the subject selected a card, that is, asked a question, to the point when he had read the answer to the question, this interval was recorded with an event marker. This specific temporal period was then called the "question period". The interval of time on the subject's record not marked by the event marker was designated as the "search period". This was the period of time when the subject presumably was integrating the information he had already gathered, and was planning to gather new information by asking another question or had come to a conclusion about the problem.

An analysis of variance indicated there was a significant difference beyond the .01 level between mean heart rate during the four experimental periods. The most conspicuous change in heart rate took place during the third and fourth experimental occasions, that is, between the most complex problem and baseline 2. These results were interpreted in terms of the subjects seeming to experience less stress during the second

baseline measurement than at the preceding periods. A more molecular analysis of mean heart rate during the four experimental periods was made in the analysis of the question and search periods for each occasion. The results of this analysis indicated that there was a significant difference between the subjects' mean heart rate during the question and search periods on the abstract problem in occasion III with a higher value for the question period. These results were tentatively interpreted as being due to the fact that during the third experimental period, the most difficult and abstract problem was presented to the subjects which may be an indication that arousal mechanisms are related to the difficulty of the task presented, and this may be related to the ability of the subjects to assimilate unfamiliar information that confronts them during the question periods. Since the study primarily was exploratory, no definite conclusions were made, however, the results do provide guidelines for more conclusive future research.

Even though this study was primarily exploratory in nature, the results obtained provided a source of direction for this present study in that there appeared to be a certain period in the problem solving process that specifically contributed to autonomic arousal. This was the question period of the actual problem. It is difficult to say this with complete certainty because of certain inadequacies of the experimental design such as using two experimental problems of different difficulty. Because two problems were used, it is difficult to attribute change in heart rate to the problems specifically because variables such as fatigue, boredom, and other maturational factors were not controlled.

In summary, the purpose of this review has been to survey the literature in terms of objectively analyzing cognitive processes and problem solving behavior in terms of the underlying process involved in reaching a solution to a problem. Secondly, the historical and contemporary research that has investigated the relationship between efficiency on a task and autonomic arousal has been surveyed.

Although contemporary behavioristic psychology emphasizes stimulus response models for problem solving experiments in that they deal with solutions or responses alone, the historical background of research in problem solving indicates that early research was focused on the process underlying problem solving behavior, and this process was usually inferred from the solutions offered by the subjects (Dewey, 1933; James, 1890; Wertheimer, 1959; Dunker, 1945; Köhler, 1927; and Thorndike, 1911).

One of the earliest attempts to quantify the problem solving process was that of Bloom and Broder (1950) where they had their subjects "think aloud" while solving problems. Similarly Glaser, Damrin and Gardner (1954) tried to get at the underlying process of electronic trouble shooting by analyzing the steps and check procedures a mechanic would go through in solving a problem related to the maintenance of a radar-computer system. Buswell's (1956) study on problem solving again emphasized process rather than product alone. He specifically was interested to see if there were certain tactics or patterns used by problem solvers or whether tactics in solving mathematical problems were unique to each individual subject.

In the field of concept formation, Bruner, Goodnow and Austin (1956) tried to externalize for observation the decisions made by subjects in their experiments.

Finally this survey traced the evolution of the Rimoldi technique beginning with one of the earliest publications using this approach (Rimoldi, 1955) and other applications of this method to problem solving behavior (Rimoldi, Haley, Fogliatto, 1962; Haley, 1960; Rimoldi and Devane, 1961; Rimoldi, Fogliatto, Haley, Reyes, Erdmann and Zacharia, 1962). Applications of the Rimoldi technique to clinical problems have been conducted in a series of studies using the Rorschach, psychiatric diagnosis, and psychotherapy (Tabor, 1959; Mohrbacher, 1961; Gunn, 1962; and Meyer, 1963).

The implication of all of the studies mentioned that concerned themselves with problem solving behavior is that there is a historical basis in the functionalist school of psychology that has served as a point of origin for some of the contemporary research conducted in problem solving where attempts have been made to externalize and quantify the underlying process of problem solving behavior.

Secondly the research investigating the relationship between efficiency on certain experimental tasks and autonomic arousal has been surveyed. One of the earliest studies in this area was conducted by Freeman (1940) where he related efficiency on certain psychomotor tasks and autonomic arousal.

Much later, Beckman and Stein (1961) investigated the relationship between complex problem solving and E.E.G. recordings. Blatt's

(1961) research concerning increments in heart rate and efficiency in problem solving provided much of the stimulus for this present research, and finally two studies conducted by Rimoldi, Meyer, Meyer and Fogliatto (1962) and Rimoldi and Meyer (1963) provided most of the ground work for the present study.

The major implication for all of these related studies is that there seems to be a certain trend and interest for some investigators to analyze the process involved in problem solving behavior, and that efficiency in problem solving may be related to autonomic arousal in that the more efficient problem solvers may experience an optimal level of arousal that facilitates their performance on a complex mental task.

CHAPTER III

PROCEDURE

Source of Data and Criterion of Problem Solving Efficiency

The subjects of this study were seventh and eighth grade students of a parochial school in the Chicago area. Two hundred and fifty-seven students were pre-tested in order to isolate two groups of problem solvers -- an efficient and an inefficient group. These two hundred and fifty-seven subjects were given the Raven Progressive Matrices (form ABCDE, 1938) and two sets of the Thought Problems developed by Tate, Stanier and Harootunian (1959). These two tests were administered in a group form to the three seventh grade classes and two eighth grade classes during three consecutive days. The pre-testing data obtained from the seventh grade group were analyzed separately from the eighth grade group because of the differences in educational level of the two groups.

A regression analysis of Thought Problem scores on Raven Progressive Matrices scores of the seventh and eighth grade subjects divided them into two separate groups -- those on the positive side of the regression line and those on the negative side. The standard error of estimate was determined for each group of subjects which was then used as an arbitrary cut-off point, thus eliminating approximately two-thirds of each group. Those subjects falling above and below the standard error of estimate composed the two groups of subjects used in this sample. Table I presents the means, standard deviations, correlation coefficients, regression equations and standard error of estimates for the two groups of

subjects.

Table I

Mean, Sigma, Correlation, Regression Equation and
Standard Error of Estimate of Seventh and Eighth
Grade Subjects on the Raven Test and Thought Problems.

	<u>Seventh Grade (N = 141)</u>		<u>Eighth Grade (N = 116)</u>	
	Raven Test	Thought Problems	Raven Test	Thought Problems
Mean	44.61	16.81	44.40	18.81
Signa	7.28	5.73	6.35	6.29
R_{xy}		.62		.46
Regression Equation	$Y' = .567X - 8.37$		$Y' = .402X + .88$	
Standard Error of Estimate	4.48		5.58	

Table 2 is a description of the final dichotomized group of subjects. Thus on the basis of the subjects' performances on the Thought Problems, efficient and inefficient subjects composed the two groups; efficiency in problem solving being defined in terms of the subjects' ability to handle successfully the tasks presented to them in the Thought Problems. Table 2 presents the subjects' mean scores on the Raven Progressive Matrices Test which gives some indication of their level of intelligence. By using "t" tests between the mean scores of the two groups,

it was observed that there was no significant difference between the two groups in terms of level of intelligence. However, when considering the subjects' scores on the Thought Problems, the two groups differed significantly beyond the .001 level. Thus, it can be said that the two groups were matched for intelligence but they were not comparable as far as the problem solving ability as measured by the Thought Problems.

Table 2
Mean Scores of Raven Test and Thought Problems
for Efficient and Inefficient Problem Solvers.

