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Tempo and Problem Solving Processes

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TEMPO AND PROBLEM SOLVING PROCESSES

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Vita

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CHAPTER I

INTRODUCTION

Measurement of human ability involves the consideration of speed among other quantifiable characteristics of behavior. Investigation of style of expression and gesture, for instance, has emphasized the role played by temporal factors in determining consistency of expression.

Many experimental studies have shown that when a number of persons are compared as to the speed at which they perform the same motor or psychomotor task, each one if unconstrained moves at his own characteristic rate or personal tempo. Furthermore, it has been found that this personal tempo remains fairly constant when the task is prolonged over considerable time or repeated frequently. Thus, personal tempo has been defined as that constant temporal pattern which an individual adopts when performing a particular group of related activities at a natural rate of speed (Rimoldi, 1951).

A review of the literature and work that has been done in this domain of personal tempo suggests that: 1) as stated above, operationally defined units of behavior show a remarkable temporal constancy; 2) a pluralistic rather than a monistic interpretation of tempo is indicated; and 3) tempos in different activities are not totally unrelated.

The relationship of speed to psychological activities, particularly "intelligence" or complex mental abilities has been discussed in a great number of studies and constitutes one of the important old controversies in the literature. As is the case with motor and psychomotor activities, many authors contend that ability with respect to speed is a "general" individual trait characteristic of mental behavior. The bulk of the evidence, however, has favored the interpretation of speed as a component independent of the intellective factors. The procedure generally used in studies dealing with this problem is to apply the same test under different time allowances or to correlate such speed measures as rate of work or reaction time to mental test socres. Measures of maximal speed, as well as of optimal or "most convenient" speed, have been used without, in many instances, a clear-cut distinction between them. Any research on personal tempo, however, should emphasize a natural rate of work.

Accordingly, the purpose of the present study is to explore the temporal characteristics of the cognitive process, when the subject performs problem-solving tasks at his most natural rate. If it were possible to operationally define units of behavior in the cognitive process, we would be able to measure their temporal duration and determine whether there exists for a given individual a temporal rate characteristic of those processes. The work of Rimoldi and associates (1960, 1964, 1967) provides a technique adequate for this purpose. The technique emphasizes the evaluation and characterization of the dynamic process that takes place when a subject is solving a problem. The underlying assumption is that the cognitive process can be identified by studying the sequence of questions (tactic) that the subject uses to solve the problem. The complexity of the logical relationships in the problem and the type of language used to present it define the difficulty of that problem. Observed tactics may be classified as ideal, good, or bad according to how closely they approximate the logical structure of the problem. It is hypothesized that the rate at which a subject asks questions is constant for a given problem. In other words, the main hypothesis is that operationally defined steps within the problem-solving process occur at regular intervals of time.

Five problems were used in this study -- four verbal problems of varied difficulty and one figure problem. Furthermore, six tempo tests representing three well-defined tempo factors were administered -- symmetrical movement and parallel movement of arms, which characterize the large muscle movement factor; reading science and reading literature, for the speed of perception or reading factor; and drawing lines and circles representing the speed of drawing factor. These tempo tests were included in the battery to determine whether, and if so how, they are related to the mean speed scores in the problems.

Three secondary hypotheses were formulated:

(A) For any specific problem there will be differences in the time or speed scores of subjects following the ideal tactic, a good tactic and a bad tactic. The "better" group will be faster.

(B) The time elapsed from the moment the subject is presented with the problem until he asks the first question -- time to understand the problem -- will be related to the difficulty of the problem.

(C) There will be individual consistency of the speed scores throughout the problems.

CHAPTER II

REVIEW OF THE LITERATURE

In the literature related to rate of performance a distinction is made between, 1) those studies which purport to link speed of response to certain "personality" types and view speed as a general personality trait; and 2) those other studies where speed is considered as a specific factor that depends on the ability tested.

Concerning the relation of speed to intelligence two opposing views are encountered: 1) the notion that speed of performance in a mental task is the same thing as mental ability of the subject, and 2) the existence of several independent traits characterizing mental tasks, among which is speed of the mental processes.

Personal Tempo

Downey (1923), Kennedy (1930), Frischeisen-Köhler (1933), and Wu (1934), are among the authors who postulated a "general" speed factor. In Downey's Will-Temperament test (1923), speed of reaction and movement are measured in samples of handwriting obtained under different conditions, depending upon the form of administration of the test, i.e., group form or individual form. Her contention is that bodily speed of movement can be detected in speed of handwriting and that it constitutes a general personality trait. Kennedy (1930) also considered speed as a personality trait. She proposed the term "irritability" to designate it. Irritability defines the characteristic or general rate of work of an individual which is different from speed in a given task and is not dependent upon intelligence.

Wu (1934) and Frischeisen-Köhler (1933) among others, have used the term "personal tempo". Wu (1934) studies both personal tempo and speed in some rate tests. In the part of the experiment devoted to the study of personal tempo the subjects were tested: 9 subjects over a period of ten weeks, and 26 subjects in a single sitting. The same six tests were used for the two groups: foot tapping, finger tapping, counting numerals, reading poetry, observing octagons and word writing. Test-retest reliability coefficients for the six tests in the first group of subjects were all positive with a median value of .875 between two of the sittings. These results, as well as those of other authors, indicate that "natural" speed in various types of performance is a highly stable individual characteristic and that for each task a subject works at his own personal tempo which is constant over considerable periods of time. For both groups and with the exception of the word-writing test, "the intercorrelations between every two of the six tests were all positive with a coefficient as high as .880 between finger tapping and counting numerals. The results point out the fairly consistent relationship of personal tempo in the different tests. Furthermore, personal tempos are more marked in some tests than in certain others." In the second part of the experiment, the speed study Wu administered the following 6 speed tests to the 26 subjects tested in a single sitting in the tempo study: foot tapping, finger tapping, word writing, number naming, packing blocks and triangle tapping. The fact that all intercorrelations were positive led the author to suggest the existence of a "general phenomenon" in the various speed tasks, in spite of the fact that no theoretical general factor could be demonstrated. This indicates that the individual who is fast in one task is more likely to be fast than slow in another. In her study, Kennedy (1930) arrived at the same conclusion through the study of the correlation matrix for a different set of rate tests. Finally, Wu compared the speed and tempo studies and found correlations as high as .51 and .56 between the two finger-tapping tests and the two word-writing tests respectively, while the intercorrelation between all the six tempo tests and all the six speed tests was .19. He concluded that "for certain tasks which have more or less similar content, an individual's natural rate of work or 'personal tempo' is somewhat related to his maximal speed."

Frischeisen-Köhler (1933a), one of the best known exponents of the concept of "personal tempo", proposed the existence of a generalized factor on the basis of the analysis of the intercorrelational pattern among a restricted number of tasks. She conducted experiments on different finger- and foot-tapping tasks as well as metronome experiments to assess the "hereditary" component of the personal tempo. She used Ss of all ages and both sexes. In the metronome experiments the Ss were presented with various speeds and were asked to report whether each tempo was too fast, or too slow, or precisely agreeable. She found smaller intra-individual constancy in the tapping tests than in the metronome tasks and noticeable inter-individual differences. By studying the personal tempos of pairs of parents and their children, 118 pairs of twins, siblings and unrelated persons, she concluded that personal tempo is definitely innate and hereditarily determined. Two other studies (1933b, 1933c), on preferred metronome tempo and sensitivity to speed differences, indicated that "personal speed of males is somewhat slower than that of females", and that the proportion of correct judgments among boys (83.8%) is somewhat higher than the proportion among girls (81.7%). Frischeisen-Köhler interpreted the latter result as "showing that there is not an inability to determine speed differences, but only a lack of sensitivity for very fine differences." A later study by Pötzl (1939) supported Frischeisen-Köhler's contention on the hereditary conditioning of individual tempo. Pötzl indicates that in Ss "with demonstrated brain lesions, experiences are perceived in the same way as with cinematographic rapid motion, corresponding to the phenomenon of the microscopic analysis of time. The sensorial mechanism of time perception is disturbed and the human individual tempo appears to be tending toward a quicker rhythm."

