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The Aged Person and Psychobiological Processes

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THE AGED PERSON AND PSYCHOBIOLOGICAL PROCESSES

by

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INTRODUCTION

In the organism's interaction with its environment a large degree of adaptive activity takes place within the organism in the form of processes that intervene between environmental stimuli and organismic adaptive responses. The execution by the organism of certain responses implies a complex reworking or reorganization of the here and now impinging stimuli. These complex internal processes have largely been subsumed under the designation of "psychological", "mental", or "central mediating" processes (Gagne, 1959). It is the study of these complex mental processes in the human organism, and some concomitant factors, that is the general subject matter of this thesis.

Investigation and experience testify that human thought processes differ, in degree at least, as the organism develops and declines in its life cycle. Studies such as those of Piaget (1957) trace the emergence and development of thought processes in children and adolescents. The bulk of investigations dealing with thought processes, however, have focused on mental processes of adults or young adults. Comparatively little research has been directed toward investigating the complex mental processes of the aged, particularly that of the advanced aged individual. It is this category, the advanced aged individual, that we propose to study. Since we are embarking into an area of largely uncharted waters, it was felt that an exploratory study of individual old people and their process of problem solving would represent a modest step toward understanding complex mental processes of the human organism in the waning years of life.

To this end, we propose to investigate what takes place within the aged individual during the problem solving process in terms of certain psychobiological parameters. Specifically, we aim to a) characterize the individual in terms of age, education and general intelligence test performance, b) characterize his problem solving process, and c) investigate the interrelationships between the individual's steps in solving a problem and 1) the time duration of each step, 2) the heart rate during each step, and 3) the information gained at each step.

It should be noted that this is an exploratory, non-predictive study of individual old people and the process of problem solving as they individually experience it.

CHAPTER II

REVIEW OF RELATED LITERATURE

The historical problem encountered in the study of thought lies in the difficulty of analyzing internal, unobservable processes. Several attempts at objectifying these processes for analysis will be seen in the studies to follow. In general, they fall into three broad categories. The earliest empirical studies of thought employed an introspective method of analysis. To provide the data for analysis, this technique utilized the self-reflective reports of either the examiner himself or of trained subjects. Such were the early studies of Wundt and Titchner as well as the analyses of Dewey (1910) and Wallas (1926) who reflectively analyzed their thought processes into various stages or steps on the basis of their self-inquiries. While this method provides a limited descriptive analysis of thought processes it suffers from the limitations of subjectivity, lack of control, and difficulty in objectively repeating the observations.

A second method combines the self-reports of the subject along with an analysis of his observable responses to supply data for inference.

Among others, the studies of Durkin (1937) and Bloom and Broder (1950) exemplify the more or less pure use of this method. Although this has proven to be a useful and productive technique for descriptive and practical purposes, it lacks certain objective and quantifiable attributes desirable in scientific research (Johnson, 1955).

A third general category embraces those techniques which strive for empirical objectivity. By and large they employ statistical and mathematical methods of analysis. This category includes those methods that analyze the response made by the organism and infer the process from its resulting product, as well as those techniques that seek to objectify the process by the study of individual differences. As will be seen, these are not hard and fast categories as some studies employ variations of all methods. They are mentioned here merely as a general frame of reference.

For the purposes of this study a review of some of the pertinent findings in the areas of problem-solving, intellectual functioning in the aged, and biological correlates of these functionings will be presented.

Research on problem-solving

Early empirical studies of thinking were conducted within the framework of Associationism. These investigators analyzed thinking as the workings of associative bonds. In this context, many felt that thought could be measured by the number of associations a subject had acquired and how easily and correctly he learns and recalls them.

The limitations of Associationistic analysis were scrutinized by a group of subsequent investigators, known as the Gestalt psychologists. If Wertheimer (1945) is taken as a spokesman, this group saw earlier attempts at thought analysis as aimed at obtaining the elements of thinking by cutting "to pieces" living, thinking processes. They charged the Associationists with overlooking the structure of thought by assuming that the process is an aggregate, a sum of elements. Reacting to thought processes as "blind" processes, the Gestalt school focused their attention on the "productive" aspects of thought and "insightful" behavior. While Kohler (1927) and Yerkes (1943) studied problem-solving in higher animals, Wertheimer (1945) and Dunker (1945) concerned themselves with human productive thinking.

Dunker had his subjects "think aloud" as a method of objectifying the process of problem-solving. While this method has the limitation of slowing thought processes to the pace of orderly speech, it can be seen as an advance over purely introspective investigations. His problems were thought or reasoning problems, worked by adults, and analyzed for the effectiveness of approach. Dunker concluded that the process of solution has two aspects, the analysis of the situation and the analysis of the goal. For a subject to achieve a solution he must ascertain the conflicting elements of the problem, analyze the materials available and vary the crucial relationships between the two.

Wertheimer (1945) also employed the talking out method and utilized qualitative observation and analysis in formulating his theory of the dynamic structure of "productive" thinking. At least in one instance he interviewed Einstein and retraced with him the steps he pursued in arriving at the theory of relativity. He felt that the problem with its structural and functional relationships must be grasped and that these features determine the process of reorganization necessary for an "intelligent" or "insightful" solution. The process is not a sum of several steps or an aggregate of several operations, but a progressive cognitive activity that grows out of the gaps in the problem situation.

While these studies by the Gestalt school hold much valuable descriptive data, their formulations evidence a reactive concern for disproving the theory of Associationism. To this extent their work focuses on those aspects of the problem-solving process which are "insightful" or sensible, as opposed to other plentiful but less "intelligent" problem-solving behavior. Their contributions to the understanding of the human problem-solving process include the observations that: habitual modes of action influence problem-solving behavior; "creative" or "productive" thinking takes place when these habitual modes are insufficient for the problem at hand; successive reorganizations of the problem in terms of its peculiar structure account for "intelligent" solutions; the readiness with which the solution is found is related to the set or fixity of the perceptual field, motivating factors and the subject's previous training. They observed that a high degree of transfer to similar problems may be expected and also that the initial period of problem analysis is an important factor in an "intelligent" solution.

In the early '40's Sargent (1940) was concerned with the changes in the thinking process which occur when the difficulty level of a specific task is raised or lowered. Using objective and introspective methods he set out to describe the individual differences in the mental processes involved in solving problems at three different levels of difficulty. College students were given anagram problems and their timed performance and introspections while unscrambling the "hidden" words were obtained and analyzed. His quantitative correlations of the number of words unscrambled in an allotted time pointed to a drop in efficiency or number of words obtained as an individual moved from one level of anagram difficulty to another. He turned to his qualitative findings in seeking a reason for this change and to explore the individual differences in approach and solution. He found that individuals were similar in that all started with a whole approach, then if a solution did not come within five to fifteen or twenty seconds, they changed to a trial and error procedure until the solution occurred, usually as a sudden reorganization. Individuals, he found, differ in many ways in their approach to various levels of difficulty. They differed, among other things, in their effectiveness in reacting to cues present in the stimulus pattern, in their ability to control and to formulate hypotheses, and in their ability to use past experience in approaching a problem. Moreover, there was little connection between an individual's efficiency at one level and his efficiency at another, because different modes of behavior were shown at the contrasting levels of difficulty. The foregoing study is of interest in that it demonstrates that individuals do differ in their modes of problem approach, and that these modes of approach change as problem difficulty changes.

The importance of "set" or "direction" in problem-solving was emphasized by N.R.F. Maier (1940) in a series of studies in which direction or set as given by the experimenter was seen as the critical factor in the successful solution to problems. These studies lend verification to the earlier observation of the Gestalt school that set or receptivity to pertinent cues in the problem situation is important for successful solutions. Other authors (Rees and Israel, 1935 and Luchins, 1942) indicated that set for a certain type of solution can be induced by previous experience with a series of problems for which such solutions are obvious. The hypothesis they proposed was that pretest experience slants the formulation toward a general class of similarities. Johnson's (1960) research also tended to bear this out: "There is a large class of problems, preparation for which consists of formulating the problem in terms of a dimension of similarity among the items and when there are alternative dimensions of similarity, this formulation is influenced by immediately preceding experience with similar problems."

The 1950 Bloom and Broder study of problem-solving dwelt at length on the usefulness and necessity of studying the process involved in the solution to a problem and not the final solution alone. The authors employed a talking out method with college students and delineated four general areas that differentiated successful from unsuccessful problem solvers. These groups differed in 1) their understanding of the nature of the problem and their ability to start an attack on the problem, 2) their understanding of the ideas contained in the problem and their ability to bring past knowledge to bear on the problem, 3) their general approach to the solution of the problem, and 4) their attitude toward the solution of the problem, which included personal confidence in their own ability. While this study is largely descriptive in nature and amply self-criticized for deficiencies, its general approach and cautious conclusions are laudable. Of particular interest is the authors' emphasis on process over product analysis, their exposure of the role of personal attitude on successful problem-solving, and the implication that problem appraisal is an important factor in problem solution.

In much the same vein, Johnson (1960) attempted to describe the whole problem-solving enterprise in terms of sequential thought processes. In a two-part analysis simple problems were solved in less than a minute. This brief episode was divided into two intervals by controlling the exposure of the problem material. He presumed that two different intellectual activities take place serially. The first or "preparatory" step was thought to be the locus of many errors and was singled out for study. The remainder of the problem-solving episode was designated as the "solution" step. Employing a serial exposure box that exposed preparatory information and solution information in varying sequences, the experimenter was able to control the duration of exposure and record, by means of interval timers, relays and clocks, the time spent on each type of material under varying conditions. In a variety of applications of this method the experimenter's college subjects performed such that the following conclusions were drawn. The overlap between one thought process and the next is smaller when the thinker himself controls the presentation of material. It is possible by this technique to identify a preparation process that preceeds the actual selection of alternative solutions to a variety of problems. This preparation period differs from the solution period in respect to the functional relation between the time spent on each and certain independent variables, such as the type of problem and the amount of preparatory material. The author recognizes limitations in his series of studies. He mentions that they are concerned with the solution of very short problems, and that if problem duration were more extended the subject's activities could shift back and forth and this type of serial analysis might be unprofitable. While the current problems were solved by selection from a display of solutions, research might consider a situation wherein the subject generates his own solution.

Before turning to the Rimoldi technique which likewise emphasizes process over product analysis, two other approaches to thinking and problem-solving currently in use should be mentioned. Guilford (1960) advocates the factor analytic approach to the study of thinking. In his research with this technique, he and his associates (Frick, Guilford, Christensen, and Merrifield, 1959) identified three kinds of flexibility in connection with thinking (problem-solving). "Spontaneous," "adaptive," and "functional fixedness" are all said to be related to behavioral approaches to problems. Likewise, analysis of a general reasoning factor identified this factor as an ability to structure or to comprehend problems preparatory to solving them (Kettner, et alii, 1956). Newell (1958) and his associates look at the problem-solving process in terms of information processing systems, described as programs for treating information. Their programs are developed by observing behavior very carefully--including introspections during actual problem-solving--and then describing this process in a program for computer verification. They thus try to duplicate the human problem-solving process by means of computer programing.

The Rimoldi technique for the study of problem-solving

The origin of the Rimoldi technique for the study of problem-solving grew out of a dissatisfaction with more "traditional" mental testing procedures that analyze the end result or the correctness or incorrectness of an answer (Rimoldi, 1955). From the study of errors made to a multiple choice test, Rimoldi (1948) came to question the accuracy of these methods for describing mental processes (Rimoldi, 1960). It was found that wrong answers were not equally wrong and that the same answer to a test question may be the final outcome of different mental processes. To overcome this difficulty and to provide a method for analyzing the process of thinking rather than its end product, Rimoldi devised a technique that explores the number, type, and sequence of questions asked by a subject in solving a problem. In this way, the process of information utilization describes the thought process and is seen as a more direct indication of how a subject thinks.

Essentially, the technique involves presenting the information necessary for the solution to a problem on individual cards. One side of a card contains a question that the subject might wish to ask in pursuing his solution; on the reverse side of each card is the corresponding answer. The examiner records the questions asked and in what order, obtaining a sequence that indicates the successive steps followed in the solution of the problem. This provides the possibility of quantification of results and standardization of procedure, characteristics lacking in more descriptive analyses of thought processes. Standardization is achieved by controlling the number and type of questions that might be asked, as well as the nature of the information provided. The original quantification procedure provided for analysis of item usefulness in terms of group performance, and random expectation (Rimoldi, 1955). The technique was applied in a variety of settings from an analysis of diagnostic skills (Rimoldi, Devane, Grib, 1958) to the process analysis of Rorschach interpretation (Tabor, 1959), with promising results (Rimoldi, 1960). A similar rationale inspired a Problem-Solving and Information Apparatus devised by Rimoldi and John to test other types of problem-solving behavior (Rimoldi and John, 1955; John, 1957). Further developments and modifications of the original technique have followed. They have focused primarily on the analysis of the quantified data and on more advanced control of the problems presented (Rimoldi, 1960; Rimoldi, Devane, and Haley, 1961; Rimoldi and Haley, 1962; Rimoldi, et alii, 1962).

With this brief review of the pertinent literature on problem-solving and a discussion of the various methods used in analyzing this type of behavior, we can now turn to a consideration of the research on thought processes in the aged.

Aging and intellectual processes

One of the general effects that aging has on the intellectual processes was observed by Shock (1951) to be a general lowering of average intelligence test scores with increasing age. Aging, however, affects different functions in different ways. Vocabulary remains relatively stable with aging (Birren, 1959). Madonick and Solomon (1947) found small decrements on vocabulary, information, and similarities test items, and a significant decline in performance on numerical computation, common sense, opposites, series completion, picture arrangement, digit symbol, and analogies problems.

Bilash and Zubek (1960) employed the King Factored Aptitude test to assess intellectual decline with age in factorially "pure" aptitudes. Their sample included 634 subjects ranging in age from 16 to 89 years. The results of their study indicated that comprehension, verbal fluency, numerical ability, and spatial ability hold up well with age and that reasoning, memory for names and faces, perception, and dexterity undergo rapid decline. Their pencil and paper battery of timed tests, however, showed pronounced decline in all functions after the age of fifty years. As the authors observed, their factored aptitude battery placed a heavy premium on speed which proved to be, perhaps, the most important single factor in their observed "intellectual" decline in those of more advanced age.

In a similar study Kamin (1957) employed Thurstone's Primary Mental Abilities test and likewise found that verbal fluency, verbal meaning, and numerical ability held up much better with age than did reasoning and spatial ability. The "reasoning" referred to here is largely the type implied in "seeing relationships between words and numbers" (Bilash and Zubek, 1960). Other kinds of more complex reasoning seem to be especially well maintained with age where experience is involved but not when flexibility of thinking is involved (Gilbert, 1952). Eysenck (1945) concluded that the ~~most~~ rapid decline is found in those tests which measure the ability to deduce relations and correlates.