	Efficient (N = 37)	Inefficient (N = 37)	p
Raven Test	44.76	44.76	N.S
Thought Problems	25.09	10.62	<.001

The Raven Progressive Matrices (Form ABCDE, 1938) was used as a measure of intelligence because it is relatively easy to administer in a group form to a large group of subjects. Although this test has received some criticism in terms of its standardization, reliability and validity (Burke, 1958), there is sufficient evidence that it is an adequate instrument to measure general intelligence in terms of its high loading in a general intelligence factor (Spearman, 1946; Spearman and Jones, 1950; Vernon and Parry, 1949; Rimoldi, 1948, 1951) and its reasonably high positive relationship with the Stanford-Binet (Raven, 1948; Keir, 1949).

The Thought Problems developed by Tate et al (1959) were used in this study because they especially were developed for seventh and eighth grade children. They found these problems to be quite an adequate instrument in the discrimination of good and poor problem solvers on the basis of correct or incorrect answers to the problems.

Methodology in Analyzing the Problem Solving Data

The technique of characterizing the problem solving process used in this study was developed by Rimoldi and Haley (1962). One reason this technique was developed by the authors was that there was a pressing need to question some of the basic assumptions in the classical stimulus-response methods in contemporary psychology. They point out that "the study of the responses is not enough to establish the veracity of the inferences that can be made about the process." This technique essentially analyzes the questions that a subject asks in order to solve a problem. By asking questions, each subject gathers information, valuable or non-valuable, to help him solve the problem. In this study, the information provided after each question and the total number of questions in the problem was controlled by the experimenter. In developing this technique, the authors point out that

a process is experimentally characterized by the sequence of questions asked by the subject. Any characterization of the process should include at least the number of choices made, type of choices and their order. The same question may have an entirely different meaning according to the questions previously asked. It is assumed that at every successive step the problem changes, and that what the subject knows and what he may still want to know is not a fixed property of the problem but varies as the solution develops. (Rimoldi and Haley, 1962)

A brief but more specific description of the problem solving situation is as follows. The subject is presented with a problem and a set of cards on which questions pertaining to the problem that he may want to ask are written. Upon choosing a card or question, the corresponding answer is found on the reverse side of the card. The number of the card is then recorded by the subject or the examiner in order to establish the sequence of the questions asked. The subject is free to choose any card he desires in any order he wishes. After reading the answer, he may decide to stop asking further questions, or to proceed further until he reaches what he considers to be the correct solution to the problem. This type of problem can be administered in a group form or individually to each subject. For the purpose of this study, a practice problem was given to all of the subjects in a group form, but the experimental problem was administered individually to each of the subjects.

A major step in the quantitative analysis of these problems using the Rimoldi Technique has recently been developed in that the structure and formal properties of the problem can be established, and thus norms based upon these formal properties can be used to score each subject's performance in terms of these norms.

By structure is meant the formal properties or schema of the problem expressed in terms of a basic set of relationships. These "schemata" are the logical frames on which various types of objects may be superimposed. By changing the formal properties, various levels of complexity can be defined. Each one of these levels is objectively characterized so that different investigators will have the same set of references when using a given schema. A graded program of schemata may be prepared once agreement has been reached as to which set of schemata

may be appropriate. This will depend on the field explored and the interest of the experimenter. (Rimoldi, Haley, Fogliatto and Erdmann, 1963)

A description of the structure of the practice and experimental problems used in this study is as follows. Figure 1 depicts the structure and formal properties of the practice problem (Problem 31A) given to the subjects in a group form.

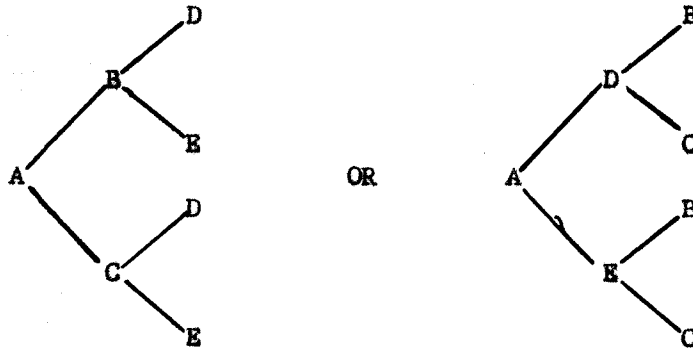


Fig. 1. The formal structure of the practice problem (problem 31A).

Fig. 2. Is an Example of a 2 x 2 matrix based upon the tree diagrams of Figure 1.

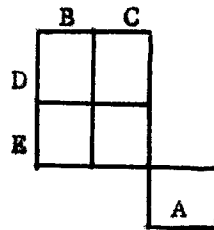


Fig. 2. A 2 x 2 matrix of the formal structure of the practice problem.

It can be observed that the cell frequencies of Figure 2 are arbitrary when only considering the structure or intrinsic properties of the problem. When the extrinsic properties of the problem are defined, these cell entries can be specified as with the practice problem in Figure 3.

Meyer, 1963) showed that because of the natural organic deterioration in these subjects, they were not able to work with the content of the problem which required a limited amount of abstract ability. A typical response of these subjects was that they couldn't deal with the content of the problem which was a dance committee serving refreshments or selling tickets because they, the geriatric subjects, had never been on a real dance committee. This typical response illustrates the very concrete nature of their thought processes. Previous research in general has indicated that when dealing with an abnormal sample, the content of a test is important, however since the sample in this study is assumed to be normal, it is then assumed that the content should not have any influence on the subjects' performances.

	More	Less	
mystery	8	2	10
sports	29	1	30
mechanical	15	5	20
	52	8	60

Figure 5. A 3 x 2 matrix of the complete structure of the experimental problem.

Complete examples of the questions and answers in the practice and experimental problem can be found in the appendix.

The practice problem (31A) was given to all of the seventy-four subjects for the purpose of acquainting them with the technique and methodology of the problem solving situation. The experimental problem was given to all of the subjects on an individual basis.

The results of the experimental problem were analyzed by the following method. The norms used for scoring each subject's performance on this problem can be found in the appendix. These norms are based upon intrinsic properties of the problem and upon the most logical sequence a subject can take while solving the problem. Each subject's sequence of questions asked was analyzed in the following manner. Regardless of what the observed sequence was, the subject only received credit for those questions asked that followed the logical sequence in the schema norms. The sum of the proportions obtained based upon the schema norms was then divided by the number of items selected which was always equal to or greater than the number of questions necessary to solve the problem as specified by the norms. In this way, the subject was given credit for any of the specified logical sequences he employed, however he was penalized for asking any redundant or irrelevant questions. This final score then represented the maximum efficiency of each of the seventy-four subjects who participated in this study.

Methodology of Analyzing the Heart Rate Data.

In analyzing the physiological data obtained, the following procedure was used. Cardiac rate was selected as the physiological variable to be measured for autonomic arousal because it is one of the more reliable measurements of autonomic activity that can be made. Heart rate responds rapidly and can be recorded continuously without limiting the subject's activity and movements. The instrument used was a Sanborn Oscillographic Recording System, Model 296T with an ECG/General Purpose Preamplifier, Model 350-3200.

Throughout the problem solving session a continuous electrocardiogram was taken on each subject. The traditional four arm and leg leads were employed while each subject sat in a wooden chair at a wooden desk which reduced any static interference. Throughout the problem solving session, the examiner controlled the electronic apparatus while an assistant administered the problem. Before the experimental session, all of the subjects were given a thorough demonstration and explanation of how the electronic equipment worked. The subjects were also encouraged to ask any questions they wished about the equipment and the experimental situation in order to reduce as much anxiety as possible.

An event marker noted the beginning of the problem solving session, whenever the subject selected a question in the problem, and the point when the problem was solved. From the moment the subject selected a card or asked a question, to the point when he had read the answer to the question, this interval was recorded with the event marker. In this study, this temporal period was called the "question period". The interval of time on the tape not marked by the event marker was designated as the "search period". This was the period when the subject was integrating the information he had already gathered and was planning to gather new information by asking another question or had come to a conclusion about the problem.