Foley (1937a, 1937b) challenged the conclusions of Frischeisen-Köhler and others on the grounds that they failed to consider determining factors other than heredity. He studied preferred metronome rate and speed of preferential and maximal tapping in five vocational groups of young female students. The groups were comparable in terms of "chronological, 'racial' or national, socio-economic, and general intellectual status." He found statistically reliable differences in motor speed and preferred auditory tempo for the various occupational groups. This, together with the fact that there were no differences in tapping and metronome scores between racial or nationality groups within the whole sample, led him to conclude that "vocational stimulation and institutionalized motor responses occurring at a particular rate of speed play a major role in conditioning the speed of motor response (optimal and maximal) and sensory (auditory) preference, as well as of motor tempo and rhythm."

As a result of more exhaustive studies the monistic interpretation of rate of work gave way to specificity or pluralistic interpretation. Moreover, tests other than those involving purely motor activities were included for assessment and a greater variety of performances from simple reaction time to fairly complex mental tasks were considered.

Antipoff (1927) and Wentscher (1931) arrived at somewhat similar conclusions. Antipoff found that maximal rate shows less variability than habitual or characteristic rate of activity in such tests as tapping, speed of walking and writing, muscular strength and tactile discrimination. The study of the coefficients of variability and the comparison of inter- and intra-variation led the author to conclude that constancy is not an individual characteristic or aptitude and that Ss vary much less among themselves in the total of all tests than they vary among themselves from one test to another. Wentscher (1931) raised the question of whether there is, for a given individual, a constant "personal work tempo" that may be traced to some fundamental factor. Out of 100 girls who were tested on four problems that required different abilities, only 18% maintained the same tempo for all the four tasks. The author concluded that the belief in a personal work tempo traceable to a fundamental unitary factor was misleading.

One of the studies that definitely favored a pluralistic or specificity interpretation of motor speeds is Allport and Vernon's Studies in Expressive

Movement (1933). It represents a definite experimental attack upon the problem of intra-individual consistency in expressive movement. The authors maintain that the expressive features of the body are not independently activated, so that there exists a considerable consistency among these features. There is a constant and stable personal style that represents the most complex and most complete form of expressive behavior, and it concerns all of the activity and not merely special skills or single regions of the body. They studied ratings on speed and 14 different measures of speed of movement in 25 male Ss. They found no evidence for a uniform 'psychic tempo' or general speed factor, but rather for three broad factors of speed, namely a verbal factor that included reading, writing, and counting, a drawing or manipulative factor, and a rhythmic factor. They also found that "each speed measure is itself reliable, indicating a high degree of constancy in 'specific speeds'"... and that "many of the speed measures correlate more highly with non-speed measures than with each other."

Among others, studies by Lauer (1933), Lanier (1934), Harrison (1941), and later on by Rimoldi (1951), Haley (1963) and Erdmann (1965), have further supported the pluralistic interpretation of motor speed and tempo. In an investigation of personal tempo and rhythm, Lauer (1933) studied voluntary and involuntary response rates. He found little relationship between specific response rates and concluded that "any tendency for bodily tempos to vary together, suggesting a speed factor, would seem to hold only for habitual response if at all." Lanier (1934) found that different types of speed variables have little in common and that a relationship between any two or more measurements of speed depends upon similarity of postural preparation and type of motor activity involved.

As Erdmann (1965) indicates, "at this point in the history of the literature of personal tempo, the area could be characterized as one plagued by confusion. Operational definitions of tempo varied, terminology differed from study to study and the controversy of the monistic versus pluralistic explanation prevailed." Confusion existed not only regarding the temporal parameters of sensory and psychomotor activities, but those of simple and complex mental tasks as well. Evidence both for and against a general factor of speed had been drawn from intercorrelations of about the same magnitude among speed measures.

The experiments supporting a concept of temporal 'character' type or personal tempo, allegedly representing a personality trait of general speed of response, had been criticized on the grounds of: a) inadequate controls, b) lack of clear definitions, and c) restricted variety of activities studied. Aware of these facts and on the basis of previous findings (1946) concerning constancy of speed at the ergograph and effect of imposed rhythms on work output, Rimoldi undertook a factorial analysis of the domain. His "Personal Tempo" study, published in 1951, is one of the most comprehensive and thorough researches reported in the literature, given the inclusion of a variety of tests covering tasks related to a wide range of psychobiological functions. Ninety-one male Ss between 19 and 25 years of age were given a battery of 59 tests comprising speed of motor activities; reaction time measurements; complex processes such as recognition of designs, judgments, etc.: intellectual processes such as those involved in Thurstone's PMA; expressive movements; preferred metronome rate; speed of walking; pulse rate, etc. Eight out of the nine factors isolated were defined, including speed of: large muscle movements, small muscle movements, drawing with feet, drawing with hands, reaction time, perception, cognition, and metronome rate. A second-order factor analysis was then performed which revealed four underlying dimensions, namely, speed of perception, speed of cognition, speed of all motor activities, and reaction time.

Later factorial studies by Haley (1963) and Erdmann (1965) verified Rimoldi's results. Haley (1963) used 47 tempo and psychological variables with attention focused on subjective time. Erdmann (1965) investigated the changes that undergo tempo variables under the effect of various drugs. The verification of the small and the large muscle movement factors and the drawing factor in both studies was relevant in the selection of the tests used in the present experiment.

Speed and Complex Mental Abilities

Many conflicting statements are encountered in psychological literature as regards the role of speed in the appraisal of mental ability. As stated above, opposing views are that speed and intelligence are synonymous as characteristic of a person's ability, and that speed is not related to intelligence. To some extent, the distinction between speed and power tests of intelligence mirrors the two conceptions, and the definition of intelligence as that which the intelligence tests test is at the basis of the issue.

Spearman (1927) is a supporter of the contention that speed of performance is an indication of intelligence. As is very well known, he postulated two factors in cognitive ability, namely, general intellective ability or "g", and specific factors characteristic of given tasks. To measure cognitive ability, he said, it is necessary to turn to the universal quantitative properties of clearness and speed which characterize all cognition. Speed or duration of a person's mental processes is inferred from the amount of time taken to respond to the stimulus. Clearness, on the other hand, is inferred from the goodness or accuracy of the response, relative to its freedom from errors and omissions. The ability to perform an operation correctly is the power of response. Both power and speed are dependent on and saturated with "g", though not to an equal extent. According to Spearman, the dependence of power of response upon "g" is evidenced in several studies where the influence of speed was eliminated experimentally -- high correlations were obtained between scores in the same intelligence test administered with different time limits or no time limit at all. As for speed, Spearman found that speed in one kind of test was correlated with speed and power in other kinds of operations. He concluded that since power is dependent on "g", speed must also be correlated with "g", and in agreement with this complete interchangeability between goodness and speed of response, neither of them constitutes a functional unity or group factor producing specific correlation. Some years later, however, Spearman (1937) differentiated experimentally speed preference ("attitude to or preference for speed") and speed ability ("speed of cognition"). He pointed out that although performance of mental tasks may reveal a general speed preference, there is no evidence of a general speed ability in tasks involving eductive processes. For tasks such as speed of reaction or rate of tapping, there may be one or several factors independent of general ability "g". In summary, his main contention was that "the almost unanimous view that some persons are on the whole unable to think quickly and yet are quite able to think clearly would seem to be a most grave error."