Birren (1959) reported that memory difficulties seem to be primarily with recent memory, and that creativity declines as brain dysfunction increases with age. Zubek and Solberg (1954) had similar findings on memory. The degree to which memory declines with age depends upon the nature of the material to be recalled. When the material involves past experience and knowledge, the decline in memory with age is relatively slight; when the material is new the decline is quite pronounced. Halstead (1943) observed that for older people the most difficult tests are those wherein the subjects are required to break away from old mental habits and to adapt to unfamiliar situations.

Factors other than age alone, seem to influence the differences in functional losses observed in the aged. Original level of ability may be a factor in differential decline in intelligence test performance. Foulds (1949) found a decrement in vocabulary ability beyond the age of 30 years in the lower 25th percentile of a large population, and a slight but measurable vocabulary increment with age up to the 55th year in the 95th percentile of the same group.

The degree of education undoubtedly influences intelligence test scores for different age groups. Birren (1959) reported that intellectual decline varies inversely with education. Earlier studies (Fox and Birren, 1949; Lewinski, 1948) showed a similar inverse relationship between education and vocabulary loss. Investigating the specific question of the influence of age and education on intelligence test scores Birren and Morrison (1961) analyzed Wechsler's WAIS standardization data for 933 native-born, white men and women in the age range 25-64 years. A principal component analysis of this data revealed two major components, one a general ability component and the other a component associated with an aging factor. Education was found to be much more significant for the first component than was chronological age over the age range 25-64 years. In this age range at least, the amount of education an individual has is more important than his age in influencing this general ability factor. In general, the manifest incremental effects of education on WAIS performance were greater than the decremental effects of aging for this age range. The effects of education on the subtests were seen to be wide spread while the age-decrement rather narrowly affected only some subtests.

Among other factors that influence intelligence test scores for different age groups, Birren (1959) also reported that more intellectual occupations seemed associated with smaller declines. Levinson (1960) reported significantly different WAIS performances between the aged of two different cultural backgrounds, and the Eisdorfer-Cohen study (1961) suggested that regional differences may account for the differences in level of old age WAIS performance.

Studies concerned with intellectual functioning in subjects over sixty years of age were few and inadequate up to 1951 (Shock, 1951). The number of studies since that time has not appreciably improved. Most studies concerned with age decrement on intellectual functioning have spanned the more easily accessible age range of the 20's through 60's. Loranger and Misiak's 1960 study of aged women 74-80 years old found their results consistent with the observation that old people have difficulty with tests involving comprehension of new ideas and adoption of new work methods. Using the Test of Primary Mental Abilities, Strother, Schaie, and Horst (1957) tested retired academic and professional workers between the ages of 70-88 years, and concluded that the earliest and largest loss occurs in memory, speed, reasoning, and spatial abilities. Vocabulary, arithmetic, and information showed the smallest decline up to age 70 and verbal meaning and numerical abilities remained above the mean for a 17 year old reference population in the majority of the subjects over 80 years of age.

A study that more closely approximates the present study is that of Ross, Vicino, and Krugman, (1960) who investigated the relationships between problem-solving ability and abstract reasoning ability in 29 male subjects between the ages of 65 and 78. After taking the Goldstein-Scheerer-Weigl Color Form Sorting test, the subjects performed on a problem-solving task of three stages of difficulty. Essentially, the task was one of translating spatial perception into motor performance. The subject was required to find the correct button to push each time that a different signal light was flashed on a board. The level of difficulty was established by varying the position of a coding card in its relation to a display and response board. The number of errors for each trial provided the measure of problem-solving ability. A highly significant relationship was found between abstract reasoning and problem-solving abilities. Those subjects who performed well on the Sorting Test made significantly fewer total errors and significantly fewer errors per stage of difficulty than did the subjects whose abstract reasoning performance was low. The "high error" group demonstrated a lessened ability to shift voluntarily and to reorganize stimulus information as the stages changed in the problem-solving task. What is of importance for the present study is the indication that a task involving abstraction proved difficult for some aged subjects, while others who handled this task adequately likewise performed better on a problem-solving task.

In summary, it seems that aging affects intellectual functioning differentially, and that individuals differ in the degree to which aging affects their mental functioning. Although the determination of which functions are most affected by aging largely depends upon the instruments used in assessing these functions, it can be said that most studies agree that vocabulary, verbal fluency, information, and comprehension test items hold up relatively well with age. There is less agreement on the extent to which numerical abilities, spatial abilities and reasoning abilities are retained over age. There does seem to be general agreement that old people have difficulty with recent memory and integration of recently acquired material, particularly when old mental habits and information are of little value in dealing with material.

On the other hand, the conflicting results found in the literature may in part be ascribed to the samples upon which their results are based, since individuals are affected differently by the aging process. An individual's original level of ability, his education and life occupation have been associated with differential retainment of intellectual functioning in later life. Individuals of different cultural backgrounds and even geographical regions have been noted to differ in their intelligence test performances. Thus, a detailed description of individuals and their functioning seems necessary before the variables that influence intellectual functioning in advanced age can be accurately described.

Biological correlates of mental processes

Of the many studies relevant to cardiac arousal (Ford, 1953; Altschule, 1953) and its relationship to task performance (Freeman, 1940; Malmo, 1957; Duffy, 1962) only two studies most closely paralleling the present study will be mentioned.

Blatt's (1961) study of cardiac arousal in complex mental activity studied cardiac rate and variability in problem-solving as it occurs in young adult males. His aim was to explore the relationship between cardiac rate as a measure of autonomic arousal and efficiency in complex mental activity. Using the Rimoldi-John Problem-Solving Apparatus, Blatt divided his eighteen subjects into two groups of efficient and inefficient problem-solvers on the basis of the number of unnecessary questions asked during an experimental problem. The total experimental session was divided into seven occasions. Measuring cardiac rate for 30-second intervals during each of these occasions, he found that there was no significant mean difference between the two groups either in rate or variability during the initial three periods (rest, instruction, rest). Blatt did, however, find significant mean differences between the efficient and inefficient subjects during the remaining four experimental occasions, both with respect to cardiac rate and variability. The author saw in his results support for his hypothesis that efficient problem-solvers are significantly more rapid and variable than inefficient subjects in cardiac rate while attempting to solve a complex mental problem. He also found support for the hypothesis that elevations in cardiac rate of efficient subjects accompany crucial developments in their problem-solving process.

He concluded the whole study by observing that arousal, as measured by elevations in cardiac rate, was clearly related to the efficiency with which his subjects solved the problems. Moveover, arousal was shown to be not a total reaction but rather a differential occurrence coming in part at crucial points in the problem-solving process. The variability of autonomic response was seen as possibly being as important a factor as the level of arousal in the relationship between problem-solving efficiency and autonomic arousal. That is, the capacity for differential reaction and response may be the important facilitating effect in problem-solving efficiency rather than the absolute level of arousal. What is of particular interest are the reported mean cardiac rates and variability measures for the two groups of subjects during the experimental problem proper. The efficient group had a mean cardiac rate of 94.16 beats per minute and a standard deviation of 6.794, while the inefficient problem-solvers had a mean rate of 80.80 beats per minute and a standard deviation of 3.180 while performing on the experimental problem. These findings offer comparative data for the present study.

A subsequent study in part stimulated by Blatt's investigation was the recent doctoral dissertation of R. A. Meyer (1964). This author examined the changes in children's cardiac rate during the problem-solving process. His seventh and eighth grade students, divided into efficient and inefficient problem-solvers on the basis of pre-test data, were given structured problems to solve while their heart rate was continuously recorded. The author's aim was 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." The experimental session was divided into three occasions, a pre-problem baseline, the experimental problem, and a post-problem baseline. Analysis of the cardiac rate for the two groups during these three occasions revealed that for both groups there was a significant increment in heart rate during the problem-solving session over the baseline periods, and that this increment was greater for the efficient group than for the inefficient group of problem-solvers. This was interpreted as lending support to the hypothesis that autonomic arousal is a characteristic of efficient functioning and that arousal has an adaptive and facilitating effect in terms of efficient functioning in a task. An analysis of the difference between question period and periods of integration within the problem session itself, showed that autonomic arousal is not a total reaction but that certain periods in the problem-solving process witness significant increments in cardiac rate over other periods. Moveover, the efficient group's sequence of information utilization was in significantly greater accord with the logical criteria than the performance of the inefficient group, thus suggesting a positive relationship between the observance of a logical sequence in the problem-solving process and efficiency as herein defined.

While these general findings are in agreement with the Blatt (1961) study they are not entirely comparable, since the experimental groups were selected according to different criteria. What is of interest for our study, however, are the implications that the adherence to a logical sequence of information utilization may be ascribed the properties of efficiency and that autonomic arousal may have an adaptive and facilitating effect in terms of efficient functioning.

CHAPTER III

PROCEDURE

The source of the data and the subjects studied

The material for this study was taken from the files of the Loyola Psychometric Laboratory which this author helped compile as part of Project No. 1787, sponsored by the Illinois State Psychiatric Training and Research Authority. The subjects were selected from two homes for the aged in the Chicago area. The essential criteria for subject selection was availability, and a willingness and interest in participating in a research project. In gathering data, approximately eight hours of actual testing was spent with each individual. This was divided into two sessions, a pre-test session and a testing session proper. In the ~~first~~ session, the information pertinent to age, education, and general intellectual functioning was gathered. A few days later, the actual testing session proper began with the administration of our experimental problems and the concomitant recording of the physiological data.

The individuals studied are sixteen geriatric subjects over seventy years of age who are either average or above average in intelligence. The ten males and six females range in age from 70 to 88 years, with a mean age of 79.8 years. They have a minimum of eight years of education to a maximum of nineteen years, with a mean of 12.6 years. The data characterizing each individual in terms of age, sex, education, and occupation, together with respective scores on the Wechsler Adult Intelligence Scale, the Raven Colored Progressive Matrices and the Tate, Stainer, Harootunian Thought Problems, Part I, are summarized in Table 1. Considering our subjects as a group, Table 2 gives some indication of our subjects' intellectual functioning as

Table 1

Age, Years of Education, Occupation and Scores on WAIS, Raven Progressive Matrices and Thought Problems for Sixteen Geriatric Subjects

Subject	Age	Education Years	WAIS IQ	Raven Score	Thought Problems	Occupation
1.	83	10	125	33	8	Teacher and Office Worker
2.	75	10	113	31	4	Postal Clerk (Retired)
3.	82	8	109	29	4	Laborer (Retired)
4.	84	10	114	24	4	Clerical Worker
5.	72	12	105	32	1	Receptionist
6.	75	8	97	32	0	Housewife (Retired)
7.	73	13	109	20	4	Medical Secretary (Retired)
8.	85	12	110	20	3	Executive
9.	82	16	119	30	5	Engineer
10.	84	19	129	10	9	Lawyer
11.	88	13	122	24	3	Organizer
12.	82	14	109	12	1	Banker
13.	76	19	137	31	16	Lawyer (Semi-Retired)
14.	81	12	133	28	4	Executive
15.	85	10	113	12	5	Executive
16.	70	15	129	29	6	Executive
Mean:	79.812	12.56	117.06	24.81	4.81	
SD:	5.28	3.28	10.79	7.56	3.68	
Range:	70-88	8-19	97-137	10-33	0-16	

Table 2

Mean and Standard Deviation of Subtest Standard Scores for Old Age Samples on the WAIS

Old Age Sample		Information	Comprehension	Arithmetic	Similarities	Digit Span	Vocabulary	Digit Symbl	Pict. Completion	Block Design	Pict. Arrng mnt.	Obj. Assembly
Present Age 70+	M	11.43	13.75	10.62	9.50	8.94	13.62	4.69	7.19	6.69	6.31	6.19
	SD	2.18	3.27	2.34	3.29	2.14	3.35	1.61	1.74	1.65	2.17	2.32
Duke[a] Age 75+	M	9.12	9.74	8.28	6.65	7.41	9.90	2.73	5.52	5.14	4.38	5.20
	SD	4.65	4.06	3.49	4.02	2.82	4.70	2.66	3.36	3.23	2.84	2.73
WAIS[b] Age 60+	M	9.55	8.96	9.51	8.77	8.82	9.61	5.36	7.14	7.82	6.88	7.77
	SD	3.17	2.27	3.58	2.82	2.89	3.25	2.80	2.30	2.80	2.55	2.93

[a] Eisdorfer, C. and Cohen, L.D. The generality of the WAIS standardization for the aged: a regional comparison. J. abnorm. soc. Psychol. 1961, 62, 520.

[b] Wechsler, D. Manual for the Wechsler Adult Intelligence Scale, New York: Psychological Corporation, 1955, 24.

compared to other reported old age groups' functioning on the WAIS. As can be seen from inspection of Table 2, our subjects as a group are functioning in a superior fashion to other groups of old people in almost all of the areas of intellectual functioning represented on the WAIS.

Problem Solving process; the problems, their presentation and characterization

The problems given to our subjects for solution and their corresponding questions and answers are illustrated in Tables 3 and 5. They were presented in the manner described above as the Rimoldi technique. That is, each of the questions was typed on a 3"x5" card with its corresponding answer typed on the reverse side. After reading the problem, the subject selected those questions he deemed necessary for the solution. The order of his selections was recorded and is taken as indicative of the order of information utilization.

It should be noted at this point that both problems can be graphically represented as having the same basic structure: Figures 1 and 2. One (45A), is presented in the concrete terms of a human family structure. The second problem (45B) is essentially the same problem presented in the abstract terms of alphabetic symbols. Both problems have parallel possible solutions, all logical in their manner of approach. In Tables 4 and 6 these possible tactics are detailed out in terms of the number of cards necessary to arrive at a solution, as well as the corresponding possible logical sequences. Both problems can be solved by asking as few as two questions, if asked in the proper order. Moreover, the problems can be solved without being logically redundant by asking as many as four questions if an appropriate sequence is followed.

Criteria and Scoring

As can be seen from the above, the criteria for scoring the sequences of card selection is based on the logical properties of the sequences involved. One need only study the problem and its structure to see the logical verification of the sequences. Of course, within a tactic reversals of sequence are possible and logical, for example, a tactic could be C-CD or CD-C (in terms of Problem 45A, questions 6-3 or 3-6).