Since the equipment was running at a constant rate of speed (5 mm./sec.), a linear transformation was made so as to describe the total session and each interval of the session (search or question periods) in terms of a mean number of heart beats per minute.

Also two baseline periods were obtained: one before and one after the experimental session. Each baseline period lasted for five minutes, and the subjects were instructed during these periods to select a random number of blank cards in a random order and at random time intervals. These two baseline periods were treated similarly as the problem solving period, in that whenever a subject selected a blank card, this then was a simulated "question period". The intervals between the selection of blank cards were designated as simulated "search periods". By employing these two baseline periods, it is believed that the effects of bodily movement on heart rate was partialled out.

CHAPTER IV

RESULTS

The presentation of the results will be made in terms of the three basic problems specified in this study, that is, the relationship between autonomic arousal as measured by heart rate and efficiency on a problem solving task, the specific variable within the problem that contributes to autonomic arousal, and the degree of efficiency manifested by the two groups of subjects on the experimental problem.

Table 3 presents the results of an analysis of variance (case VII, McNemar, 1963) on mean heart rate for 37 efficient problem solvers during three different experimental occasions -- baseline 1, the experimental problem and baseline 2. The obtained F ratio indicates that there was a statistically significant difference in mean heart rate during these three occasions. This difference is observed quite clearly in Figure 6 where the mean heart rate for this group is plotted out against the three experimental occasions.

Table 4 presents the results of an analysis of variance on the mean heart rate for 37 inefficient subjects during the three experimental occasions. The observed F ratio indicates that there was a statistically significant difference in mean heart rate during the three occasions. This difference is more clearly observed in Figure 7 where the mean heart rate for this group is plotted against the three occasions.

Table 3
Analysis of Variance of Mean Heart Rate for
37 Efficient Problem Solvers

Source	Sum of Squares	df	Variance Estimate	F Ratio
Experimental Occasions	696.04	2	348.02	19.83 *
Subjects	15,377.62	36	427.02	
Remainder	1,263.92	72	17.55	
Total	17,337.58	110		

* Significant beyond the .001 level

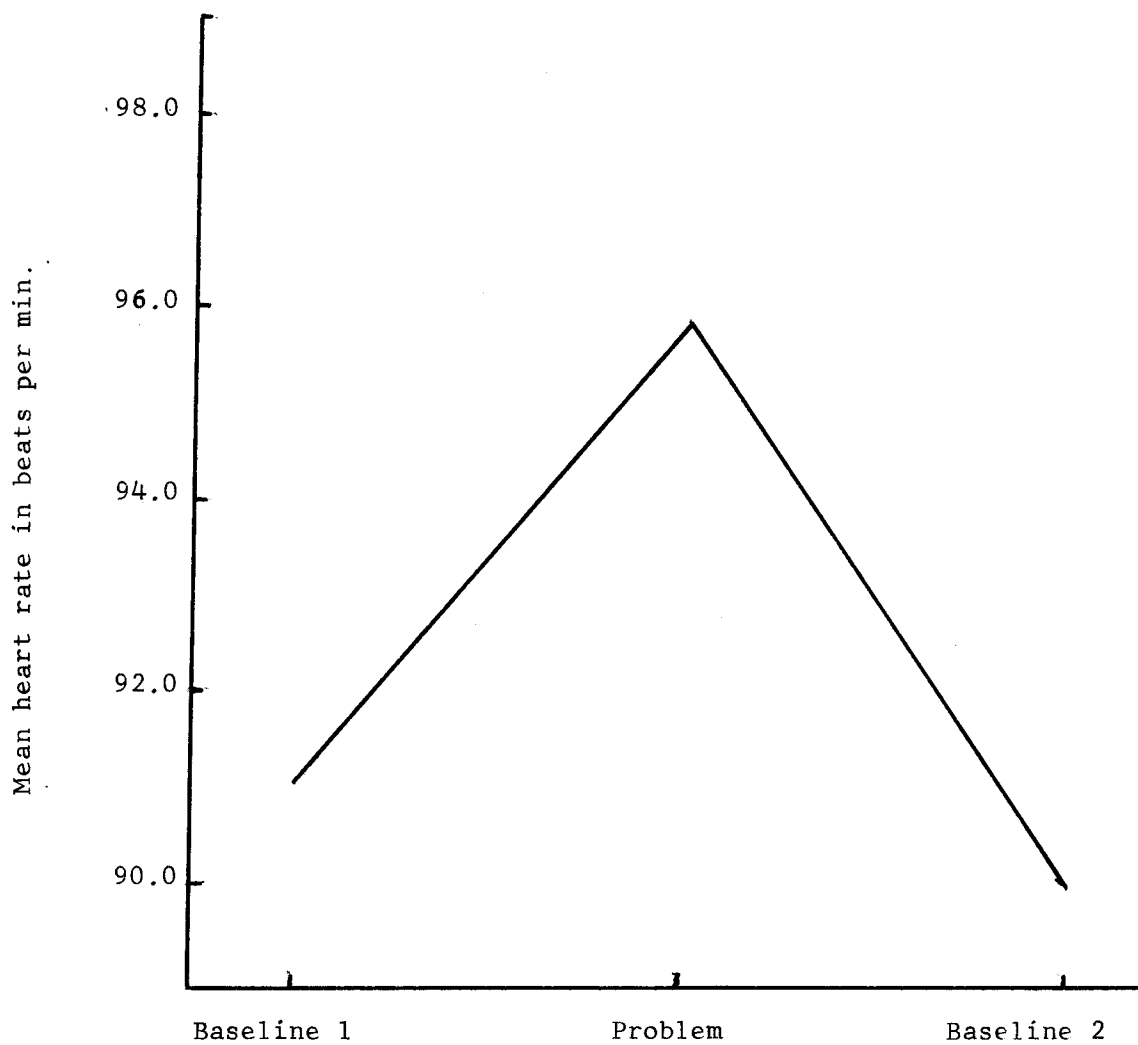


Fig. 6. Mean heart rate during 3 experimental occasions for 37 efficient problem solvers.

Table 4
 Analysis of Variance of Mean Heart Rate for
 37 Inefficient Problem Solvers

Source	Sum of Squares	df	Variance Estimates	F Ratio
Experimental Occasions	170.88	2	85.44	4.18 *
Subjects	16,583.80	36	460.66	
Remainder	1,471.14	72	20.43	
Total	18,225.82	110		