The "unanimous view" to which Spearman refers corresponds to the notion that speed is not related to intelligence. Perhaps the best known supporter of the theory of the specific nature of speed of response is Thorndike (1926). As far back as 1902 he presented evidence to demonstrate that "there is no such thing as a trait of quickness of association characterizing the work of a given individual on various simple mental tasks." He proposed the analysis of mental ability into three separable aspects, namely, level, range and speed. Level or altitude, which defines ability as power, is the level of difficulty attained by an individual. Range refers to the number of tasks he can perform at any specific level of difficulty. Speed is the individual's rate of performance; that is, the number of tasks that are completed in unit time. Thorndike indicated that although the best intellect is one that can accomplish the largest number of tasks at the highest level of difficulty in the shortest period of time, altitude is the only aspect of intelligence that cannot be dispensed with. He further indicated that altitude and speed are slightly but positively associated. In 1937 Thurstone published a paper on the subject, where he defined an individual's ability as "that degree of difficulty for which the probability is 1/2 that he will complete the task in infinite time." He represented the relations between ability as altitude, motivation and speed by a psychometric surface, and theoretically showed that "the appraisal of an individual's ability for a specified kind of power task, as distinguished from tasks involving rate, can be made experimentally so as to be independent of speed of performance and also independent of his motivation."

Much research was done after Spearman's work, aimed primarily at specifying the nature of intelligence. Few studies lent support to Spearman's two-factor theory, while many others presented evidence favoring the specificity theory. Among the isolated basic components of intellectual abilities some authors identified a factor of speed. Sutherland (1934), Dubois (1932), Line and Kaplan (1932) and Thurstone (1938), found evidence pointing to the existence of a speed factor running mainly through speed tests.

During the early studies bearing on the problem of the relation of speed to mental ability are the very much discussed works of Bernstein (1924) and Peak and Boring (1926).

Bernstein's (1924) study is among those designed specifically to assess the existence of a general speed factor. Bernstein administered a series of tests including sentence completion, direction, concomitants, analogies and moral classifications to two groups of school children, under conditions of "leisure" and "haste", i.e., with long and short time limits. "Slowness" scores were calculated by subtracting "haste" scores from "leisure" scores, which were correlated with teachers' estimates of intelligence and "slowness". On the basis of the low correlations varying from -.23 to .19, the author concluded against the existence of a speed ability apart from general intelligence. The results were used by Spearman (1927) as evidence of his contentions. Intelligence estimates correlated .56 with both haste and leisure scores, while ratings on slowness correlated -.37 with haste and -.45 with leisure. The correlations among and between both types of scores were of about the same degree ranging from .66 to .73. Mainly on the basis of these coefficients, DuBois (1932) criticized Bernstein's methodology and argued that "if leisure and haste tests measure different abilities, their respective intercorrelations should be higher than the correlations with each other." Though the leisure tests had fewer items, all the tests used by Bernstein were very short and a time limit of 30 seconds per page was allowed. Sutherland (1934) contended that it is doubtful that leisure conditions were produced, so that the conditions between intelligence and haste and leisure tests were really correlations between intelligence ratings and two different speed scores. Kennedy (1930) also criticized Bernstein's work on the score of non-validity of his measure of slowness and pointed out that "in the case of these tests, as in the work done by others on the effect of different time limits, the fact remains that the test with short limits is still a "power" test, and there is no assurance that a high score on such a test means speed, or that a low score means slowness."

Using five advanced students, two men and three women tested individually, the authors timed each item separately on two forms each of the Otis and Alpha tests. For each of the subjects a time score in each test was defined as the average number of seconds he spent on items performed correctly by all the five subjects; this was done to control for differences in accuracy. The average time scores so defined were then correlated with the tests scores obtained under standard and unlimited time, and with speed of reaction time. Very high correlations of the order .70 to unity were found, a) between average time scores and reaction time, and b) between the various measures of speed and the tests scores under standard time limit. The findings led the authors to support Spearman's contention and conclude that since "there is a high correlation between score in an intelligence test, speed in an intelligence test, and speed in simple reaction, ...speed of reaction is an important, and probably the most important factor in individual differences in the intelligent act." Peak and Boring hardly discussed the correlations, ranging from -.20 to .10 between the different speed measures and the intelligence test scores obtained under no time limit. They merely pointed out that this may occur because the faster subject does not have an opportunity to take advantage of the additional time allowed. Later on Bennett (1941) criticized this explanation and argued that the correlations obtained under the unlimited time condition could very well be used as evidence leading to a completely different interpretation of the results. The small number of subjects alone makes the conclusions of very slight importance.

More adequate studies by Lemmon (1927) and Fansworth, Seashore and Tinker (1927) failed to support Peak and Boring's results. Lemmon (1927), using 100 subjects, found a correlation of .13 between the scores in the Thorndike intelligence examination and 200 discriminative reaction times from each subject. Fansworth et al. (1927) intended to replicate Peak and Boring's study with a sample of 34 subjects. Three measures were added, namely, serial reaction times and scores in the Thorndike and Ohio State University tests. To determine the degree of relationship between simple reaction time and average speed scores on Alpha and Otis as defined in the referred study, the subjects were divided into 5 subgroups and the time scores were calculated for each of them separately. The range of correlations obtained, from -.66 to .90, was interpreted as evidence against the existence of a general speed factor underlying both kinds of speed measures. As for the correlation between reaction time and intelligence, the authors used the entire group of subjects and obtained coefficients from -.16 to -.24 between the intelligence tests under standard time limit and simple reaction time, and from .14 for Ohio to .53 for Alpha with serial reaction time. On the other hand, coefficients of correlation between serial reaction time and test scores obtained under the unlimited time condition were again low for Ohio and Otis, .07 and .10, but higher for the Army Alpha, .36. The authors concluded that what the different intelligence tests measure varies and that "the Army Alpha test tends to become merely a serial reaction test, whereas the Ohio State and Thorndike examinations remain more clearly tests of content in which the speed factor is unimportant."

The results in all these experiments seem to point to the conclusion that the relation between mental ability, we measured by standard intelligence tests, and simple reaction time is negligible. Furthermore, it would seem that when accuracy is kept constant, there is no consistent relationship between simple reaction time and speed of the mental process involved in the task being measured.

Other studies dealing with the problem of the relation of speed to intelligence have gone beyond the sole consideration of reaction time. Speed in simple motor, sensory-motor and mental tasks has been assessed and intercorrelational analysis of the data generally has led to the formulation of statements on the general or specific "nature" of speed.

Both Sisk (1926) and Dowd (1926) found no evidence for a general speed factor. Working with intercorrelations of speed in simple and complex responses and scores in the Army Alpha test from a sample of 100 college students, Sisk (1926) found: 1) no evidence for a subject who is fast in simple reaction to be equally fast in a complex reaction; 2) only a slight tendency for one who is fast or slow in a complex reaction to be relatively fast or slow in another complex reaction; 3) a high Army Alpha score seems to only a small extent to be related to ability to react to a complex situation.