The scoring of an individual's sequence of questions asked is based upon these logical sequences. The scoring and weighting of these tactics are detailed in the Appendix. Essentially, each tactic was weighted in favor of the least number of cards selected, since the directions to the problems enjoined "asking as few questions as possible." Making the total scoring table equal to unity, each tactic and the steps within the tactic are given a proportional value, such that an individual solving the problem in two steps will receive proportionally more for each step than an individual who asks three or four questions in arriving at his solution. Moreover, the interposing of redundant or inappropriate questions into the

Table 3

Instructions and Corresponding Questions and Answers for Problem 45 A

Instructions

The total group of people in this problem is called the Jones family. You are to find out how many female children are members of the Jones family, and you will be able to do this by asking any of the following questions. Try to solve the problem by asking as few questions as possible.

Questions	Answers
1. How many people are in the Jones family?	1. Ten.
2. How many men and boys are in the Jones family?	2. Seven.
3. How many adult women are in the Jones family?	3. Two.
4. How many men are in the Jones family?	4. Three.
5. How many boys are in the Jones family?	5. Four.
6. How many women and girls are in the Jones family?	6. Three.

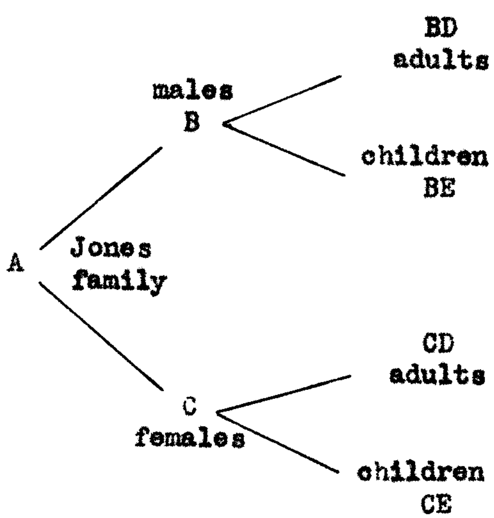

Fig. 1. Structure of Problem 45 A

Table 4

Tactics, Number and Logical Sequences of Questions for Problem 45 A

Tactic	Number of Questions	Sequences of Questions
a_1	2	C-CD 6-3
a_2		(3-6)
b	3	A-B-CD 1-2-3
c_1	4	CD-BD-A-BE 3-4-1-5
c_2		(1-3-4-5)
c_3		(1-4-3-5)

Table 5

Instructions and Corresponding Questions and Answers for Problem 45 B

Instructions

The total group of objects in this problem is called "A". Now an "A" can be either a "B" or "C", and B's and C's can be either D's or E's.

You are to find out how many C's are E's, and you will be able to do this by asking any of the following questions. Try to solve the problem by asking as few questions as possible.

Questions	Answers
1. How many A's are in the group?	1. Twelve.
2. How many A's are B's?	2. Four.
3. How many A's are C's?	3. Eight.
4. How many C's are D's?	4. Three.
5. How many B's are D's?	5. Three.
6. How many B's are E's?	6. One.

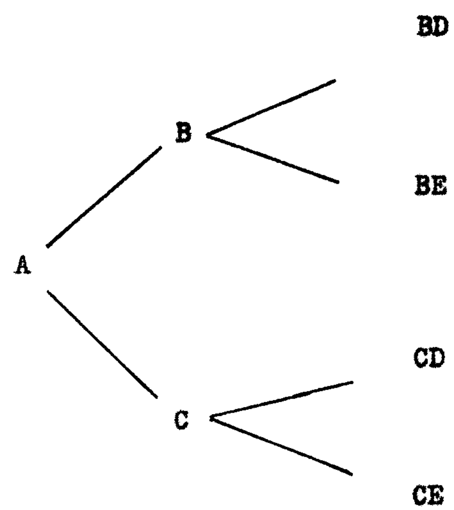

Fig. 2. Structure of Problem 45 B

Table 6

Tactics, Number and Logical Sequences of Questions for Problem 45 B

Tactic	Number of Questions	Sequences of Questions
a_1	2	C-CD 3-4
a_2		(4-3)
b	3	A-B-CD 1-2-4
c_1	4	CD-BD-A-BE 4-5-1-6
c_2		(1-4-5-6)
c_3		(1-5-4-6)

sequence was penalized by dividing the individual's total score by the total number of cards used in arriving at a solution. Thus, the final proportional values for each step most adequately represents the individual's adherence to a logical sequence, in accord with the directions, as he attempted to solve the problem.

Graphic representation of information utilization

Figure 3 is a graphic representation of a subject's performance on Problem 45B. The final proportional values for each step are cumulatively graphed to produce a performance curve. (The origin of these values can be found in the example in the Appendix.) Plateaus in this curve can be interpreted as instances in the information utilization sequence where the particular information chosen was of little or no value in terms of the logical sequence of questions being asked. The subject's first two choices of information received maximal value in terms of possible logical sequences. The third choice was a question whose utility in this position only occured in one of the possible tactics and the fourth question asked did not occur in this position in any of the possible criteria sequences. Thus, the plateau in Figure 3 can be interpreted as representing a departure from a logical pursuit of information utilization.

Accompanying parameters: Time and Cardiac Rate

For the entire problem-solving session a continuous Polygraphic record-

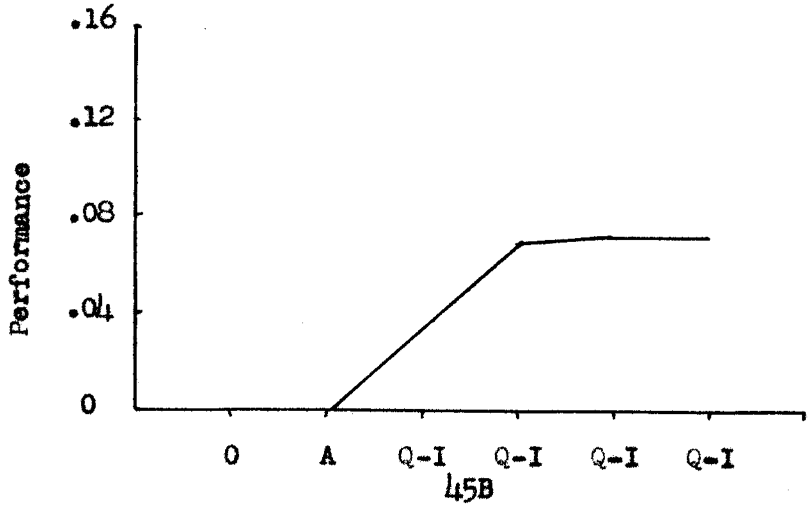

Fig. 3. A subject's performance values for problem 45B cumulatively plotted over Appraisal and Question-Integration periods of the problem-solving process.

ing of time and heart rate on a Sanborn Oscillographic Recording System, Model 296-T made it possible to plot the time duration of each step in the problem-solving process, together with the level and fluctuations in heart rate during these periods. An event marker on the recording designated the choice point for each of the questions asked. It was thus possible to divide the problem-solving process into the following periods: an initial Appraisal period, wherein the subject reads the problem and surveys the possible questions to be asked. The choice of the first question marks the beginning of the first Question-Integration period, wherein the subject selects his first information and presumably integrates it with what he knows of the problem. The selection of the second card marks the beginning of the second Question-

Integration period, and so on until the subject arrives at a solution or discontinues his attempt to do so.

Since the recording system was moving at a constant rate of speed (2.5 mm. per second), the number of millimeters per period and the number of beats per millimeter could be transformed so that each period can be expressed in terms of minutes and the heart rate in terms of beats per minute. These measures are graphically represented on the same abscissa as the Performance values. Thus, the time spent on a particular phase of the problem together with the heart rate at that point can be compared with the information value of that step to give a graphic representation of the subject's performance throughout the problem-solving process in these three parameters. Moreover, the percentage of the total time spent on the initial appraisal period was computed and presented in the left-hand side of each time graph to facilitate the evaluation of the importance of this appraisal period. The time is cumulatively graphed to more clearly correspond to the cumulated performance values.

Finally, since this is an exploratory study of individual old people only general trends are sought in our graphic presentation of their problem-solving performance.

CHAPTER IV

RESULTS AND DISCUSSION

Results

The results of our sixteen subjects' performance on the two problems, 45A and 45B, are graphically presented in Figures 4 through 19, wherein cumulated time and performance values together with the corresponding heart rate for each step in the problem-solving process are represented for each individual subject. In Table 7 the individuals' performance in terms of logical sequence of information utilization are summarized from these graphs. From the graphs and this table it can be seen that: 1) in general these old people tended to have less difficulty with a problem when presented in concrete terms than when presented in abstract terms at least as far as logical approach is concerned. 2) Plateaus, or a breakdown in logical information utilization, tend to occur toward the middle in problem 45B and the end in both problems. 3) Only three individuals performed optimally on both problems. Those individuals who lacked plateaus in both problems (Nos. 10,11,13) are in the group's highest IQ range.

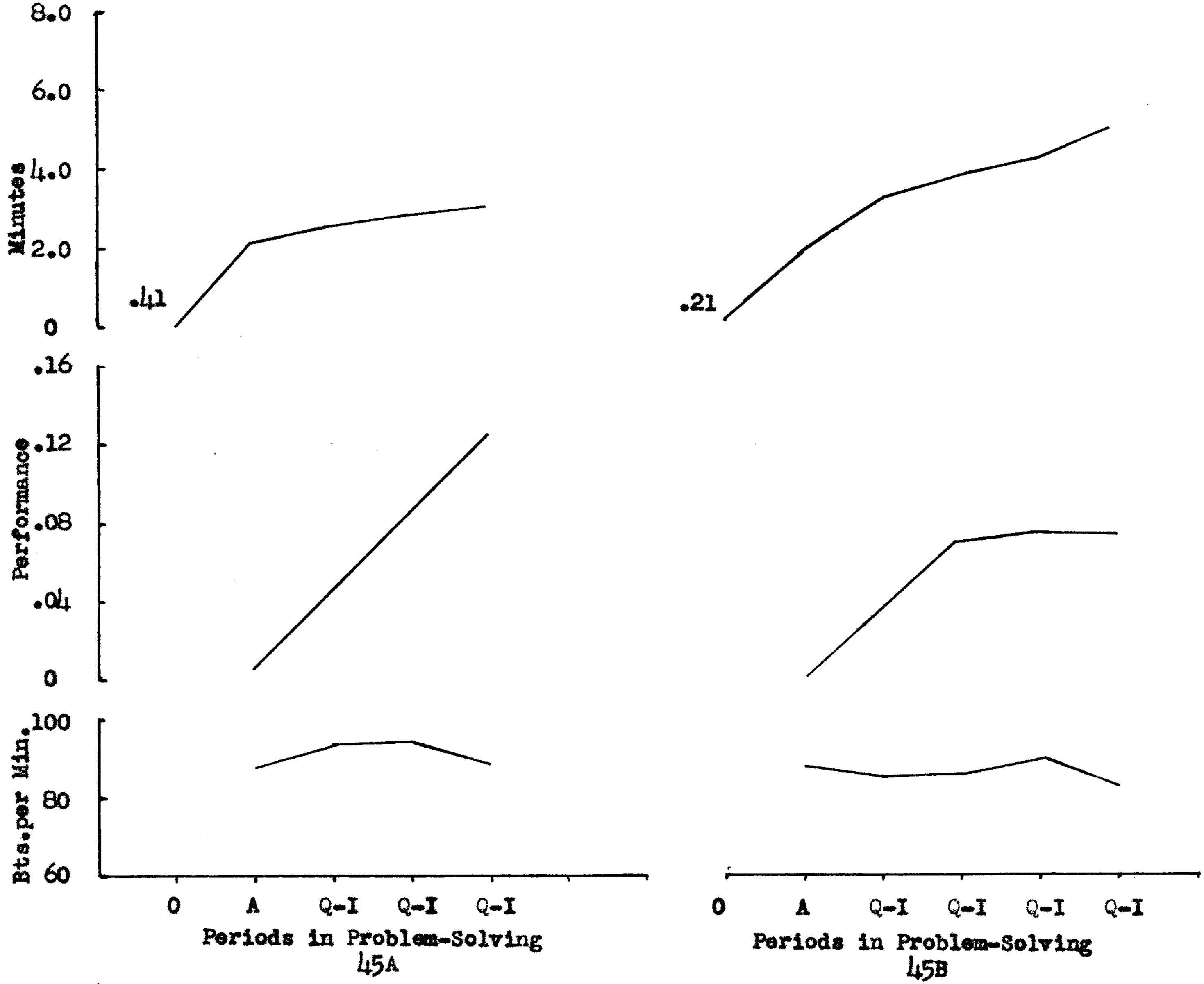

Fig. 4. Heart Rate, Performance and Time Values for Subject No. 1.