* Significant beyond the .05 level

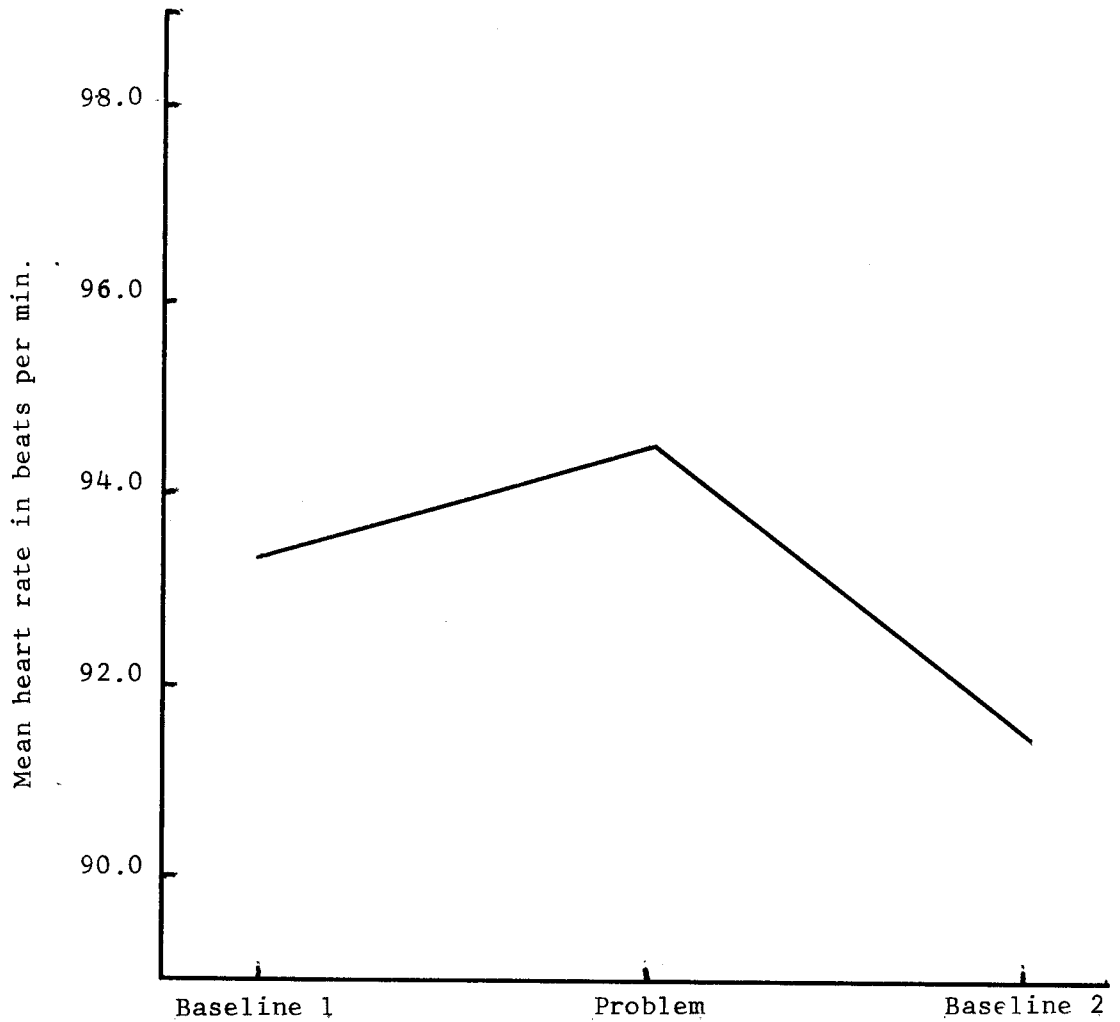


Fig. 7. Mean heart rate during 3 experimental occasions for 37 inefficient problem solvers.

"T" tests were made between the mean heart rate during the problem period and the mean heart rate of the combined baseline periods for both the efficient and inefficient problem solvers. This combined baseline period was the mean of each subject's mean heart rate for baselines 1 and 2.

Statistically significant differences were observed in both groups of subjects between their mean heart rate during the combined baselines and the problem periods with the change in heart rate in both cases being an increment during the problem period. However, the increment in heart rate was greater for the efficient subjects, the mean difference being 5.27 beats per minute -- this difference being significant beyond .001 level. The mean difference in heart rate for the inefficient subjects was 2.09 beats per minute which was significant beyond the .01 level. It is important to note that these statistically significant differences were between the different experimental occasions of each group of subjects and not for one group of subjects against the other group.

When considering the search and question periods of the three experimental occasions, Table 5 gives the results of "t" tests for correlated means for the 37 efficient subjects. The only significant difference found was between the mean heart rate of the question and search periods of the experimental problem with the increment in heart rate taking place during the question period. Figure 8 is a graphic description of these results.

Table 5
 Mean Heart Rate for 37 Efficient Problem Solvers during
 Search and Question Periods for 3 Experimental Occasions

	Baseline 1	Problem	Baseline 2
Search Period	91.05	95.64	90.04
Question Period	91.70	98.06	91.22
M_D	.64	2.43	1.16
S_{M_D}	.79	.58	.69
t values	.81	4.20 *	1.67

* Significant beyond the .001 level

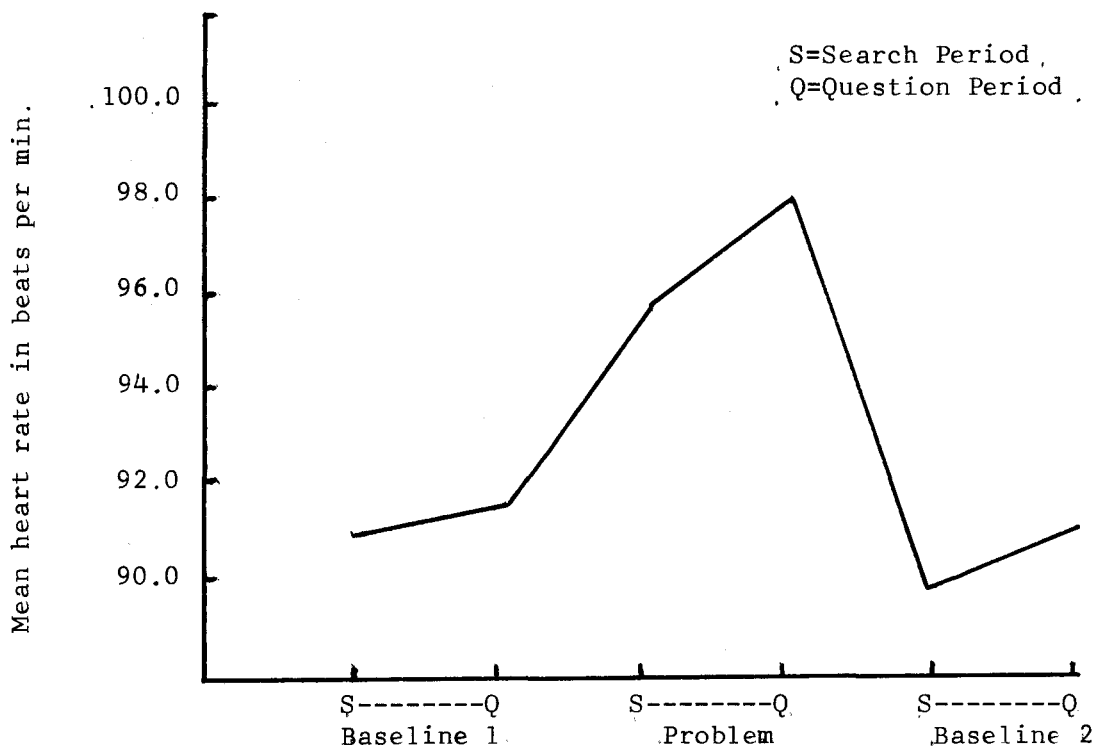


Fig. 8. Mean heart rate for search and question periods during 3 experimental occasions for 37 efficient problem solvers.

Table 6
 Mean Heart Rate for 37 Inefficient Problem Solvers during
 Search and Question Periods for 3 Experimental Occasions

	Baseline 1	Problem	Baseline 2
Search Period	93.27	94.36	91.34
Question Period	93.99	96.77	93.51
M _D	.72	2.41	2.17
S _{M_D}	1.13	1.06	.72
t values	.64	2.27 *	3.03 **