Dowd (1926) intercorrelated rate of work in 9 tests: cancellation, underlining a's, reading tests, tests for speed of movements, writing tests and arithmetic tests. She found no general speed factor, the only high correlations being between tests of similar content, and a very low correlation between these speed measures and scores on the Otis Advanced Examination1

Kennedy (1930) and McFarland (1930) reported high correlations between simple and complex abilities, which they took as evidence in favor of the general factor hypothesis. Kennedy (1930), mentioned earlier in another connection, administered various speed tests involving simple and complex abilities to two samples of adult subjects. The intercorrelations ranged from .02 to .70 with a mean of .34 for one group, and from .11 to .81 with a mean of .45 for the other group, and were not greatly affected when variability due to intelligence was held constant. In the first group a composite of the Otis and the Terman tests scores was used, whereas score on the Army Alpha given with double time was used in the second. The results were interpreted as giving evidence of a general speed factor responsible for the consistency of individual differences in rate of work in any given task, which bears no relation to intelligence. This rate of work she proposed to call "irritability". The more complex the task, the less is the effect of "irritability" and the greater the effect of general intelligence in determining speed of work.

In a similar attempt to study the relationship between speed and mental ability, McFarland (1930) used tests of varied degrees of difficulty such as free association, pencil maze, simple auditory reaction time, opposites, etc., containing a large number of items. He timed each item individually and isolated speed ability by keeping accuracy constant. The correlations ranged from .00 to .88 and fell into a hierarchy. This the author took as evidence of a speed factor involving general ability similar to that described by Spearman and concluded that ability with respect to speed is a "general" individual trait which is characteristic of mental behavior. Kennedy's and McFarland's conclusions were criticized by several authors: There is little evidence of a speed factor in Kennedy's results, and McFarland seems to have gone far beyond the implications of his data in his contentions. McFarland interpreted his results as agreeing with those of other investigators who, like Peak and Boring have maintained that speed of response is what primarily defines mental ability.

The main body of research on the interrelationships among simple and complex speed activities, however, has yielded evidence of specificity of speed of response. High intercorrelations among rate scores are between tests of similar content and between those tests of complex processes where a common function or related functions are at work. As regards the specific problem of the relationships between various rate scores and different measures of intelligence, the results of these and related studies suggest that they are slightly and apparently insignificant.

An important limitation in many of these studies is the lack of a measure of level of intelligence, mental ability or "altitude", in Thorndike's meaning of the word. Measurements of altitude and speed in the same function have been obtained following two methods: They are measured in different tests with similar material, varying the levels of difficulty; or they are measured in the same test. No consistent results have been obtained. In the present study, "altitude" and rate of work will be measured in the same tests, which will vary in difficulty.

Tyron and Jones (1933) measured rate of work as indicated by success on simple completion tests, which involved exposure of simple narrative and descriptive meaterial on a screen at four different exposure rates. Altitude was measured by scores obtained in the completion items of Thorndike's CAVD examinations. One hundred and sixteen subjects were tested. It was found that the correlations between the test of altitude and the four speed scores did not differ significantly from each other. The results were interpreted as indicating that mental ability is not contingent upon the speed of mental processes.

Hunsicker (1925) used a graded series of arithmetic problems and sentence-completion problems, defining ability as the highest level of difficulty at which a subject could answer 50% of the items correctly. The rate of work score she defined as the time it took to complete the first two pages of easy items. She found correlations from .57 to .31 between the speed scores in both types of tasks and coefficients from .39 to .61 between rate and altitude. The findings led her to conclude that there is a fairly consistent positive relationship between rate and ability. Furthermore, considering that ability in sentence completion and arithmetic are due to general intelligence, she concluded that speed is related to level of general ability, constituting an individual trait.

In 1921 the Army test report, and several later studies, gave results of the correlation between Army Alpha scores obtained in a standard time limit and double or longer time allowances. Very close correlations were found, which were taken as an indication of relation between speed, defined as rate of work, and intelligence. The validity of these conclusions is doubtful. They seem to be going quite beyond the immediate implications of the results, which would rather seem to indicate that speed of work plays a minor role in the Army Alpha scores obtained under standard time limit. Freeman (1932), as reported above, pointed out that the correlation between rate and altitude is by no means perfect, and that many time-limit tests "obscure the real level of attainment of a small, though important, number of individuals."

Studying the reciprocal influence of speed, quality and duration in individual performances, Courthial, Van de Stadt and Claparède (1932) gave two tests to 54 male students aged 16-20 and 23 female students aged 19-21. The tests were carré de chiffres consisting of disordered numbers to be re-arranged in correct order, and arithmetic computation, including addition, subtraction, multiplication and division. The results showed: difference between the sexes as regards speed and constancy of speed and quality within each type of task. The correlational analysis showed that there is a relationship between speed in different categories of operations, but no relation as regards accuracy. When the speed in both tests was considered, however, the constancy of rate of work was lowered considerably. Also, the authors found a low correlation between speed and quality, though there was evidence that the rapid type is more often accurate, and the slow inaccurate.

Graf (1932) showed that the length of time which a subject is permitted to spend on a given intelligence test may significantly influence his score. He studied the accomplishment of 100 subjects after various periods of time -- 5, 10, 15, 30, 45 and 60 minutes -- and found that almost without exceptions, they attained constancy of group rank only after a long period of work had elapsed. He pointed out that there is a difference between intelligence and "speed of adjustment" and that many mental tests emphasize the second factor while they are interpreted as measuring intelligence.

Kennedy (1930) had previously found that a positive correlation of .54 between Army Alpha scores obtained under standard time and a rank composite score of various speed tests dropped to .00 when double time was allowed.

Triska (1935) and Bennett (1941) are also among the investigators who studied the relation of speed to mental ability, varying the time allowance for the completion of the tasks. Triska (1935) used two forms of an intelligence test: in one form the work-limit method was followed so that speed was measured by the stop-watch; in the second form, administered two weeks later, time limit was used, speed being measured by the number of items attempted. The correlations between these scores and school grades led Triska to conclude that what is usually measured in serial reactions is a common factor of 'working speed', whose degree of relation to performance depends on the difficulty of the task. In simple reactions, on the other hand, the correlations depend upon the similarity of the abilities tested, as it is 'mental speed' that is being measured as an index of efficiency. Finally, the author suggested that "there seems to be no independent factor of 'mental speed' which is only a measure of innate or acquired ability to perform a given function, though there appears to be an independent factor contained in failures and successes which is part of the 'working speed!'"

Bennet (1941) found that rate of successful work, defined as the average amount of time spent on items done correctly, is low but positively and consistently related not only to altitude scores, but to scores on speed tests of intelligence as well, independently of test content. A high correlation of .95 between standard time limit scores on the Terman and unlimited-time or altitude scores on the same test, suggested that the ranking in respect to intelligence is hardly affected by the imposition of time.

Friede (1934) studying the interdependence of speed, amount of work, and quality of work, found that a change in the manner of work of the subject depends upon the difficulty of the test and that quality of work is more variable than speed and amount of work.

Aigner (1935), studied the performances of 30 subjects on the Bobertag and Burt intelligence tests, a simple and a choice reaction test and three groups of choice distrimination tests. Time and accuracy of response (or choice) in all tests were intercorrelated. Two clusters of positive correlations were found: all the speed measures, regardless of tests, and the intelligence scores. Two factors, one of intelligence and one of speed or "individual speed tempo" were suggested. The author indicated that "speed and accuracy of performance do not go hand in hand, at least not to the extent that is usually assumed."