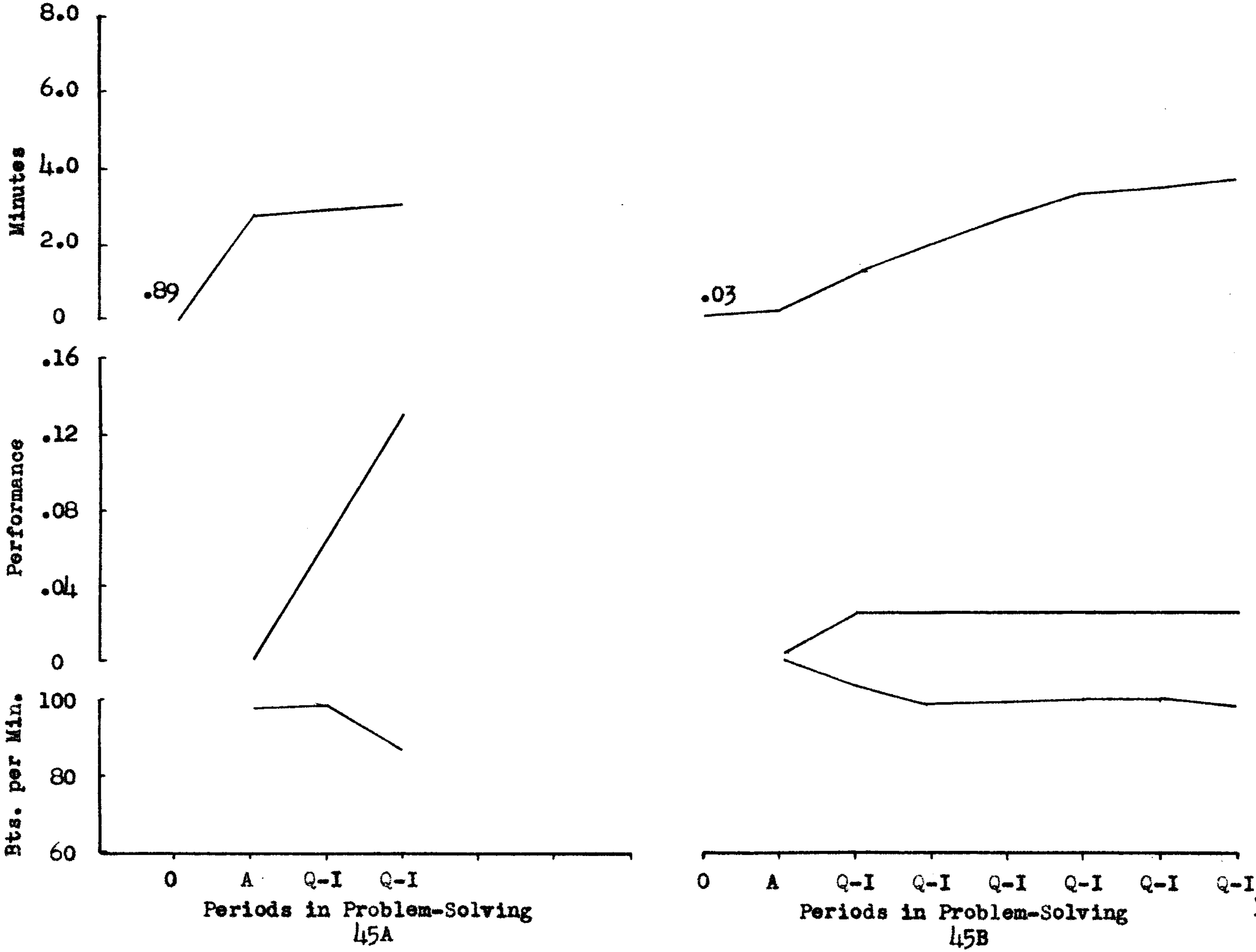

Fig. 5. Heart Rate, Performance and Time Values for Subject No. 2.

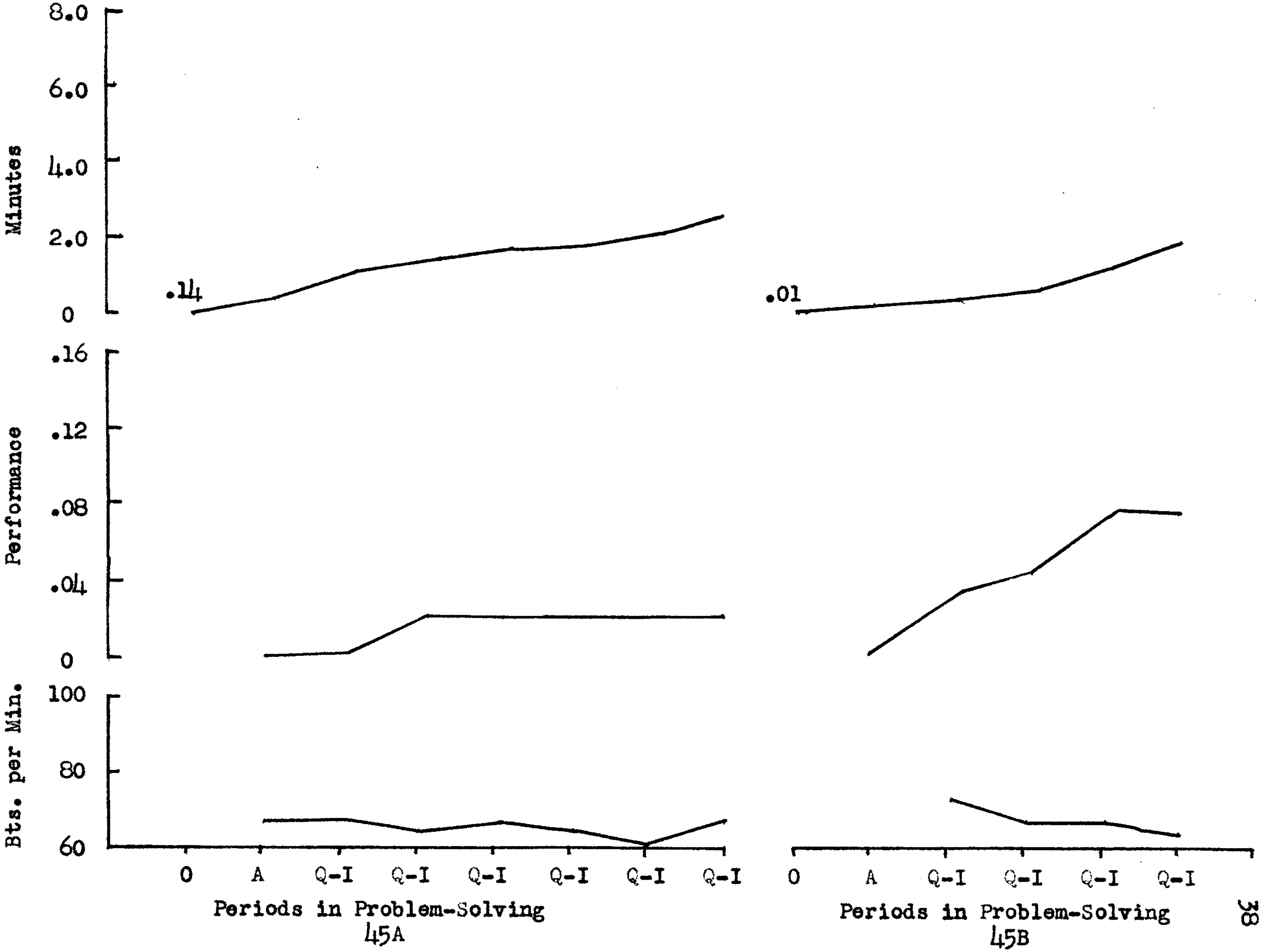

Fig. 6. Heart Rate, Performance and Time Values for Subject No. 3.

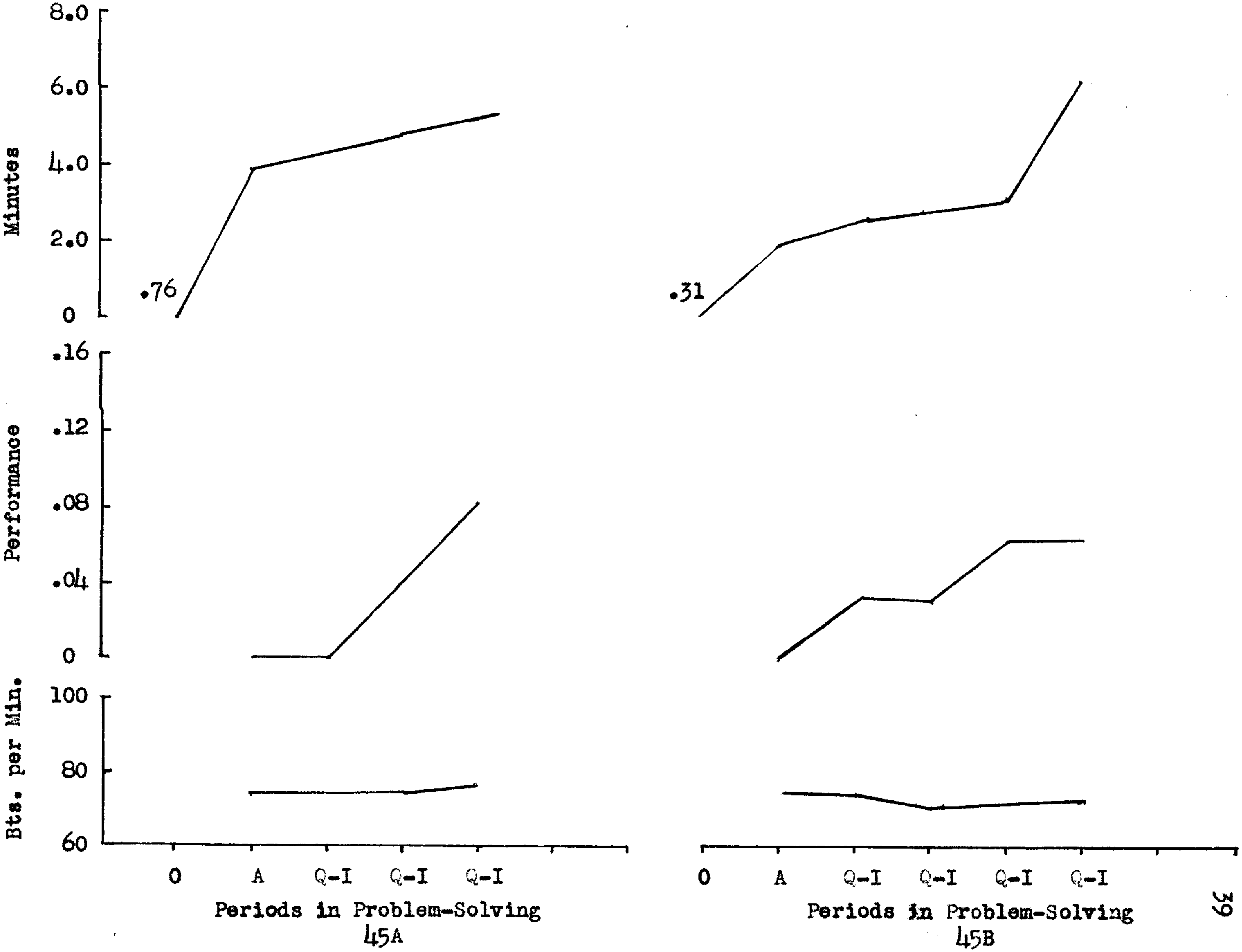

Fig. 7. Heart Rate, Performance and Time Values for Subject No. 4.

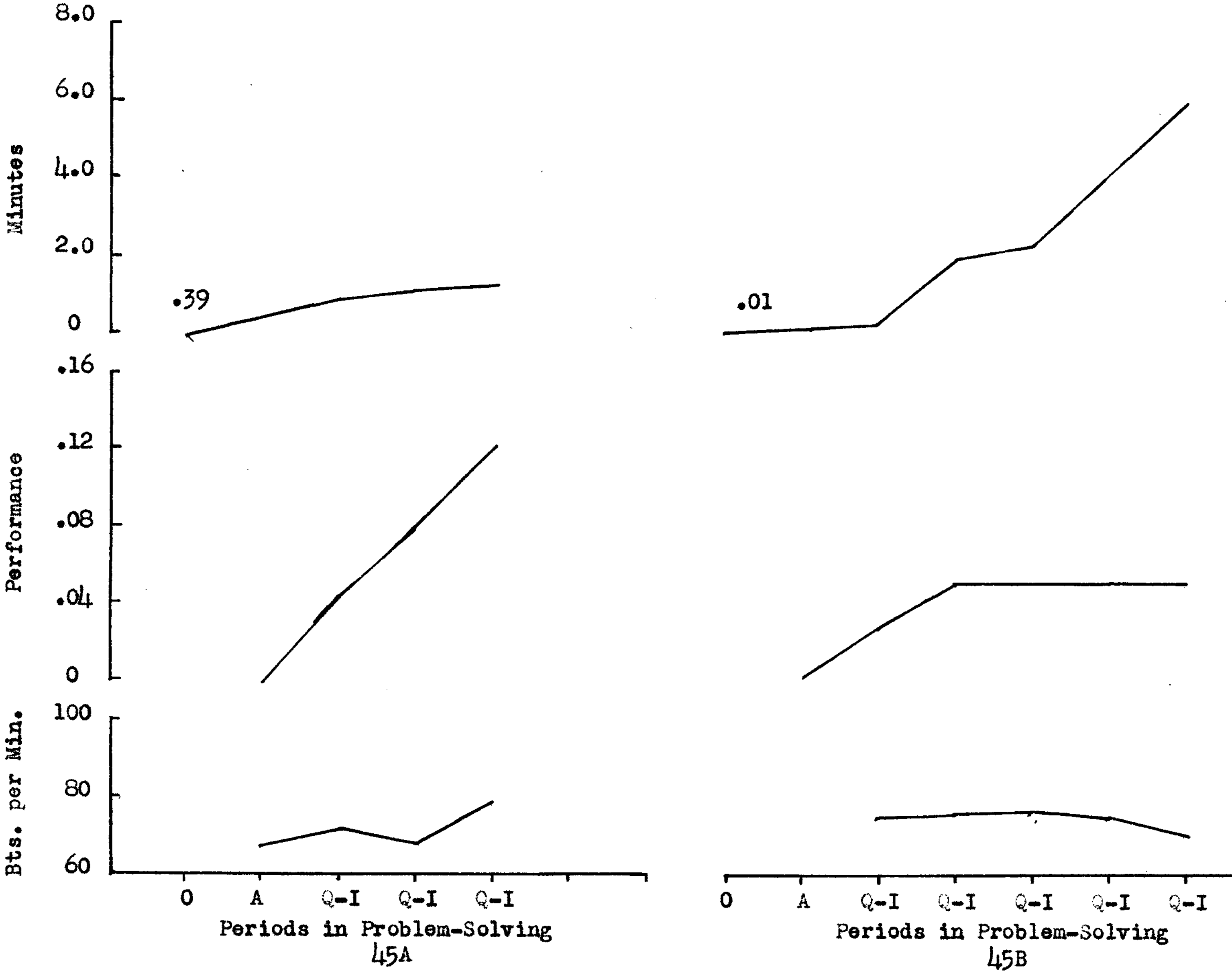

Fig. 8. Heart Rate, Performance and Time Values for Subject No. 5.