* Significant beyond the .05 level
 ** Significant beyond the .01 level

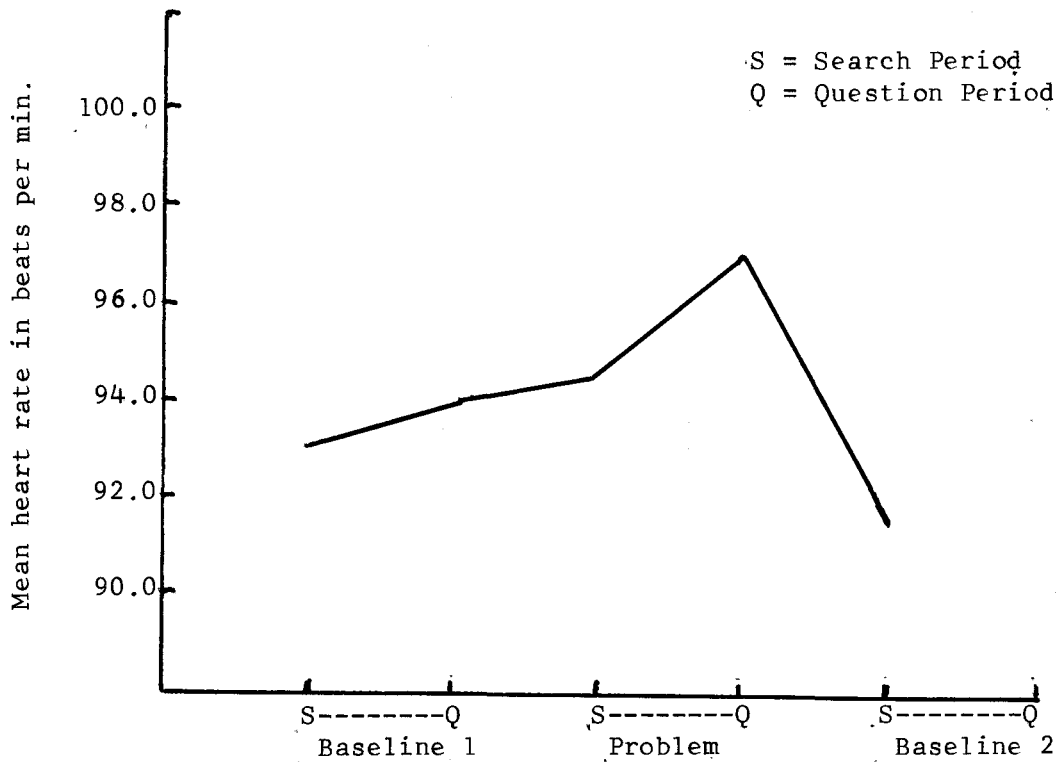


Fig. 9. Mean heart rate for search and question periods during 3 experimental occasions for 37 inefficient problem solvers.

Table 6 compares mean heart rate during question and search periods for the 37 inefficient subjects. A significant difference was found between search and question periods in both the experimental problem and baseline 2, with increments in heart rate in both occasions taking place during the question period. Figure 9 is graphic representation of these results.

Considering the actual performance i.e., the mean final score of both groups of subjects in solving the experimental problem, a "t" test for uncorrelated means indicated that a mean difference of .0047 between the two groups, with the efficient subjects having the higher mean score, was statistically significant beyond the .005 level (one-tail test).

Table 7 presents the numbers of correct solutions obtained by each group, the mean number of inappropriate questions and the mean number of irrelevant questions asked by each group of subjects.

Inappropriate questions are defined as those questions that had some value for reaching a correct, logical solution, yet lost their value because they were asked in an illogical sequence. Irrelevant questions are defined as those questions whose answers provided no meaningful information for arriving at a correct, logical solution to the problem.

Table 7

Number of Correct Solutions Observed, Mean Score on Experimental Problem, Mean Number of Irrelevant Questions Asked, and Mean Number of Inappropriate Questions Asked for 37 Efficient and 37 Inefficient Problem Solvers

	Efficient	Inefficient	M _D	S _{MD}	P.
Number of Correct Solutions Observed	18	18	.00		N.S.
Mean Score on Experimental Problem	.032935	.028178	.004757	.00158	.005 *
Mean Number of Irrelevant Questions Asked	3.10	3.02	.08	.274	N.S.
Mean Number of Inappropriate Questions Asked	1.94	1.94	.00		N.S.

* 1-tail test

A further analysis, interpretation and discussion of these results will be made in the next chapter.

CHAPTER V

DISCUSSION

In the first chapter, three general hypotheses were stated concerning the basic problems involved in this study. The first hypothesis was that the problem solving situation will serve as a stimulus that will produce an increment in heart rate for both groups of problem solvers, and that the increment will be greater in the efficient problem solvers.

The results of the analyses of variance in tables 3 and 4 on the mean heart rate for both groups indicates that changes in heart rate that took place during the three experimental occasions were statistically significantly different. Inspection of figures 6 and 7 indicate that the change in heart rate was actually an increment that took place during the problem solving sessions. When the two baseline periods for each subject were combined and compared with the mean heart rate for the problem solving period, statistically significant differences again were observed with the increment in heart rate in both groups taking place during the problem period with the larger increase in heart rate taking place in the efficient group of subjects.

These results tend to support the hypothesis that autonomic arousal is a characteristic of efficient functioning and that arousal has an adaptive and facilitation effect in terms of efficient functioning on a task. In a previously cited article by Beckman and Stein (1961), it was observed that efficiency in problem solving correlated significantly

with reduced amount of alpha in resting EEG records. On the basis of these results the authors speculated that the more efficient problem solver may be operating with a generally higher level of "cortical excitation" and are consequently in a state of readiness to integrate external information. Their results being interpreted in terms of general "cortical excitation" in efficient subjects are consistent with the results of this study in that the efficient subjects in this study also manifested greater autonomic arousal than the inefficient subjects.

The results of this study also indicate that autonomic arousal is not a total reaction in that arousal is not experienced by the subject continuously during a task, but at certain periods of an assigned task, the subject has to cope with a stimulus condition which produces autonomic arousal.

When considering the search and question periods, table 5 indicates that as predicted in the second hypothesis, there was an increment in heart rate during the question period for the problem solving situation for the 37 efficient subjects. Again this was expected in terms of the hypothesis that arousal takes place when a situation confronts a subject, a situation with which he has to cope, a situation that demands a certain expenditure of energy. This phenomena was observed in a previous study (Rimoldi and Meyer, 1963) where subjects when confronted with the task of integrating the information they acquired during the problem solving situation manifested an increment in heart rate.

When considering the search and question periods of the three experimental occasions of the 37 inefficient problem solvers, a similar

increment in heart rate during the question period was observed during the problem solving session. Again this manifestation of arousal is interpreted as an indication that the subject is in a state of readiness or alertness that is needed when he is confronted with information that he must integrate and assimilate in order to efficiently handle the problem solving task. It is of special interest to note that this group also manifested an increase in arousal during the second baseline period, that is, there was a significant increase in heart rate during the simulated question period. This observation is difficult to interpret without other substantiating data available, but the increment in heart rate may have been a carry over from the problem solving session in that these subjects were still apprehensive about having to integrate further information, and even the selection of blank cards served as a cue to put these subjects in a state of readiness. It is unfortunate that more quantified data was not received from the subjects that would give some indication of the subjects' feelings about the experimental task. Just from observing the subjects' behavior, it seemed that many of the efficient subjects enjoyed the problem solving task, and some of them verbally expressed their pleasure in that the problem was a challenge to them. However, many of the inefficient subjects seemed apprehensive when confronted with the problem solving task, and they seemed to have been experiencing a good deal of frustration during the problem. Other inefficient subjects seemed thoroughly bored with the task and seemed happy when the experiment was completed. Planned future research concerning the problems encountered in this study will have subjects fill out some type of rating scale or

questionnaire to get at the subjects' feelings about the problem solving task. This may add further clarification to the relationship between autonomic arousal and efficiency on a task. Another variable that will be considered in future research will be the length of time the subjects need to solve the problem. This may be another means of observing their efficiency of their performance.

When considering the actual efficiency of the two groups of subjects on the experimental problem, table 7 indicates that an equal number of subjects from both groups reached the correct solution, and that there were no significant differences in the two groups of subjects between the mean number of irrelevant questions asked or inappropriate questions asked. Irrelevant questions were those questions in the problem that provided no value whatsoever in reaching a solution to the problem. Inappropriate questions were questions that lost their value when they were asked at an inappropriate time during the problem.