Other studies bearing on the role of speed in mental ability at different levels of difficulty, are those of Sutherland (1934), Slater (1938), and DuBois (1932). Slater (1938) worked with scores obtained on the Thorndike's CAVD and on five separate non-verbal tests administered under a time-limit condition for 226 school children. The subjects worked at their own pace and recorded for themselves the time spent on each item. The deviation of this estimate from the average amount of time taken by the group to solve each problem correctly defined each subject's speed rate. The author found that the measures of speed rate tended to be consistent for a given subject without a close association with measures of intelligence obtained from either verbal or non-verbal material given with or without time limits, and independent from the degree of difficulty of the task. While Slater's conclusions brought evidence in favor of Spearman's conceptions, DuBois (1932) and Sutherland (1934) concurred in the interpretation of speed as independent from altitude. DuBois (1932) tested 139 adult subjects using five speed tests of approximately the same low degree of difficulty, two level tests and two tests where speed and level were not clearly separated. He found evidence for the existence of a factor common to the speed tests but not affecting the level tests to any great extent. Sutherland (1934) intercorrelated speed and altitude scores. The positive relationship practically disappeared when the influence of the intelligence factor was removed. Sutherland concluded that his results provided little evidence for an independent factor of speed "when the conditions demand a uniform altitude of securing maximum accuracy at the greatest speed." However, a factor of speed came into operation when the problems were of low difficulty.

The review of the literature has shown that there is no agreement among investigators who have dealt with problems relevant to the present study. Nevertheless, a survey of these and other findings reported in the literature suggests that:

1) When performing a particular motor or perceptual activity, individuals adopt a characteristic rate or tempo that is kept constant during the whole performance. Some points of interest in this respect have been pointed out, among others, by Braun (1927), Kupke (1933), Allport and Vernon (1933), Gühlstorf (1939), Yacorzynski (1942), Rimoldi (1948), Mishima (1951), Fraisse (1954), and Rimoldi and Cabanski (1961).

2) A pluralistic interpretation of the domain of tempo is more adequate than the monistic viewpoint. In this respect Haley's (1963) and Erdmann's (1965) results provided further support to the pluralistic interpretation since they discovered various factors found by Allport and Vernon (1933) and Rimoldi (1951).

3) Tempos in different activities are not totally unrelated. A few well identified parameters have been isolated in different studies, thus indicating the possibility of predicting related types of speed.

4) For a specific activity, individuals tend to be consistently fast or slow within relatively long periods of time. This seems to hold for a wide range of psychological activities.

5) No clear statements can be made regarding consistency of speed in all types of performances.

6) The speed component in intellectual functions isolated by several authors using different test batteries suggests that "g" is not a unitary factor as Spearman contended.

7) For a given individual, the quality of work is more variable than the speed.

8) The relation between quality and speed appears to be a function of the difficulty of the tasks.

9) There is not a close relationship between the accuracy of work in different categories of tests.

10) The fast subject is more often accurate and the slow subject more often inaccurate, though not to any significant extent.

In summary, the discussion has focused on representative research underlying two distinct theoretical interpretations of personal tempo, with special emphasis on those studies relating speed to mental performance. Though the discrepancies in the results are obvious, it is apparent that: 1) there is a negligible relation between mental ability and a variety of speed scores on simple and discriminative reactions, as well as scores on simple motor and mental functions; 2) mental ability, considered as level or altitude in Thorndike's sense, does not bear a consistent relation to rate of performance on simple mental tasks; 3) whenever a relation was found, it seemed due to similarity of content; 4) mental ability and rate of response measured on the same test tend to be significantly related when the material is of low difficulty.

It is also apparent that in all the reported studies, mental ability was measured in terms of accuracy of the solution of the task, in the sense that attention was focused on the final product of the thinking process rather than on the process itself. In the present study, mental ability will be quantified in terms of the problem solving process, using the Rimoldi approach to problem-solving behavior.

In 1955, Rimoldi devised an objective method to characterize the thinking process by analyzing the questions that a subject asks in order to solve a problem. The sequence of questions asked is called a tactic and "each tactic is experimentally defined by the number, type and order of the questions asked."

The assumptions underlying the method are as follows:

a) "that subjects are assumed to actively search for and combine information that they consider necessary and sufficient to reach a solution,

b) "that tactics are an index of the subject's thinking process,

c) "that various tactics may be used respectively by different subjects, or by the same subject in different occasions, in order to reach the solution of a problem,

d) "that individual differences are more likely to be highlighted through the study of the tactics than through the study of the final answers, and

e) "that any inferences from final answers to tactics is risky if not misleading." (Rimoldi, 1967)

Since 1955, the method has been intensively developed and has been successfully applied to investigations in a variety of areas. Furthermore, new scoring techniques have been devised that allow the characterization of a subject's thinking process, in terms of logical structure of the problems rather than of group norms.

The Rimoldi technique was first applied to characterize clinical diagnostic processes in medical students (Rimoldi, Haley, and Fogliatto, 1962). Other studies have dealt with effects of training in problem solving, problem solving at different ages and educational levels, Rorschach interpretation, interdisciplinary evaluation of organic pathology, appraisal of personality parameters, schizophrenic thinking, physiological correlates, open- and closed-mindedness, etc. The reader is referred to Erdmann (1967) for a detailed account of the applications of the technique.

CHAPTER III

METHOD

Sample of Subjects

The sample used in this study consisted of 30 subjects, all females, with ages ranging from 18 to 30 years. All the subjects were graduate students at the Universidad Nacional de Córdoba, Argentina. All graduate students were chosen so that there would be homogeneity with respect to educational level.

Testing Procedure and Design

Each subject was tested individually by the same examiner in a single session that lasted approximately one hour. The entire testing was conducted in Spanish. At the beginning of the experimental session and before each test was administered, the subject was instructed to perform the tasks at a comfortable rate which she found most natural. Several tests were administered involving psychological and psychomotor activities. Measurements of frequency per time interval or measurements in units of time were utilized. Negative correlations between some of the variables considered were expected; that would be a function of the scoring method rather than an evidence of negative relationship.

As stated previously, six "tempo" tests were used. They were selected on the basis of previous studies (Allport and Vernon, 1933; Rimoldi, 1951; Haley, 1963; Erdmann, 1965) as the most highly loaded in three well defined factors: large movements, speed of drawing, and speed of perception. The numbers associated with the various tests indicate the order in which the tests were administered. These numbers will also be used to identify the tests in the respective tables.

The following instructions, taken from Erdmann's study (1965), were given verbally:

> In this experiment you will be given a series of tasks which you are to perform at the rate that is most comfortable for you. Before each performance you will be given specific instructions which you are to carry out in the most natural way. You will start at a given signal and continue until told to stop. If at any time the instructions are not clear, do not hesitate to ask questions.

The score used was frequently per thirty-second intervals. Listed in the order of presentation in the experiment the tests were:

1) Arms Parallel. The subject was instructed to hold his arms parallel out in front of himself and keeping them parallel, swing them back and forth through the same arc. Measurement: number of swings in a 30-second interval.

2) Arms Symmetrical. The subject was instructed to stretch his arms out from his sides and swing them together straight in front and apart in a symmetrical fashion. Measurement: number of swings in a 30-second interval.

3) Reading Science. The subject was given an extract from an article on the characteristics of the photosynthesis of plants in different climatic regions. He was told to read it for himself at his habitual rate. After 30 seconds had elapsed from the start signal, the subject was told to stop and he was asked the last word he had read. Measurement: number of words in a 30-second interval.

4) Reading Literature. Same as Reading Science. The paragraph chosen was taken from a literary work by Italo Calvino. Measurement: number of words read in a 30-second interval.