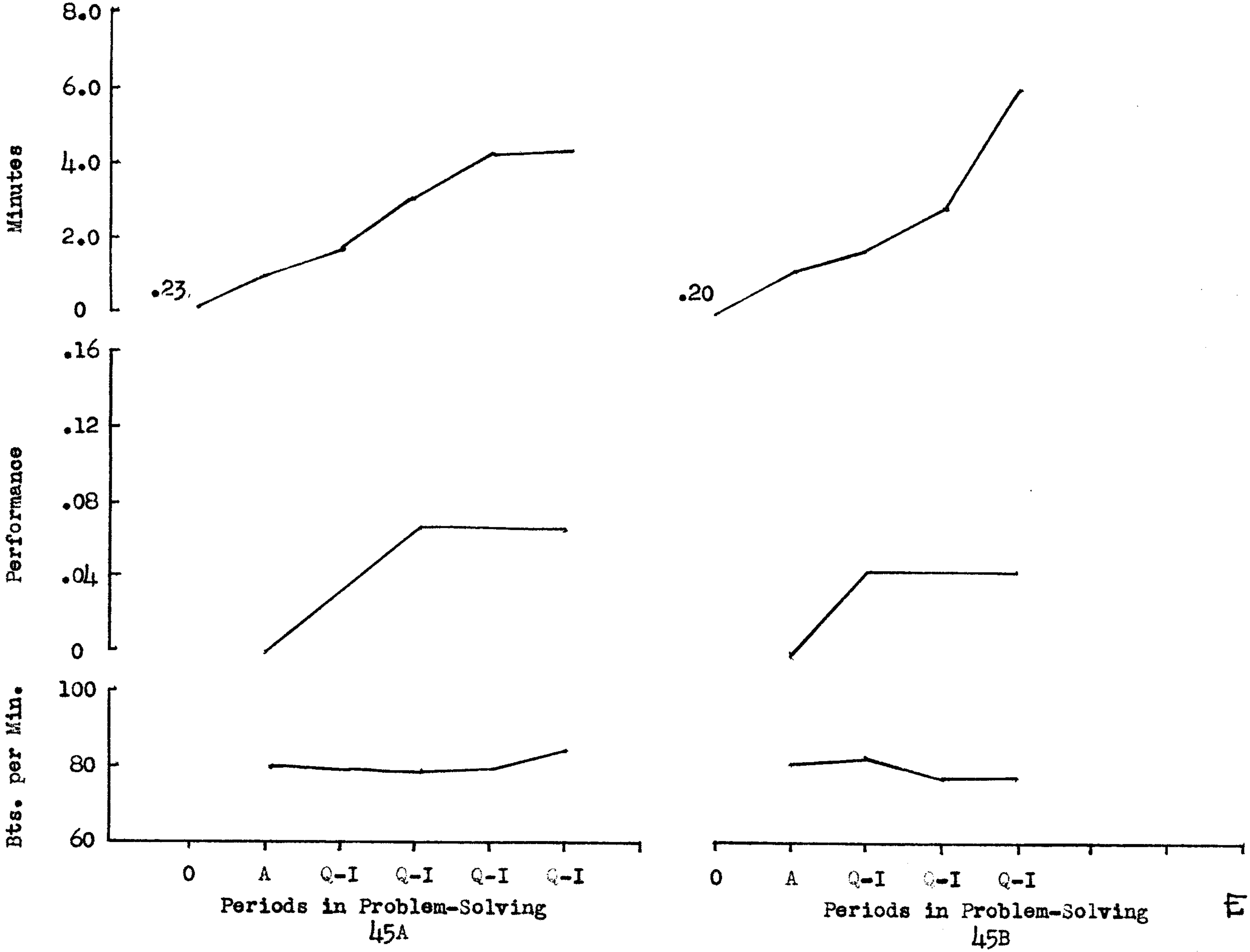

Fig. 9. Heart Rate, Performance and Time Values for Subject No. 6.

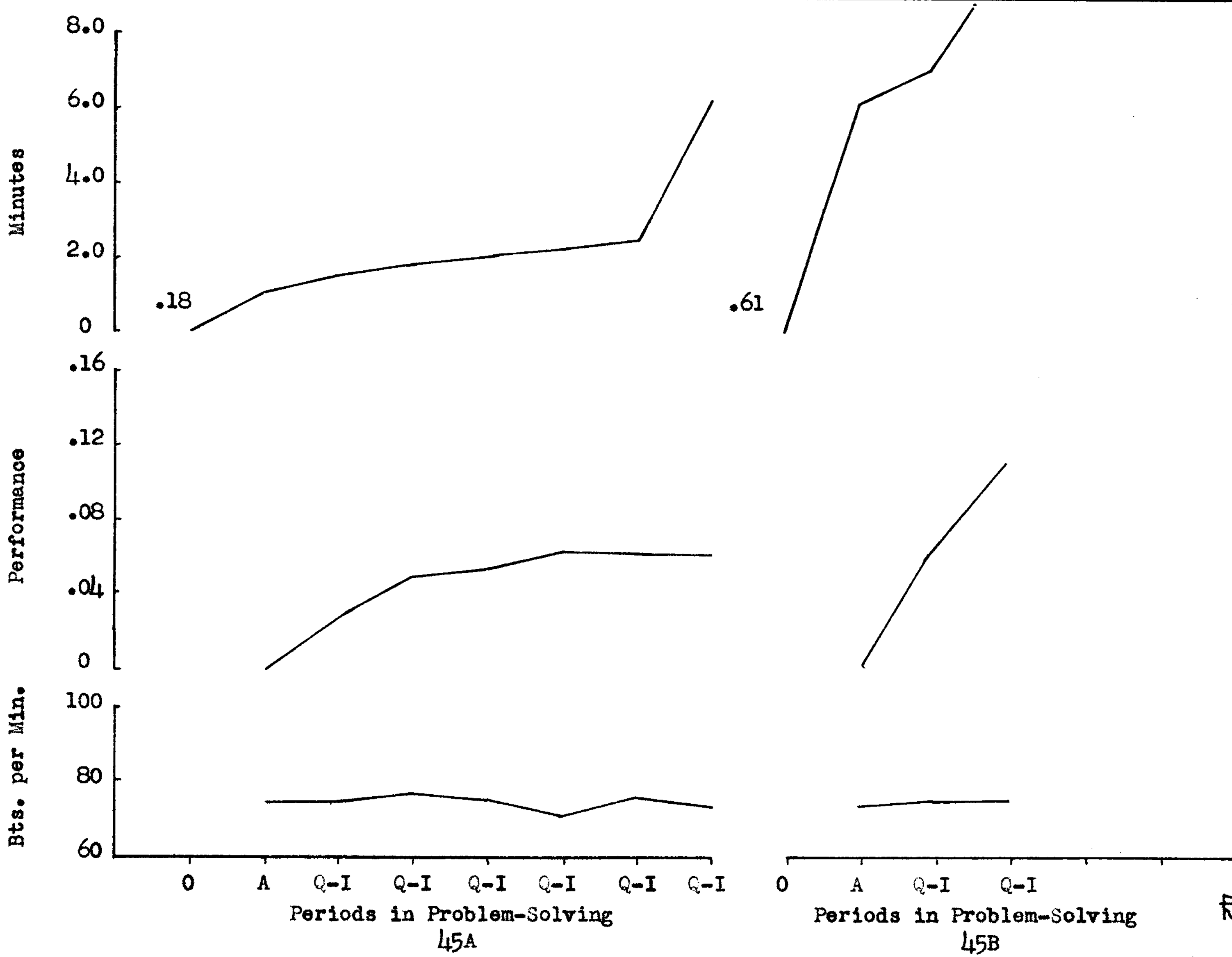

Fig. 10. Heart Rate, Performance and Time Values for Subject No. 7.

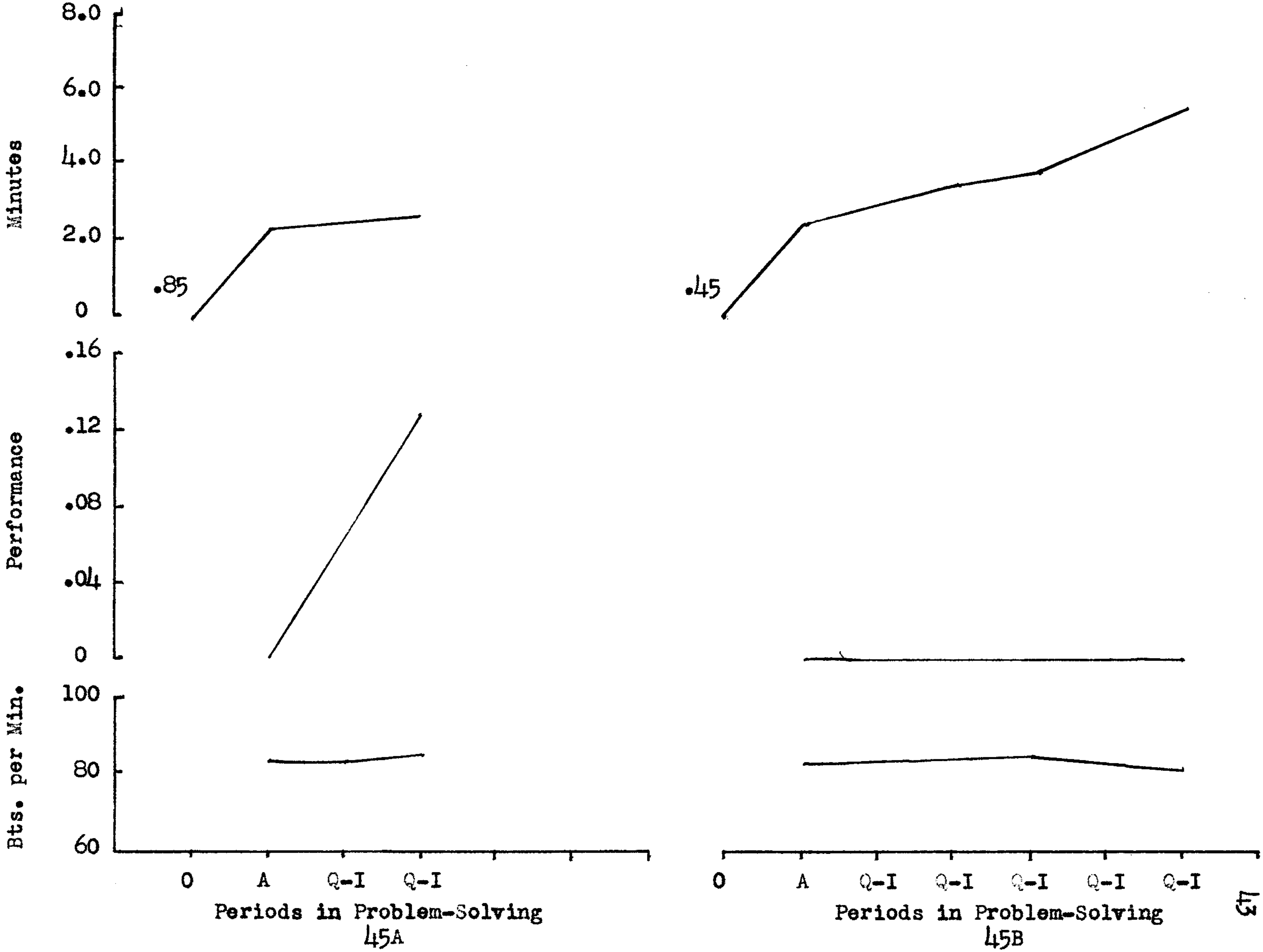

Fig. 11. Heart Rate, Performance and Time Values for Subject No. 8.

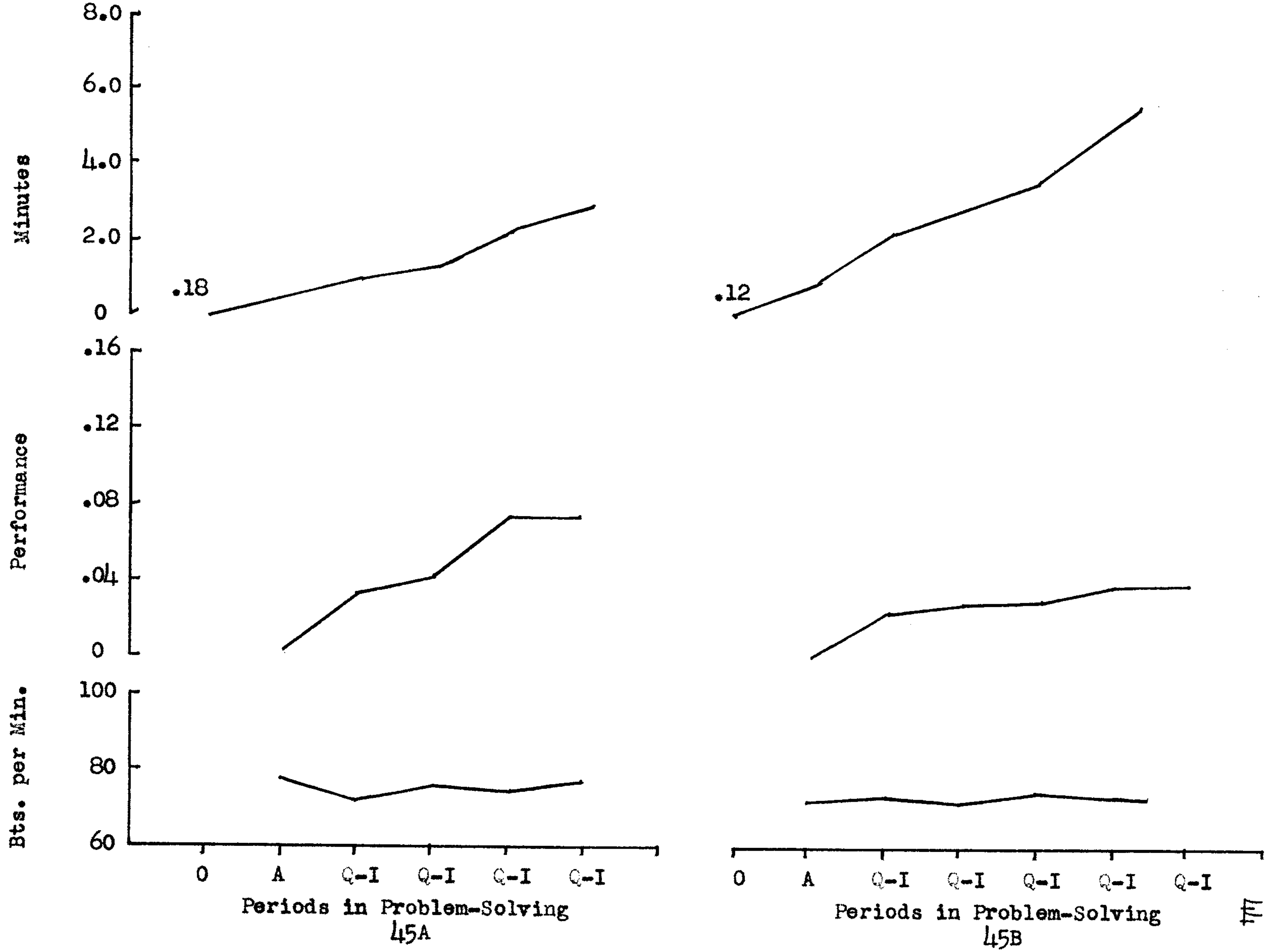

Fig. 12. Heart Rate, Performance and Time Values for Subject No. 9.