In the light of these results, it is interesting to see that there was observed a statistically significant difference between the two groups of subjects when considering their final mean score with the efficient problem solvers doing better than the inefficient subjects. The value of using the "pulling out" method of scoring subjects' performances lies in the type of variables that are considered in reaching a final score. This method takes into account the number of irrelevant questions asked, the number of inappropriate questions asked by each subject, and it also takes into account the subject's approximation to an adequate,

logical tactic in solving the problem. Since the two groups showed no significant differences in the number of correct solutions obtained, the mean number of inappropriate questions asked, and the mean number of irrelevant questions asked, then the basis for the efficient subjects performing significantly better than the inefficient subjects in terms of mean final scores must be that the efficient subjects approximated or employed an appropriate, logical sequence of questions more often than the inefficient subjects.

There are some important implications in the results observed in the problem solving behavior of these subjects. These implications have to do with test theory in general and the practical problem of selecting or screening subjects for some specified purpose. In many instances, the subject's correct or incorrect response on a task is the only variable considered in the selection process. However, the results and analysis of the problem solving behavior of the two groups of subjects in this study indicates that there are several variables that can and should be considered that are involved in the process of problem solving.

If only the subjects' correct and incorrect responses were observed and analyzed, then the two groups of subjects showed no difference in their ability and efficiency in solving the problem. Even if their inappropriate or irrelevant questions were observed and analyzed, no difference between the two groups would be observed. However, a statistically significant difference between the two groups was observed when their logical approach to the problem was considered, in that the efficient

subjects used or approximated the best logical sequences more often than the inefficient subjects. This logical approach is reflected in the sequence of questions asked by the subjects and the total score each subject accumulated based upon the specific schematic norms for the experimental problem. Thus the correctness or incorrectness of a response is not sufficient in assessing efficiency in a subject's behavior. Efficiency in problem solving or testing is not a dichotomous variable in that a subject is either efficient or inefficient, but when analyzing the problem solving process, efficiency becomes a continuous variable in that some subjects approach a task in a completely illogical manner, and some subjects may be more logical or efficient than other subjects. Certainly the correctness or incorrectness of a response to a task is important, however, if a subject does make a correct response, it can only be assumed that he used a logical or efficient approach to the problem. This assumption is not always appropriate in that a correct response may be the product of random guessing, or even cheating on a task by getting the correct answer from some outside source. Yet when analyzing the process of problem solving, the subject's degree of efficient behavior can be observed step by step which then allows for greater accuracy in specifying how efficient a subject really is in a problem solving or testing situation.

Also there are some implications stemming from the results of this study that aid and clarify for understanding the construct of efficiency in terms of autonomic arousal. Apparently the more efficient subjects experienced more arousal than the less efficient subjects, and that this arousal may have facilitated the subjects' problem solving

ability; in that the efficient subjects operationally defined by their performance on an outside criterion (Thought Problems) manifested a greater degree of autonomic arousal during the problem period than the inefficient subjects. An optimal amount of tension experienced by a subject thus tones up the subject; it makes him more alert and attentive so that he can integrate the information he received in a much more efficient manner. In plans for future research resulting from this study, it is hoped that by analyzing the types of questions asked by the subjects, it will become clear what kind of questions actually produce an increment in heart rate. Does autonomic arousal take place when a subject asks appropriate, meaningful questions, or does it take place when he receives irrelevant and inappropriate information that is difficult for him to integrate with some meaning?

CHAPTER VI

SUMMARY

The purpose of this study was to analyze and characterize the process that a group of efficient and inefficient subjects go through in solving a problem, and to see how autonomic arousal, measured in terms of heart rate, was related to the construct of efficiency in problem solving.

Several general hypotheses were tested:

1) Problem solving as a task will produce an increment in heart rate in both groups of problem solvers during the problem period as compared to their baseline periods,

2) The increment in heart rate will take place while the subject is trying to incorporate and assimilate the information he has requested in solving the problem, that is, during the "question period"

3) In analyzing the problem solving process, the efficient subjects will do significantly better in solving the experimental problem than the inefficient subjects.

A review of the literature related to the purpose of this research indicates a great deal of interest among behavioral scientists concerning the problem of efficiency in problem solving and its relationship to autonomic arousal.

The early historical background of research in problem solving indicates an interest in focusing on the process that underlies problem

solving behavior (Dewey, 1933; James, 1890; Wertheimer, 1959; Dunker, 1945; Köhler, 1927; and Thorndike, 1911). Some of the earliest attempts to quantify the problem solving process were made by Bloom and Broder (1950), Glaser, Damrin and Gardner (1954), Buswell (1956), and Brunner, Goodnow and Austin (1956). For the special purpose of this research, the methodology developed by Rimoldi (1955) was carefully reviewed in terms of its theoretical evolution and practical application of its technique.

Research investigating the relationship between efficiency on certain experimental tasks and autonomic arousal has also been surveyed. Freeman (1940) demonstrated the relationship of autonomic arousal to efficiency on certain psychomotor tasks. Beckman and Stein investigated the relationship between complex problem solving and E.E.G. recordings. And Blatt (1961), Rimoldi, Meyer, Meyer, and Fogliatto (1962), and Rimoldi and Meyer (1963), conducted research concerning increments in heart rate and efficiency in problem solving which provided much of the stimulus for this particular study.

Two hundred and fifty-seven seventh and eighth grade students were pre-tested, and on the basis of these results, two groups of subjects were selected. The two groups were then designated as the efficient problem solvers and the inefficient ones. Each group was composed of 37 subjects. All subjects were given a practice problem in order to familiarize them with the problem solving technique, and they received a detailed explanation and demonstration of the electronic equipment to be employed in measuring heart rate. Each subject was tested individually by two observers -- one handling the electronic equipment and the other

administering the experimental problem. A baseline period was secured before and after the experimental period. The experimental period was divided into two areas: the time the subjects spend in asking questions necessary to solve the problem and the time he spends in integrating the information made available to him.

The results of this study confirm the first hypothesis in that the efficient subjects manifested a statistically significant increase in heart rate during the problem period when compared to their baseline performance, and the inefficient subjects also produced a statistically significant increase in heart rate during the problem period. It is important to note that the increment manifested in both groups was a statistically significant increase only when comparing the subjects during the experimental periods of their own particular group. A "t" test for uncorrelated means was performed on the mean heart rate for both groups of subjects and the mean difference proved not to be statistically significant, but this should be expected because the design of the study explicitly states that the performance of subjects in each group would be compared with their own group baseline results. When this was observed, it was clear that degree of increase in heart rate for the efficient subjects was much greater than the increment that took place in the inefficient group.

Similar results were observed when considering the question and search periods of the three experimental occasions. Both groups showed a statistically significant increase in heart rate during the question period of the problem solving session, and it is hoped that

future research will uncover the specific variable or type of question asked by the subjects that contributed to this increment in heart rate. Another implication of these results indicates that in terms of degrees of expenditure of energy, as measured by cardiac activity, efficient problem solvers expend more energy while solving a problem than inefficient subjects.

Finally, an analysis of the problem solving behavior of the two groups indicates that the efficient group did statistically significantly better on the experimental problem than the inefficient subjects when considering one of the crucial aspects of the problem solving process. This aspect was that as a group, the efficient subjects employed or approximated the most logical tactics, as defined by the schema norms, more than the inefficient subjects. Again an important implication of these results is that when considering efficiency on a task, it is not enough to consider only the correctness of the final response. The correctness or incorrectness of a final response may be the result of guessing or other chance factors, however if the problem solving process is analyzed, it can be observed that efficiency in problem solving is not a discrete phenomena in that a subject is correct or incorrect in his solution, but that efficiency is a continuous variable in that one subject may be more correct in his logical approach than another subject. If these conclusions are valid, the important implications to the theory of testing and measurement are obvious when contemporary test theory is based upon the analysis of discrete, correct or incorrect responses of a subject.