5) Drawing Lines. The subject was given a pencil and a blank sheet of paper of standard size and was asked to draw lines without restrictions as in length or position on the paper. Measurement: number of lines drawn in a 30-second interval.

6) Drawing Circles. In this test the subject was requested to draw circles, and again there were no restrictions as to size or placement on the page. Measurement: number of circles drawn in a 30-second interval.

The remaining measures were obtained from problem-solving tasks. Five problems constructed according to Rimoldi technique were used, viz., problems 31A, 31B, 35A, 35B and 42. They were administered in the listed order immediately after the tempo battery.

Problems 31 and 35 are verbal problems. In labelling the problems, the number refers to logical structure, and the accompanying letter refers to the language in which the problem is presented. Language A is ordinary written verbal language and language B uses symbols to stand for objects.

Problem 42 is a figure problem consisting of a group of numbered areas; the task of the subject being to identify a preselected area.

In the Rimoldi approach to the study of problem-solving processes, the concepts of logical structure and language have been used to control the problems more strictly. By logical structure is meant "the formal properties or schema of the problem, expressed in terms of a basic set of logical relationships"... "Language is understood as a set of words, symbols, objects, etc., used to express a logical structure (schema), provided there is a rule of correspondence between the components of the logical structure and the language used. Thus, the same logical structure can be presented in different languages (isomorphic problems), and the same language can be used to express different logical structures." (Rimoldi and Erdmann, 1967). Furthermore, Rimoldi has postulated that the difficulty of a problem is defined, not in terms of percentages of passes, but in terms of: a) the complexity of the logical structure (intrinsic difficulty), and b) the language used (extrinsic difficulty), Rimoldi, 1967; Rimoldi, 1968.

In all five problems used in this study, the subject is given a card on which the problem is stated and ten additional cards, each with one question that the subject may choose to ask. The answer to each question is written on the reverse side of the card. Before the problems were administered, a sample problem was presented in order to acquaint the subject with the required task, and to answer any question he might pose. The following written instructions were given:

> You will be given a packet of cards on which are typed a particular problem situation and a set of questions and answers relevant to the problem. The question is one one side of the card, and the same question with its answer is on the other side. Read over the problem carefully. Next proceed by reading over all the questions. At this time do not turn the cards over. Decide on the first question you would like to have answered and write its number on the page provided. Then take the card from the folder, and read the answer on the back of the card. After having read the answer, decide on the next question you would like to have answered. Write down its number and then take the card from the folder. Proceed in this way. When you are satisfied that you have arrived at the answer, stop

drawing cards, and write down your answer. Remember: you may choose as many questions as you need to solve the problem, but do not choose any more than you need. There is no time limit for the solution of any of the problems. Work at the rate that is most comfortable for you.

The measurement used for the problem-solving tasks was time per unit of performance. With the aid of a stopwatch, time was recorded in seconds, with precision to 1/10 of a second, whenever the subject asked a question and when he gave the answer to the problem. Three distinct units of performance or experimental periods during the problem-solving process were defined for investigation:

a) Presentation time or first question period, defined as the time elapsed from the moment the subject was presented the problem until he asked the first question.

b) Interquestion period, defined as the time between asking any two successive questions. For a given subject in a given problem the number of interquestion periods was equal to the number of questions asked minus one. A specific interquestion period was labelled the *i*-th question time, or question *i* period, where *i* refers to the higher order questions and $i=2...n$, *n* being the number of questions asked. For example, the third question time or question 3 period is the time elapsed between asking the second and the third question.

c) Answer period, defined as the time from the last question until the answer of the problem was given.

The general label for an observation in any of the periods was time measure or time score. Thus we could talk about the time score for the first question (presentation), time score for the second question, etc., and time score for the answer.

A mean speed score or rate of work score was determined for each subject on each one of the problems, with the purpose of comparing rate of mental performance at various levels of difficulty, and to determine the relationship of such rate to the tempo variables. A mean speed score was defined as the mean interquestion time, i.e., the time elapsed between asking the first and the last questions divided by the number of interquestion periods, or, equivalently, by the number of questions asked minus one.

Total time was also used as a further time measure, and was defined for every subject in each problem as the time elapsed from the moment he was presented the problem until he gave the answer.

The problem-solving data was also analyzed using Rimoldi's technique. As stated above, this technique allows for the evaluation and scoring of the problem-solving process, which is experimentally characterized by the tactic or sequence of questions chosen by the subject. Scoring of the tactic is done in terms of its approximation to the logical structure of the problem. "By approximating the logical structure, we mean asking first the more general questions and thereafter questions of increasing specificity. The ideal tactic fulfills these requirements, that is: maximum correspondence between the generality of the question and its position in the tactic, with the minimum number of questions that exhaust the information necessary to solve the problem. In the scoring system used, these ideal tactics will obtain the maximum score. Scores are lower to the degree that they violate the above conditions, that is: reversals in order, irrelevancy and/or redundancy of the questions asked, lack of parsimony, failure to choose meaningful questions, etc." (Rimoldi, 1968)

In general, a tactic that provides sufficient information for the solution of a problem is called a good tactic. Among these, the optimum is the ideal tactic. Conversely, a tactic that does not provide enough information is categorized as a bad tactic. The analysis of the tactic followed by each subject and its categorization as ideal, good or bad, provided a criterion for grouping the subjects on any problem in terms of their problem-solving ability.

The problems used and their corresponding English versions, ideal tactics and solutions are presented in the Appendix. The logical structures of problems 31 and 35 are presented in Figures 1 and 2 respectively.

Given that the subjects do not ask necessarily the same number of questions and that the ideal and a good tactic are not necessarily of the same length, at least for problem 31, the analysis of the data was rather complex.

The main hypothesis of the study, namely, that the rate at which a subject asks questions is constant for a given problem, was tested in the following manner. Means and standard deviations of the time scores on each of the interquestion periods were calculated, and comparison between successive periods was made for each problem by performing *t* tests for correlated means. Each *t* test, therefore, included only those subjects who had asked questions in the two periods being compared.

The secondary hypothesis that for any specific problem there will be differences in the time scores of subjects following the ideal tactic, a good tactic, and a bad tactic, was tested for each problem separately by using the analysis-of-variance approach to profile data. This technique also provided

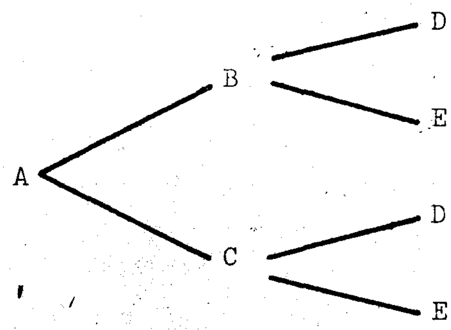

Figure 1. Logical structure of problems 31.