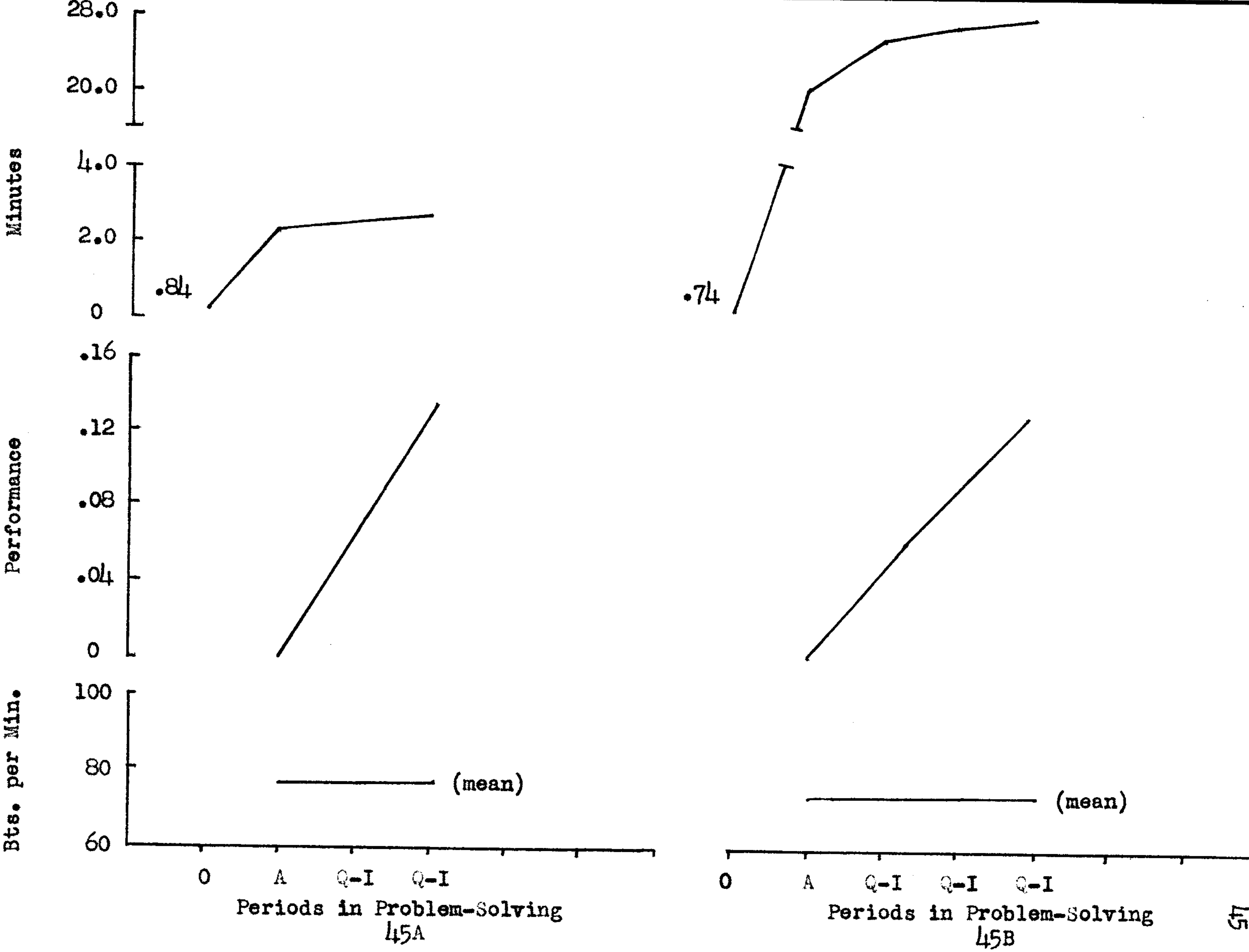

Fig. 13. Heart Rate, Performance and Time Values for Subject No. 10

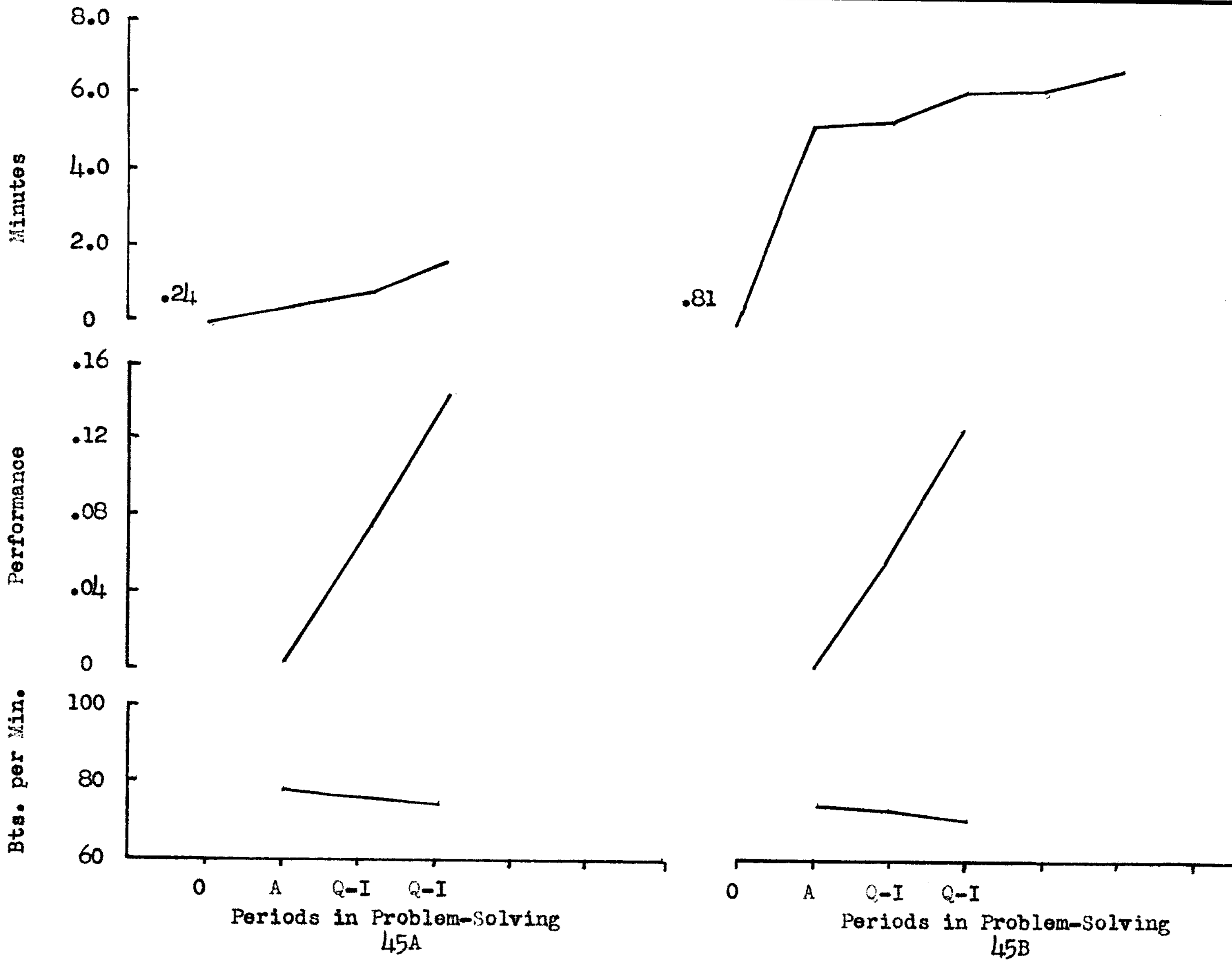

Fig. 14. Heart Rate, Performance and Time Values for Subject No. 11.

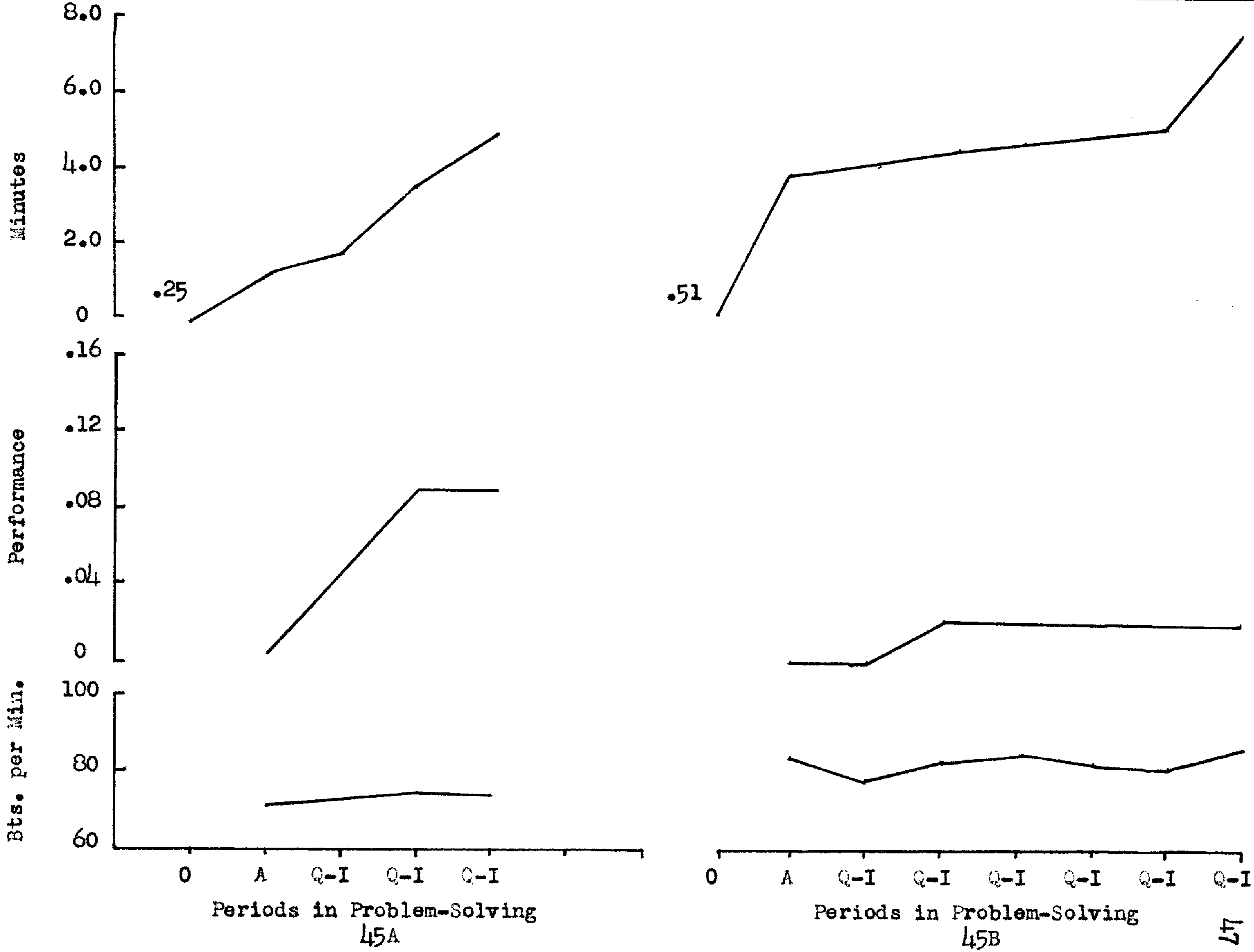

Fig. 15. Heart Rate, Performance and Time Values for Subject No. 12.

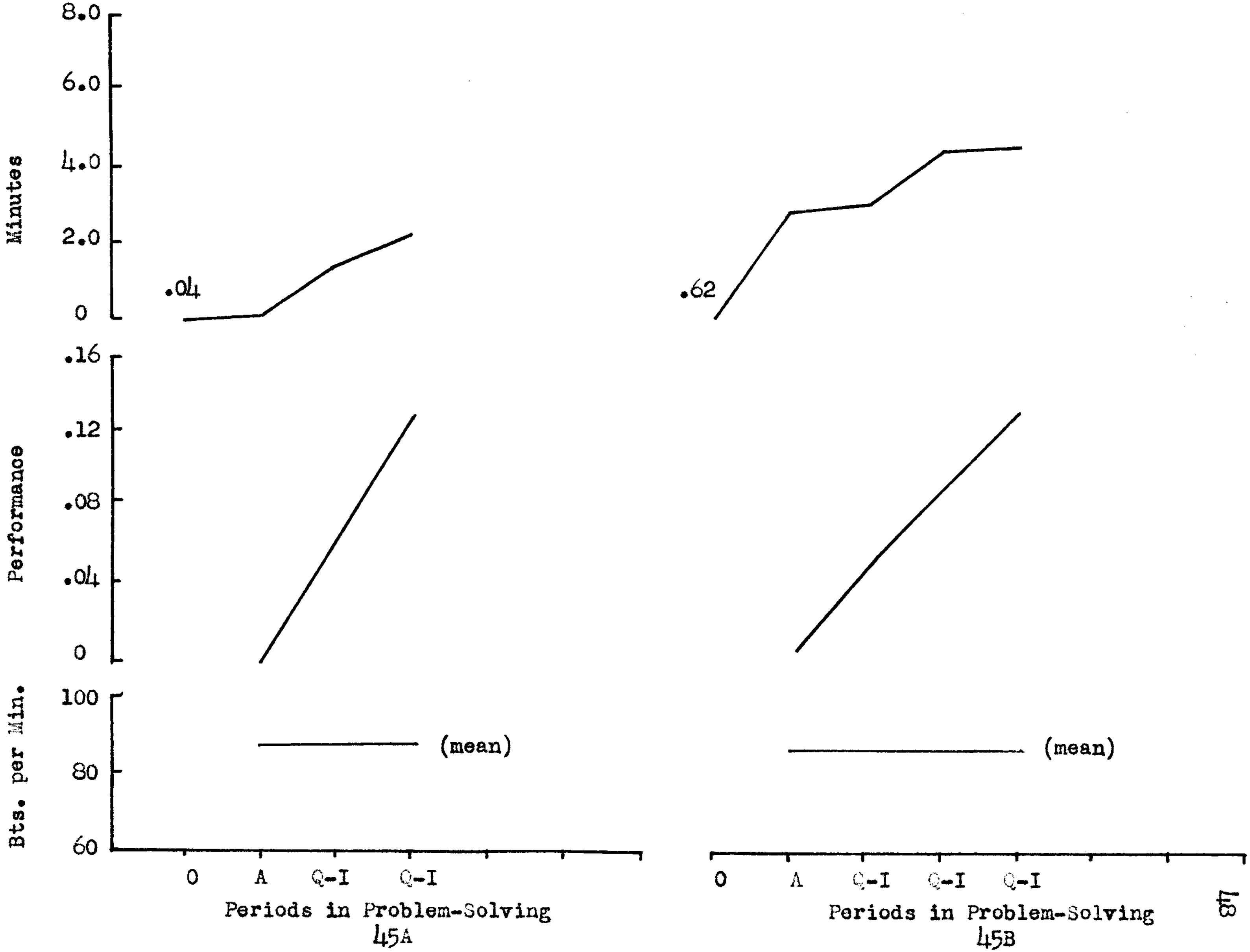

Fig. 16. Heart Rate, Performance and Time Values for Subject No. 13.