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APPENDICES

APPENDIX I

Problem 31A
(Practice Problem)

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 coeducational 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.

APPENDIX II

Problem 33A
(Experimental Problem)

Instructions and Corresponding Questions and Answers

A drug-store owner receives different types of magazines that have different prices. Some cost less than 25¢, some cost more than 25¢. You are to find out how many mystery magazines cost more than 25¢. Read all the questions carefully.

Questions	Answers
1. What kinds of magazines does the store receive?	1. Mystery, sports and mechanical magazines.
2. Has the store more magazines about mechanics than sports?	2. No.
3. Has the store more magazines about mechanics than mystery magazines?	3. Yes.
4. How many different prices do the magazines have?	4. 3
5. What is the total number of magazines which the store receives?	5. 60.
6. How many magazines cost 25¢ or more?	6. 52.
7. How many mechanics magazines cost less than 25¢?	7. 5.
8. Do all the sports magazines cost less than 25¢?	8. No.
9. How many sports magazines and mechanics magazines cost less than 25¢?	9. 6.
10. Do all the mystery magazines cost less than 25¢?	10. No.
11. How many sports magazines are received?	11. 30.
12. How many mechanics magazines are received?	12. 20.
13. How many mystery magazines are received?	13. 10.

APPENDIX III

SCHEMA NORMS FOR PROBLEM 33A (EXPERIMENTAL PROBLEM)

QUESTIONS

ORDER OF SELECTION	1	2	3	4	5	6	7	8	9	10	11	12	13	Sum
1					.1250	.1250								.2500
2						.0625			.0625		.0312	.0312	.0625	.2499
3						.0312			.0625		.0625	.0625	.0312	.2499
4						.0312			.1250		.0312	.0312	.0312	.2499
														<hr style="width: 100px; margin-left: auto; margin-right: 0;"/> .9997

IDEAL SEQUENCES FOR PROBLEM 33A

- | | |
|----------|-----------|
| 5-6-13-9 | 6-11-12-9 |
| 5-13-6-9 | 6-12-11-9 |
| 5-6-9-13 | 6-9-11-12 |
| 5-13-9-6 | 6-9-12-11 |

APPENDIX IV

The Pulling-out Method of Scoring (Erdmann, 1964)

This method attempts to account for any restructuring or late understanding 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 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 1,10,3,3,2,6, 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 1,6,7,8,3,2,5, 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 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.

APPENDIX V

Name _____ School _____ Date _____

THOUGHT PROBLEMS. PART I

Directions: On the following pages there are 20 thought problems. Some are hard, but you can solve most of them if you read and re-read carefully, think straight, and take enough time. If you find some extremely hard, go on the next one and return to the hard ones later.

In the problems which require figuring on paper, please use the space provided and the margin of the page. Be sure to show all of your figures so that credit can be given for correct steps even though your answer may be wrong.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

1. In our school two-thirds of the boys play football and two-thirds play basketball. Of the following statements, which is necessarily true
 - Some boys play neither football nor basketball.
 - Some boys play both football and basketball.

2. In a certain school the positions of principal, assistant principal, and coach were held by Green, Burns, and Smith, though not necessarily in that order. The principal, who was an only child, earns the most. Burns, who married Green's sister, earns less than the coach.
 - What position is held by Green? _____
 - What position is held by Burns? _____
 - What position is held by Smith? _____

3. When you enter my house you will find a window on your right in the side wall of the entry. When the sun sets it shines straight through this window on the opposite wall. What direction are you facing when you stand in the doorway and look across the street?

4. Suppose that the Yankees lead the league and that the Red Sox are fifth, while the White Sox are midway between them. If the Indians are ahead of the Red Sox and Tigers immediately behind the White Sox, which team is in the second place?

5. In a farmer's papers, a receipt was found: 24 dozen eggs ...\$. . The first and last digit of the amount had been blotted out.
 - What are the two missing digits? _____
 - What was the price of a dozen eggs? _____

6. I started from the school and walked 100 yards; I turned to the right and walked 50 yards; I turned to the right again and walked 100 yards. How far from the school am I?

7. There are six push buttons lettered A,B,C,D,E,F. Two of the buttons will ring a bell, four will not. The buttons can be pushed in combinations only of three. It is known that:
 - Combination A,B,C rings the bell
 - Combination B,C,E does not ring the bell
 - Combination C,D,E rings the bell
 - Combination B,C,D rings the bell
 - Combination D,E,F rings the bell
 Which two buttons are connected with the bell?

8. My birthday is on December 27, and I am just four days older than Tom. This year Christmas day comes on Tuesday. On what day of the week is Tom's birthday?

9. A pound of meat should roast for half an hour; two pounds of meat should roast for three-quarters of an hour; three pounds of meat should roast for one hour; eight pounds of meat should roast for two hours and a quarter. If you were writing a cookbook, how would you state the rule by which a person could tell from the weight of a piece of meat how long it should roast?
10. Three playing cards are placed in a row, face down. To the right of a King, there are one or two Queens. To the left of a Queen, there are one or two Queens. To the left of a heart, there are one or two spades. To the right of a spade, there are one or two spades. One of the cards is the Queen of hearts. What are the other two?
11. The witness said, "I heard my clock strike yesterday, about ten minutes before the shot was fired. I did not count the chimes, but I'm sure it struck more than once and that it struck an odd number. The witness had been out all morning and her clock stopped at 5 minutes to 5 the same afternoon. When do you think the shot was fired?"
12. If the A's have a bigger army than B's, we ought first either to fight the B's or attack the C's by sea, but not attack the A's. If the A's army is smaller, we should attack the A's first. If the C's have a bigger navy than we, we ought to either fight the B's or the A's, but not the C's. If C's navy is smaller, we should first attack the C's by sea. The sizes of armies and navies are ---

	Men	Ships
A.	7,000,000	300
B.	5,000,000	400
C	4,000,000	500
ourselves	6,000,000	200

Whom should we attack first? _____

13. A cube is 3 inches on each side. It is painted red, then sliced up into one-inch cubes.

How many one-inch cubes will there be? _____

How many one-inch cubes will have 3 red sides? _____

How many one-inch cubes will have 2 red sides? _____

How many one-inch cubes will have 1 red side? _____

How many one-inch cubes will have no red sides? _____

14. Bill came home with a new bicycle. There is clay on his feet and soot on his forehead. The only places he can have been are West Philadelphia, North Philadelphia, South Philadelphia, and Camden. He has not had time to go to more than one of these. There are bicycle shops only in North Philadelphia, West Philadelphia, and Camden. There is soot in the air only in North Philadelphia, South Philadelphia, and Camden. The streets are not being repaired in North Philadelphia, but they may be in other places. Where had Bill been?
15. In numbering the pages of a book a printer used 111 digits. (The digits are 0,1,2,3,4,5,6,7,8 and 9.) How many pages has the book?
16. There are six push buttons lettered D,E,F,G,H,I. Two of the buttons acting together ring a bell. The buttons can only be pushed in combinations of three. It is known that
 Combination DEF does not ring the bell
 Combination EFG does not ring the bell
 Combination FGH rings the bell
 Combination GHI does not ring the bell
 Which two buttons acting together ring the bell?
17. What idea can you draw from the following facts? Iron nails will not float in a pool; a cup of pure gold dust weighs nearly twenty times as much as a cup of water the same size; if you drop a dime or penny into a puddle it will sink to the bottom; a leaden weight will drop to the bottom of the ocean; a cubic inch (about a tablespoon) of water weighs less than half an ounce, while a cubic inch of brass weighs over two ounces. Sum up all these facts into one short statement:
 Most _____ are _____.
18. Where the climate is hot, bananas and rubber trees will grow. Strawberries and potatoes will grow where it is cool. Strawberries and rubber trees require plenty of moisture; potatoes and bananas need fairly dry regions. Near the Amazon river it is very hot and very damp. Which of the above grows there?
19. A broker bought 5 shares of stock at \$10 each which he sold at \$8 each. But he sold at \$3 each some shares he had bought at \$2 each. If his profit was \$15, how many shares did he sell at \$3?
20. On a six-day vacation, John drank twice as much coke each day as he did the day before. On the 6th day he drank a quart. On what day did he drink a pint?