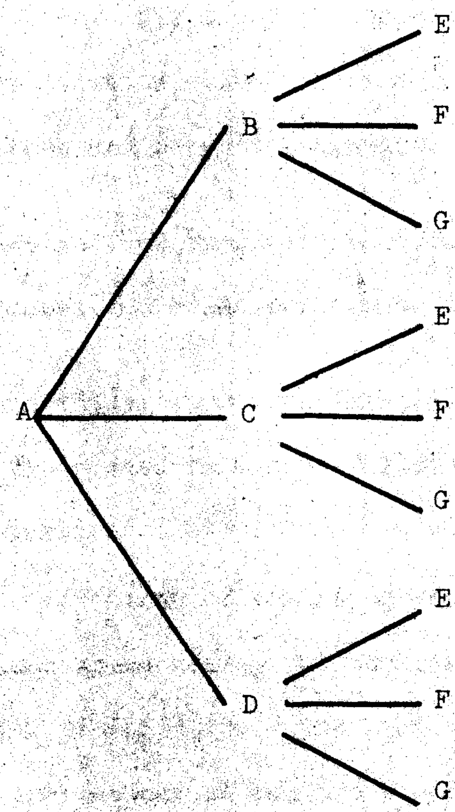

Figure 2. Logical structure of problems 35.

a further test on the main hypothesis of the study, as well as a test on the parallelism of the groups' profiles. Once these analyses were completed, simultaneous confidence intervals were determined by the Scheffé technique to test multiple comparisons among the means.

The hypothesis that the time elapsing from the moment the subject is presented with the problem until he asks the first question (time to understand the problem) will be related to the difficulty of the problem, was tested independently from the previous analyses. In this case no distinction was made between subjects regarding the tactics followed and a different model of analysis of variance was used. The analysis compared the total means of the time scores for the first question within the same structure, within the same language, between structures and between languages.

The same model of analysis of variance was also used to compare: 1) mean speed scores, 2) total times, and 3) answer times through all the problems.

The hypothesis of individual speed consistency throughout the problems was difficult to test. The procedure was as follows: 1) For each subject, central tendency and dispersion of the mean speed scores on the five problems were calculated; 2) the coefficient of variation was computed for each subject; and 3) the mean of the mean speed scores for each subject was plotted against the respective coefficient of variation. The plot was studied so as to determine variations in consistency as related to speed.

The subsequent concern in the analysis of the data was the study of rate of work in the problems as related to the tempo variables. Initially a factor analysis of the six tempo tests was performed using Thurstone's centroid method, in order to corroborate the assumption that we were dealing with three distinct factors of tempo. Then, correlations between the tempo tests and the mean speed scores in the problems were calculated. It should be noted at this point that in the original design of this experiment, various tapping tests had been included in the battery to represent the small muscle movement factor repeatedly recovered in various studies. Unfortunately, records of these tests were spoiled for 20 out of the 30 subjects due to mechanical difficulties in the recording apparatus. Given the impossibility of carrying out a new testing, and the fact that no inclusion of a small movement temporal parameter seemed crucial for the study, the analysis of the relationships above mentioned was reduced to three well established temporal factors.

Additional relationships were investigated, viz., between problem-solving score and mean speed score, first question time (understanding of the problem), total time, and answer time respectively for each problem; between accuracy of the solution (final answer) and mean speed score, first question time, and total time respectively for each problem; and finally between accuracy of solution in each possible pair of problems.

Finally it seemed worthwhile to investigate the mean speed score of subjects following the ideal tactic, a good tactic and a bad tactic. These contrasts were studied within each problem, since the subjects did not follow consistently the same type of tactic throughout the problems. For this purpose t tests were used. Furthermore, the coefficient of variation for each tactic-group within a specific problem was determined, in order to compare the groups in regard to their mean speed variation.

CHAPTER IV

RESULTS

The major hypothesis of this study was that the rate at which a subject asks questions to solve a given problem is constant for that problem. Table 1 presents the time score means, standard deviations and number of observations on the operationally defined units, and mean and standard deviation of total time, for each problem. As it becomes apparent from the inspection of the table, subjects ask different numbers of questions in their attempt to solve any specific problem.

A preliminary test on the main hypothesis was performed by using t tests for correlated observations between the means of successive interquestion times. Obviously, the number of observations compared in each case was equal to the number of observations in the higher order interquestion period. Three interquestion periods were compared in problem 31A, four in 31B, four in 35A, five in 35B, and nine in problem 42. The results as presented in Table 2 indicate that there are no significant differences in the time score means of successive interquestion periods and they are seen as supporting the basic hypothesis of this research.

To further test for possible differences between the periods and to test the hypothesis that there would be significant differences between the time performance of subjects following varied tactics, factorial designs with repeated measurements (Winer, 1962) were utilized for the verbal problems.

TABLE 1

MEANS, STANDARD DEVIATIONS AND NUMBER OF SUBJECTS FOR TOTAL TIME AND TIME MEASURES ON THE QUESTION AND ANSWER PERIODS FOR ALL PROBLEMS

Problems		Question Periods 1	2	3	4	5
31A	M	56.42	25.58	17.88	26.22	--
	σ	23.35	35.85	9.59	11.81	
	N	30	30	20	5	
31B	M	141.56	51.43	48.42	56.04	50.54
	σ	78.14	37.41	41.71	30.10	44.65
	N	30	27	22	13	5
35A	M	77.77	25.92	27.22	34.50	88.85
	σ	37.23	16.02	14.32	14.82	91.53
	N	30	30	29	5	4
35B	M	137.58	55.81	56.66	77.69	136.89
	σ	62.77	46.50	66.18	68.81	98.04
	N	29	28	27	18	7
42	M	98.39	39.84	47.77	49.09	55.86
	σ	35.66	24.40	30.33	30.12	62.95
	N	30	30	30	30	28

Table 1 (Continued)

MEANS, STANDARD DEVIATIONS AND NUMBER OF SUBJECTS FOR TOTAL TIME AND TIME MEASURES ON THE QUESTION AND ANSWER PERIODS FOR ALL PROBLEMS

Problems		Question Periods 6	7	8	9	10	Answer	Total Time
31A	M	--	--	--	--	--	23.79	122.08
	σ						26.54	76.86
	N						30	30
31B	M	22.80	17.90	24.40	--	--	70.40	318.77
	σ	14.20	.00	.00			107.11	172.04
	N	2	1	1			29*	29*
35A	M	30.90	41.30	--	--	--	20.13	172.20
	σ	3.75	.00				27.19	110.55
	N	3	1				30	30
35B	M	25.45	17.70	23.90	8.40	5.00	38.89	369.77
	σ	13.32	.00	.00	.00	.00	34.01	221.30
	N	4	1	1	1	1	29	29
42	M	36.21	44.50	51.75	34.14	9.63	124.15	509.42
	σ	27.31	40.27	33.99	27.74	4.81	116.57	223.78
	N	22	20	17	9	7	30	30

*There was a mistake in the recording of the answer time for one subject in problem 31B: This accounts for the different N's in question 1, and answer and total time. The same subject did not attempt solving problem 35B.

TABLE 2

SIGNIFICANCE OF DIFFERENCES BETWEEN TIME SCORE MEANS OF SUCCESSIVE INTERQUESTION PERIODS IN ALL PROBLEMS

Problem	Interquestion Periods a		b	M_a	M_b	M_D	σ_{M_D}	N	t-value
31A	3	-	2	17.885	29.125	-11.240	8.579	20	-1.310
	4	-	3	26.220	26.540	-0.320	5.259	5	-0.061
31B	3	-	2	48.418	49.177	-0.759	8.265	22	-0.092
	4	-	3	56.038	55.546	0.492	7.716	13	0.064
	5	-	4	50.540	49.840	0.700	17.588	5	0.040
35A	3	-	2	27.217	25.645	1.572	3.858	29	0.408
	4	-	3	34.500	32.940	1.560	8.140	5	0.192
	5	-	4	88.850	27.925	60.925	49.293	4	1.236
35B	3	-	2	56.659	56.467	0.192	14.266	27	0.014
	4	-	3	77.689	69.006	8.683	20.494	18	0.424
	5	-	4	136.886	53.086	83.800	50.403	7	1.663
	6	-	5	25.450	75.750	-50.300	24.375	4	2.064
42	3	-	2	47.770	39.843	7.927	5.983	30	1.325
	4	-	3	49.090	47.770	1.320	8.342	30	0.158
	5	-	4	55.864	48.625	7.239	13.580	28	0.533
	6	-	5	36.209	41.641	-5.432	10.212	22	-0.532
	7	-	6	44.500	36.190	8.310	7.131	20	1.165
	8	-	7	51.747	48.153	3.594	12.104	17	0.297
	9	-	8	34.144	46.766	-12.622	10.360	9	-1.218
	10	-	9	9.628	37.071	-27.443	11.367	7	-2.414