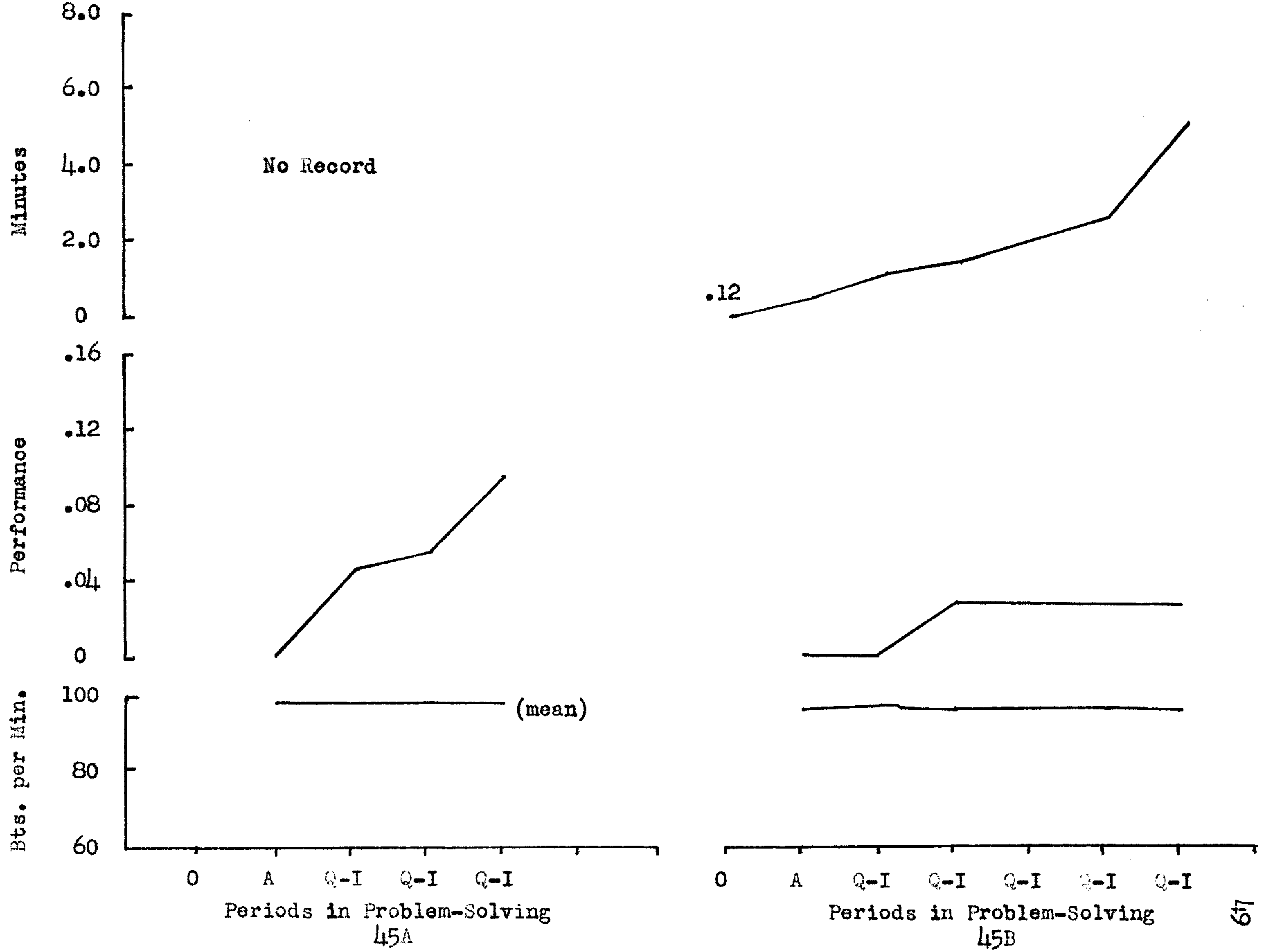

Fig. 17. Heart Rate, Performance and Time Values for Subject No. 14.

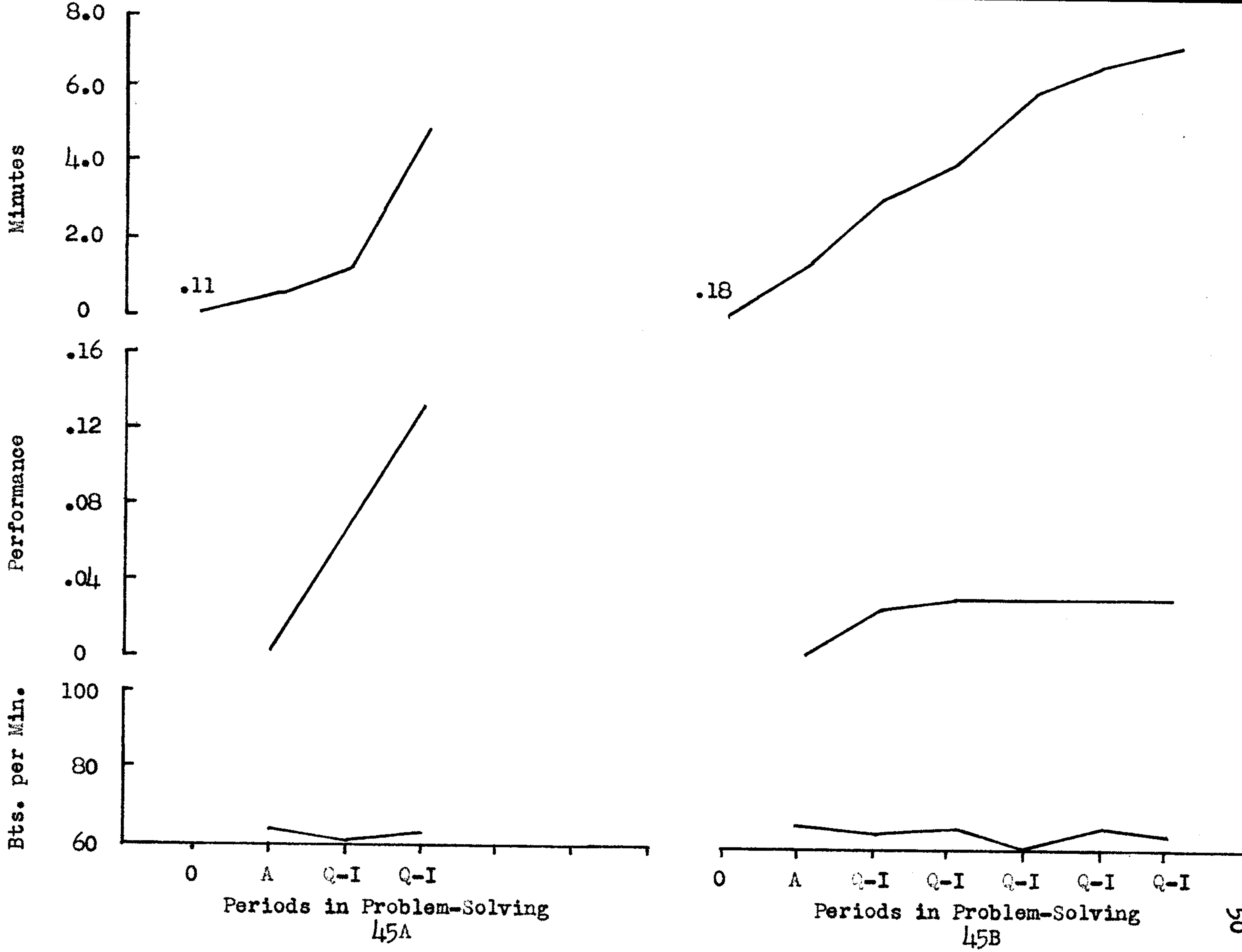

Fig. 18. Heart Rate, Performance and Time Values for Subject No. 15.

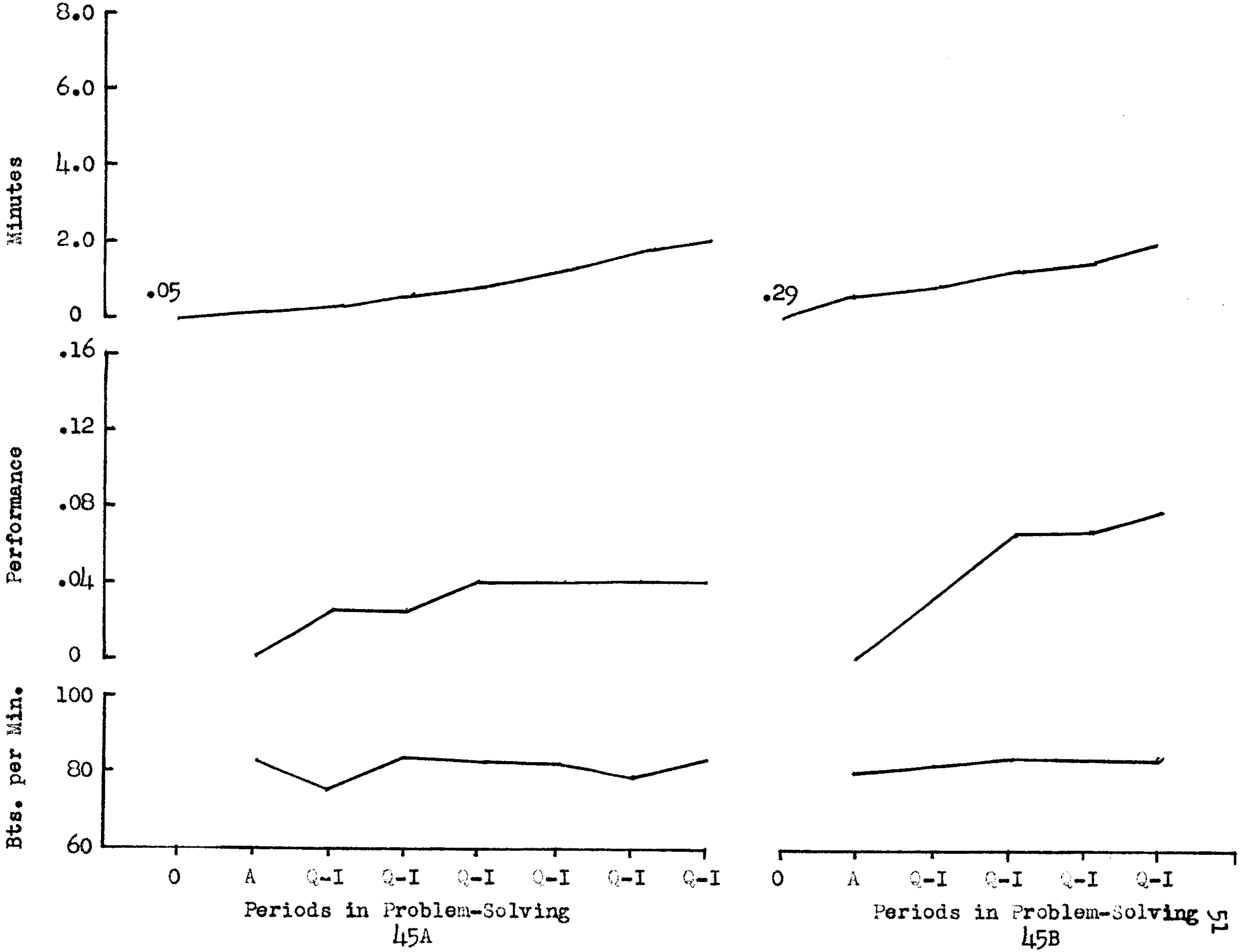

Fig. 19. Heart Rate, Performance and Time Values for Subject No. 16.

Table 7

Summary of Performance in Information Utilization

Subject	Age	WAIS IQ	Education (Years)	Plateaus 45A Begin.	Plateaus 45A Middle	Plateaus 45A End	Plateaus 45B Begin.	Plateaus 45B Middle	Plateaus 45B End
1.	83	125	10						X
2.	75	113	10					X	X
3.	82	109	8	X		X			X
4.	84	114	10	X				X	X
5.	72	105	12					X	X
6.	75	97	8			X		X	X
7.	73	109	13			X			
8.	85	110	12				X	X	X
9.	82	119	16			X			X
10.	84	129	19						
11.	88	122	13						
12.	82	109	14				X		X
13.	76	137	19						
14.	81	113	12				X		X
15.	85	113	10					X	X
16.	70	129	15		X	X		X	

Note.—This is <u>only</u> a general designation of plateaus from inspection of the graphs. It <u>is not</u> a rigid designation in terms of the number of questions involved.

Two of these individuals (Nos. 10,11) are also within the group's upper age range (84 and 88 years respectively). 4) In general, those of higher IQ and education did better in terms of information utilization (Nos.10,11,13) than those of lower IQ and educational background (Nos. 3,6). 5) Rather strikingly, only one subject (No. 11) employed the same tactics for both problems.

Time and Performance

Table 8 summarizes some of the more noteworthy aspects of the time graphs in relation to the problem solving process. In column 3 comparison can be made of appraisal percentages for problems 45A and B; it can be seen that 1) the majority of the individuals spend a greater percentage of time appraising 45A than 45B, 2) of those individuals (Nos. 7,11,12,13,15, 16) who have a higher appraisal percentage for 45B, three (Nos. 7,11,13) have optimal performance values (Col. 4) in this more difficult problem. Another (No. 16) performed better on 45B than on the less difficult 45A. It should also be noted that subject 10 who performed optimally in both problems, spent a great percentage of total time on appraisal in both problems.