Name _____ School _____ Date _____

THOUGHT PROBLEMS. PART II

Directions: On the following pages there are 20 thought problems. Some are hard, but you can solve most of them if you read and re-read carefully, think straight, and take enough time. If you find some extremely hard, go on to the next one and return to the hard ones later.

In the problems which require figuring on paper, please use the spaces provided and the margin of the page. Be sure to show all of your figures so that credit can be given for correct steps even though your answer may be wrong.

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21. Some children were asked: "why are towns nearly always more unhealthy than the country?" They gave the following replies: (underline the best two replies).

"Some country places are by the seaside."

"There are more doctors in the town."

"The smoke and fumes in the city make the air less pure."

"People in the country sleep more."

"Diseases spread more where people are crowded together."

22. The doctor thinks Jack has caught some disease. If he has a rash, it is probably chicken-pox, measles, or scarlet fever. If he has been ailing with a cold or cough, he may develop whooping-cough, measles, or mumps. He has been sneezing and coughing for some days, and now spots are appearing on his face and arms. What disease does Jack probably have?
23. John has 7 pockets and 20 dimes. He wants to put his dimes into his pockets so that each pocket contains a different number of dimes.

Can he do so?

Explain your answer.

24. Helen walked four blocks west on Elm Street. She turned left and walked two blocks, turned right and walked two more blocks, and then turned right again and walked one block. Which direction was Helen walking in the last block?
25. There are five books in a pile. The green one is directly under the blue one and is above the yellow one. The red one is above the brown one, but not next to it. The brown book is directly under the green book. Which book is on top?
26. There are a number of bacteria in a flask at 9 o'clock. There were half as many at 8 o'clock; there will be twice as many at 10 o'clock. At this rate the flask will be full at 4 o'clock. At what time will it be half full?
27. After eating at the Company cafeteria, a number of workers got sick. Each worker had selected three items of food from the five: ham sandwich, cole slaw, rice pudding, milk, cocoa. The company nurse interviewed the workers and found that those who had eaten items ham sandwich, cole slaw, and milk got sick, as did those who had eaten cole slaw, rice pudding, and milk. However, those who had eaten ham sandwich, cole slaw, and cocoa didn't get sick. What two foods may have caused the sickness?

28. Bentonville is 75 miles east of Austin. Centerburg is 25 miles north of Bentonville. Dearborn is 75 miles west of Centerburg. How far is Dearborn from Austin?
29. Captain Watts and his son James have been found shot -- the father in the chest and the son in the back. Both clearly died instantaneously. A gun fired close to a person -- as, for example, when a man shoots himself -- will blacken and even burn the skin or clothes; fired from a greater distance it will leave no such mark. The two bodies were found near the middle of a large hall used as a rifle range. Its floor is covered with damp sand which shows every footprint distinctly. Inside the room there are two pairs of footprints only. A third man standing just outside the door or window could aim at any part of the room, but the pavement outside would show no footprints. Under Captain Watts' body was found a gun; no such weapon was found near James. In each case the coat, where the bullet entered was blackened with gunpowder, and the cloth a little singed. Captain Watts was devoted to his son, and would have died rather than harm him purposely; hence it is impossible to suppose that he killed him deliberately, even in self-defense. But some think that James secretly disliked his father, and hoped to inherit his fortune at his death.

Was Captain Watts' death due to murder, accident, or suicide?

Was James' death due to murder, accident, or suicide?

30. The winning horse in a race finished at 4:31 P.M. He was six lengths ahead of the second horse, which finished nine lengths ahead of the third horse. The third horse ran the race in 2 minutes and 3 seconds. In the last quarter of the race, each horse was traveling one length in $\frac{1}{5}$ second.

How long did it take the winning horse to win the race?

At what time did the race start?

31. During a class play one of the stagehands has to change the spot-light from red to blue. There are six switches that can be pulled. They are numbered 1,2,3,4,5 and 6. Two of the switches will turn on the blue light; the others will not. The stagehand knows that ----

1,2 and 3 pulled together will make the light blue.

4,5 and 6 pulled together will make the light blue.

2,3 and 5 pulled together will make the light blue.

3,4 and 6 pulled together will not make the light blue.

2,5 and 6 pulled together will make the light blue.

Which two switches will turn the light blue?

32. A fireman stood on the middle rung of a ladder, directing water into a burning building. As the smoke lessened, he stepped up three rungs and continued his work from that point. A sudden flare-up forced him to go down five rungs. Later he climbed up seven rungs and worked there until the fire was out. Then he climbed the remaining six rungs and entered the building. Write down the number of rungs in the ladder.
33. I am at cross roads. I have come from the South and want to go to Philadelphia. The road to the right leads somewhere else. The road straight ahead leads only to a farm. In which direction is Philadelphia?

Circle the right answer: North, East, South, West.

34. Four boys, one of whom was known to have broken a window, were questioned by the principal. Each made a statement: Dave: "Tom did it." Tom: "Bill did it." Jack: "I didn't do it." Bill: "Tom lied when he said I did it." If only one of the four statements is false, who is the guilty boy?
35. George is running his little brother's train set. He wants to switch the engine onto a different track. There are six colored pushbuttons on the control panel - red, yellow, orange, green, blue, and purple. Two of the pushbuttons acting together will switch the train to a different track. George knows that +

Pushbuttons Orange, Green, and Purple acting together will not switch tracks.

Pushbuttons Red, Yellow, and Blue acting together will not switch tracks.

Pushbuttons Red, Yellow, and Orange acting together will switch tracks.

Pushbuttons Yellow, Orange, and Green acting together will not switch tracks.

Which two pushbuttons acting together will switch tracks?

36. Dave bought the following Christmas presents: a pipe, some music, a carton of cigarettes, a bracelet, a toy engine, a bat, a book, a doll, a walking stick, and an umbrella. His brother is 18; he does not smoke, nor play baseball, nor play the piano. Dave wants to give the walking stick to his father and the umbrella to his mother. Which of the presents shall he give to his brother?

37. Three boxes are piled on top of each other. All are of the same size, 3 by 4 by 5 feet. The lower box rests on its 3 by 5 side, the second box on its 4 by 5 side, and top box on its 3 by 4 side. What is the height of the pile?
38. A cube is 3 inches on each side. It is painted white on two opposite sides; red on two opposite sides; and blue on two opposite sides. It is then sliced up into one-inch cubes.

How many one-inch cubes will there be? _____

How many will show the colors red, white, and blue? _____

How many will show white only? _____

How many will show red only? _____

How many will show blue only? _____

How many will show two colors only? _____

How many will show no colors? _____

39. A farmer sold 5 turkeys at \$10 each, although it had cost him \$12 to raise them. At the same time he sold at \$2 each some chickens in which he had invested only \$1 each. If his profit was \$10, how many chickens did he sell for \$2 each.
40. In cold, damp climate, root crops like potatoes and turnips grow best. In temperate climates there are many pastures, and oats and barley grow well. In subtropical climates wheat, olives, and vines grow well. In tropical climates date-palms and rice grow best. The ancient Verberites lived largely on bread, with oil instead of butter; they had wine to drink and raisins for fruit. Which climate do you think they had?

APPROVAL SHEET

The dissertation submitted by Robert A. Meyer has been read and approved by five members of the Department of Psychology.

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

The dissertation is therefore accepted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

January 20, 1964
Date

Frank Kobler
Signature of Adviser