In comparing the percentage of total time spent on appraisal (Col.3) with the corresponding performance value for the problem (Col. 4) it can be seen that in general, the greater the appraisal percentage for a problem

Table 8

Summary of Time and Performance

Subject	Problem 45__	Appraisal % of Total Time	Total Performance Value	More Time on 45B
1.	A	.41	.125	X
	B	.21	.073	
2.	A	.89	.132	X
	B	.03	.021	
3.	A	.14	.021	
	B	.01	.069	
4.	A	.76	.083	X
	B	.31	.062	
5.	A	.39	.125	X
	B	.02	.053	
6.	A	.23	.066	X
	B	.20	.046	
7.	A	.18	.064	X
	B	.62	.132	
8.	A	.85	.132	X
	B	.45	.000	
9.	A	.18	.073	X
	B	.12	.042	
10.	A	.84	.132	X
	B	.74	.129	
11.	A	.24	.132	X
	B	.81	.132	
12.	A	.25	.088	X
	B	.51	.021	
13.	A	.04	.132	X
	B	.62	.129	
14.	A	.--	.097	X
	B	.12	.028	
15.	A	.11	.132	X
	B	.18	.033	
16.	A	.05	.044	X
	B	.30	.079	

the greater is the corresponding performance value. Only three of the sixteen subjects (Nos. 3,12,15) reverse this observation.

In column 5 of Table 8 consideration is given to the absolute total time spent on the problems. As can be seen with one exception (No. 3), more over-all time was spent by this group of old people on the abstract problem 45B than on the more concrete problem 45A.

Heart Rate

Since the general intra-subject heart rate variability was quite ~~low~~ (Group mean SD: 2.29; range 5.22 to 1.08) any comparison with concomitant fluctuations in the other variables would be questionable.

Table 9

Level and Variability of Cardiac Rate for Young Adults and Geriatric Subjects on Experimental Problems

Cardiac Rate	Young Adults[a] Efficient P.-Solvers	Young Adults[a] Inefficient P.-Solvers	Geriatric Subjects
Mean	94.16	80.80	79.43
Standard Deviation	6.79	3.18	2.29
Coefficient of Variability	7.21	3.93	2.88

[a]Blatt, S.J. Patterns of cardiac arousal during complex mental activity. J. abnorm. soc. Psychol., 1961, 63, 272-282.

What is of interest, however, is this very fact of a relatively low heart rate variability. In Table 9 a comparison is made of the heart rate means and standard deviations of Blatt's (1961) young adults and our old people. As can be seen, the geriatric subjects' general level of heart rate, as well as the heart rate variability, is considerably lower than the young efficient problem solvers, and even lower than the young inefficient group. The coefficients of variability make comparable the measures of fluctuation for these groups with different means. It should also be noted that the mean cardiac rate for the old people was the lowest of the three groups.

Discussion

From inspection of the descriptive information on our subjects it seems evident that they displayed an unusually high level of intellectual performance for aged individuals (Loranger and Misiak, 1960; Levinson, 1960; Eisdorfer and Cohen, 1961; Shock, 1951). At the same time the decrements in functioning appear consonant with the decrements ascribed to the aging factor (Birren, 1959; Halstead, 1943). General information, common sense judgment, and vocabulary which can be said to be related to past memory, previous experience, and often used material hold up consistently well for our subjects. While arithmetic, similarities, and digit span which seem to be related to attention span, ability to form abstract concepts, and do mental manipulation are generally somewhat lower for these aged subjects.

Most significantly affected are those tasks involving psycho-motor coordination and timed performance (Schaie and Horst, 1957).

Our results proper indicate that these aged subjects have less difficulty with a problem when presented in concrete terms rather than in symbolic form. This would lend weight to the proposition that abstract tasks are less easily dealt with by the aged, at least as far as their ability to organize their approach to a problem is concerned. They seem more able to organize concrete, familiar material than abstract concepts. This is reinforced by the observation that with one exception more over-all time was spent by these old people on the abstract problem than on the concrete problem. While these old people seem to have little difficulty initiating a consistent process of information utilization, they tend to fall down as the process proceeds. This may be related to difficulties in maintaining attention, as well as impairment of recent memory, and the ability to hold recently acquired information long enough to operate on it. All of which seems to be implied in Birren's (1959) "creativity" and recent memory that was seen to decline in the aged.

That those individuals who lacked plateaus in both problems are in the group's highest IQ range suggests that IQ is a positive factor in logical information utilization, as well as in the ability to deal with abstract and concrete material with comparable efficiency. The fact that two of these individuals were also within the group's highest age bracket provokes the question whether factors other than those implied in age alone influence the retainment of the intellectual abilities involved in the performance of our task. Our other finding, that those more advanced in IQ and educational experience tended to do better on our task than those of lower educational background and IQ, suggests that these factors and perhaps the concomitant factor of life long employment of intellectual capacities are some of the positively related factors that determine differential retainment of intellectual abilities in the aged. Thus, while the aging factor takes its toll of some intellectual functions in all individuals some functions, such as those implied in our task, seem more dependent on IQ, education, and life long utilization than on the aging factor alone.

Considering the research on "set" (Maier, 1940; Rees and Israel, 1935) and the influence of previous problem solutions on subsequent problem behavior (Johnson, 1960), one might expect that in our problems where theoretically "set" is maximized (the same basic problem under two conditions) there would be observed a similarity in problem approach on both of our problems. That this was not the case, and only one subject utilized the same sequence of question selection for both problems indicates that actually there was little, if any, "set" influence from problem to problem. Moreover, research (Halstead, 1943) suggests that old people would be most inclined to rely on previous experience to solve subsequent tasks. The most likely interpretation to be made is that the symbolic presentation of the second problem actually adds a significantly different dimension to the basic structure and considerably increases the level of difficulty as Sargent's (1940) research implies.

Our results on time utilization and performance achievement lend weight to the observation that old people do tend to rely on their previous experience and are less likely to take the time to evaluate a second problem, even though it is more difficult. Those that do spend more time evaluating the more difficult problem, in general, do better as far as sequence of information utilization is concerned. Moreover, our results confirm experimentally the Gestalt observation that the initial period of problem analysis is an important factor in an "intelligent" solution. For our results indicate that the more time an individual spends appraising a problem, the greater is the likelihood that he will approach the problem in a logical, economical manner.

As is expected of geriatric subjects, the cardiac rate and variability of our subjects was found to be lower than that of young adults. What is of interest, however, is the implication of Blatt's (1961) research that level and fluctuation of cardiac rate is associated with efficiency on problem-solving tasks, where efficiency is defined in terms of the number of redundant questions asked in pursuing a solution. Our findings, that only three of our sixteen subjects performed optimally on both our problems in terms of this "efficiency" criterion, and that as a group they evidenced a lower cardiac rate and variability than even the young "inefficient" problem-solvers, hold the tentative implication that decrement in autonomic arousal may be related to "inefficiency" in problem-solving. This seems additionally supported by Meyer's (1964) research. According to a different "efficiency" criterion, autonomic arousal was seen as a characteristic of efficient functioning. In a negative way, the difficulty our subjects evidenced with the more abstract problem and their lack of appreciable variability at any particular stage in the problem-solving process would seem compatible with these findings.

Tying some of these strands together, it can be seen from this and related research that the aging process affects different individuals in different ways, despite the general decrement that afflicts all. Aged subjects seem to have difficulty with timed tasks, particularly those involving Psychomotor coordination. Likewise, abstract or symbolic material appears more difficult for aged subjects than concrete material. Our research suggests that symbolic presentation represents a different dimension and level of difficulty over the concrete, at least for these geriatric subjects. Generally, aged subjects seem to have difficulty maintaining attention and utilizing recently acquired data effectively. Concomitantly, they evidence a tendency to rely on past experience and functioning in approaching current situations.

Our tentative findings pose several questions for future investigation. First of all, it seems evident that factors other than those implied in the physiological slowing characteristic of the aging process influence the differential retainment of capacities. Are these factors related to training and the cultivation of intellectual habits, as implied in our association of IQ and educational background with retainment of functioning? Are the individual differences observed in the aged related to lifelong utilization of developed capacities and the observed tendency to rely on past experience and functioning in approaching current problems? Is the factor of appraisal time, which we found to be associated with subsequent logical utilization of information, a function of these mental habits and previous training? What in fact is the relationship between reduced autonomic arousal as generally observed in the aged and their "efficiency" in intellectual functioning? Is it a related factor as research tends to suggest? If so, what is the implication of motivating or arousal sustaining factors in the "intellectual" assessment of the aged? Hopefully, future research will follow up some of these tentative findings and more definitely outline the factors responsible for diffential decrement in intellectual functioning observed in the aged.

CHAPTER V

SUMMARY

In this exploratory study of individual old people our goal has been to investigate what takes place within the aged person during the problem-solving process. Each of our sixteen geriatric subjects was characterized in terms of age, education, and general intelligence test performance. With this information in mind, we presented each subject with two problems, one in familiar concrete terms, the other in an abstract, symbolic form. Their sequence of information utilization was characterized by the Rimoldi technique of sequential evaluation and compared with concomitant measures of the time duration and heart rate variability for each step in the problem-solving process.

Our results indicated that these old people have less difficulty with a problem when presented in concrete familiar terms than when presented in symbolic form. The symbolic presentation of a problem seemed to add a significantly different dimension to its basic structure and considerably increased the level of difficulty for these aged subjects. While these old people seemed to have little difficulty initiating a consistent process of information utilization they tended to fall down as the process proceeded. IQ was suggested as a positive factor in the ability of the aged to logically gather information and deal with abstract and concrete material with comparable efficiency.

While the aging factor was seen to take its toll of some intellectual functions in all individuals, some functions such as those implied in our task seemed more dependent on IQ, education and perhaps lifelong utilization than on the aging factor alone.

The utilization of time was seen to be an important factor in problem performance. Those aged individuals who spent more time appraising and evaluating a problem before they began gathering information tended to do better as far as information utilization is concerned than those who spent less time in appraisal. This was especially true for the more difficult abstract problem. While the uniformly reduced cardiac rate and variability of our subjects precluded association with concomitant fluctuations in our other variables, it did raise the question as to the association of reduced autonomic arousal and "efficiency" in information utilization.

As a tentative, explorative venture, this study emphasized the differential retainment of functioning in those of advanced age and suggested IQ, education, and possible life long utilization as factors influencing this phenomena. It pointed to the importance of appraisal time as a factor in problem-solving and suggested that the question of reduced autonomic arousal and its influence on the mental functioning of the aged be more thoroughly investigated.

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APPENDIX

The scoring and weighting of tactics for problems 45A and 45B - Schema Norms

To score an individual's sequence of card selection a criterion or norm based on the schema or structure of the problem was devised. The schemata illustrated in the text (Figures 1 and 2) represent the logical relationships within the problem and are used to generate logical tactics or sequences of question selection. Thus, a tactic is a particular sequence of question selection determined by the logical properties of the problem. Tactic a_1 (Table 10) for problem 45A is the sequence of Question 6 asked first and Question 3 asked second. This tactic is determined by the information contained in these questions and their logical relation to the problem.

Table 10

Tactics and Question Sequences for Problem 45A

Tactics	Questions					
	1	2	3	4	5	6
a_1			2			1
a_2			1			2
b	1	2	3			
c_1	3		1	2	4	
c_2	1		2	3	4	
c_3	1		3	2	4	

Table 10 represents the various logical tactics for problem 45A and the questions that are involved. The order of the questions for a tactic appear in the cells of the table. Thus, tactic b requires Question 1 to be asked first, Question 2 second, and Question 3 third. Since the instructions enjoined asking as few questions as possible, the tactics with the least number of questions were given greater weight than the tactics involving more questions.

In weighting these tactics, a_1 and a_2 were assigned a value equal to .5000 of the total table since they contain the least number of questions. Tactic b received .3333 of the total table value and tactics c_1, c_2, and c_3 received .1666 of the total table value. Each cell entry in these sequences was then assigned proportional values on this basis. This can be seen in Table 11 where the total table is made equal to unity and each step within

Table 11

Proportional Weighting of Tactics for Problem 45A

Tactics	Questions 1	2	3	4	5	6	Sum	Total Weights
a_1			.125			.125	.25000	.50000
a_2			.125			.125	.25000	
b	.11111	.11111	.11111				.33333	.33333
c_1	.01388		.01388	.01388	.01388		.05552	
c_2	.01388		.01388	.01388	.01388		.05552	.16656
c_3	.01388		.01388	.01388	.01388		.05552	
Sum							.99989	.99989

a particular tactic is given a value proportional to the tactic's weighted value.

If Table 10 were superimposed on Table 11 it would be evident that each cell value in Table 11 represents a particular question in a particular order according to the various tactics. Summing the values of a particular question in a particular order over all the tactics generates a value that represents that question's usefulness in that particular order according to all the logical tactics. Thus, Question 1 (Table 10) is in first position in tactics b, c_2, and c_3. Summing the corresponding values of Table 11 gives the value .13887 for card or Question 1 in first position for all the tactics. This procedure was followed in constructing Table 12 where the individual tactics are eliminated and each question has a value consonant with its position in the various logical sequences or tactics.

Table 12

Weights for Questions of Problem 45A (Schema Norm)

Order	Questions						Sum
	1	2	3	4	5	6	
1.	.13887		.13888			.12500	.40275
2.		.11111	.13888	.02776		.12500	.40275
3.	.01388		.12499	.01388			.15275
4.					.04164		.04164
Sum	.15275	.11111	.40275	.04164	.04164	.25000	.99989

Thus, Question 1 asked first receives a value of .13887, while Question 4 asked in the second position of a sequence is assigned a value of .02776, and so on. It should be noted that in this way a question asked in an order compatible with one of the logical tactics receives a value proportional to that question's usefulness in that order in the various tactics.

The same procedure was followed in constructing Table 13, the schema norm for Problem 45B.

Table 13

Weights for Questions of Problem 45B (Schema Norm)

Order	Questions 1	2	3	4	5	6	Sum
1.	.13887		.12500	.13888			.40275
2.		.11111	.12500	.13888	.02776		.40275
3.	.01388			.12499	.01388		.15275
4.						.04164	.04164
Sum	.15275	.11111	.25000	.40275	.04164	.04164	.99989

Each individual's sequence of card selection is judged against these norms. As an example, suppose an individual's sequence of card or question selection for Problem 45B were: Questions 1,4,5,2. (Table 14)

Table 14

A Subject's Sequence of Questions and its Scoring

Scoring Procedure	Sequence of Questions Asked 1	4	5	2
Question Value	.13887	.13888	.01388	.00000
Division (by 4)	.03472	.03472	.00347	.00000
Cumulated Values	.03472	.06944	.07291	.07291

The performance values for these questions are taken from Table 13. As was mentioned in the text, these values are divided by the total number of questions asked as a penalty for any redundant questions interposed into the sequence. The resulting values are cumulated and graphed to give a performance curve (Fig. 3 in the text).

Approval Sheet

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

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

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

1 June 64

Date

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