t-values non-significant

Table 3 presents the results of the analysis of variance of the time score means of two groups of subjects for first question period (1), second question period (2), and the answer period (A) in problem 31A. The groups compared were ideal-tactic group including nine subjects and good-tactic group with twenty subjects. The mean performance of the two groups as plotted for each of the periods is presented in Figure 3. The number of interquestion periods considered in this and other problems is a function of the length of the ideal tactic. Since in both problems 31 the respective ideal tactics have two questions, only one interquestion period, viz., question 2 period, was included in the corresponding analyses.

The two non-significant F ratios in Table 3 indicate that the time measure profiles in problem 31A are parallel ($F = 1.609$, $df = 2, 54$) and that the groups do not differ ($F = 1.020$, $df = 1, 27$). However, inspection of the profiles in Figure 3 suggested that application of a more powerful test might indicate a difference between the groups. As indicated by Morrison (1967) a two-sample t statistic was computed from the sums of the time scores on the three periods. It was found that the grand mean of the ideal-tactic group was significantly lower (one-sided t) than the grand mean of the good-tactic group at the .05 level ($t = -1.750$, $df = 27$) as shown in Table 4. Finally, the statistical hypothesis of equivalent parameters in the three periods was rejected at the .001 level of confidence ($F = 13.266$, $df = 2, 54$).

In order to determine which periods differed within and between groups, Scheffé intervals were calculated. The results are presented in Table 5 indicating: 1) Regardless of groups, the first question differed signif-

TABLE 3

ANALYSIS OF VARIANCE OF TIME SCORE MEANS OF "IDEAL" AND "GOOD" GROUPS FOR THREE EXPERIMENTAL PERIODS IN PROBLEM 31A

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Between Subjects	36167.747	28		
Groups	1321.708	1	1321.708	1.020
Subjects within Groups	34846.039	27	1290.594	
Within Subjects	57299.347	58		
Periods (1, 2, A)	18153.051	2	9076.526	13.266***
Periods x Groups	2201.134	2	1100.567	1.609
Periods x Subjects within Groups	36945.162	54	684.170	
Total	93467.094	86		

*** $p < .001$

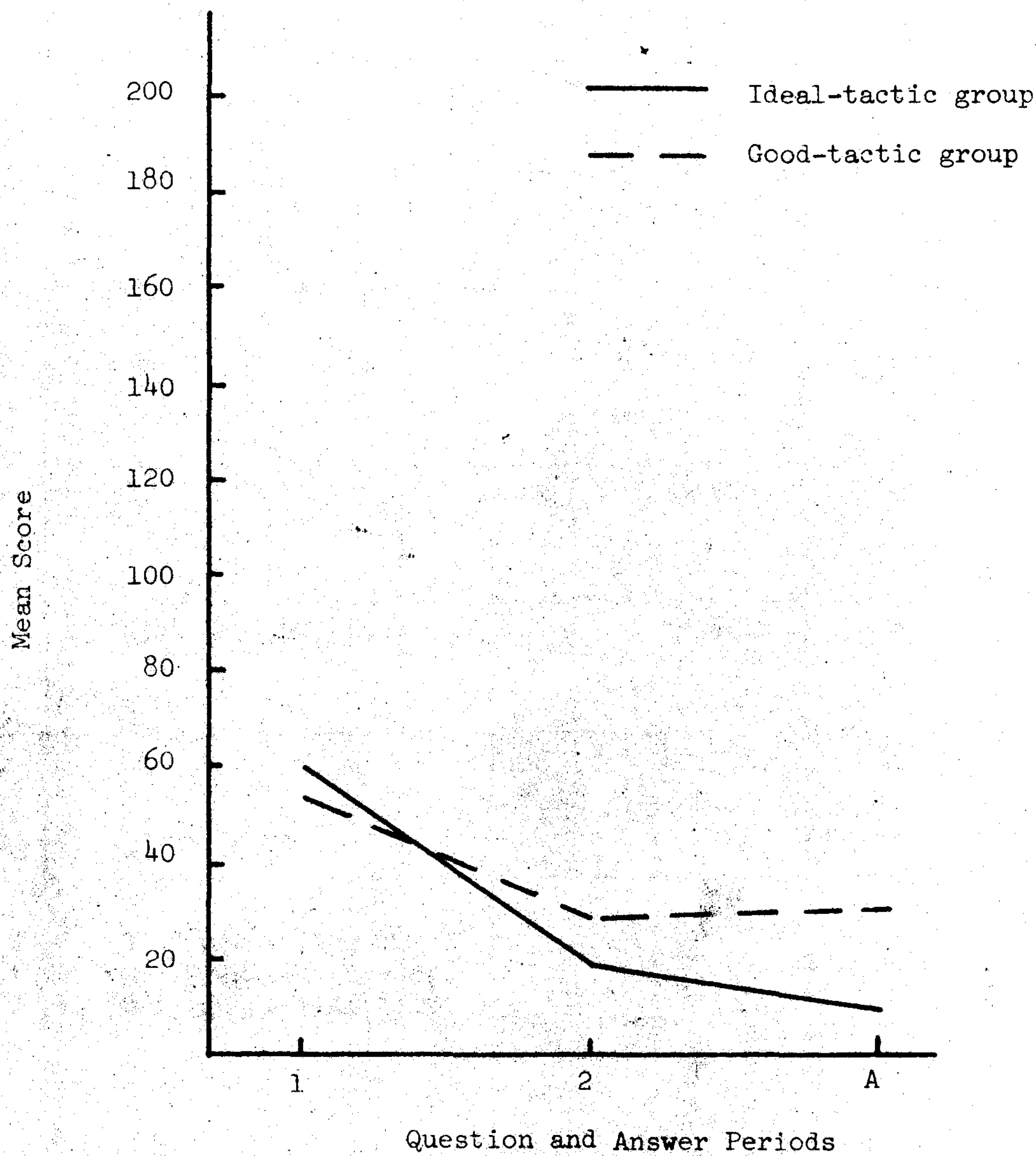

Figure 3. Problem 31A: Mean time score profiles for three experimental periods -- Ideal- and good-tactic groups.

TABLE 4

t-VALUES FOR THE DIFFERENCES BETWEEN PROFILE LEVELS BASED ON TIME MEASURES IN THE VERBAL PROBLEMS

Problem		Tactic-group			σ_{D_M}	df	t-value
		Ideal	Good	Bad			
31A	M	88.400	113.675	--	14.418	27	-1.750*
	N	9	20				
31B	M	--	231.171	301.43	35.840	22	-1.960*
	N		14	10			
35A	M	125.306	204.450	--	10.868	26	-7.282***
	N	17	11				
35B	M	--	320.043	226.00	40.776	23	2.306**
	N		21	4			

* $p < .05$ (one-tailed test)
** $p < .05$ (one-tailed test)
*** $p < .001$ (one-tailed test)

TABLE 5

SIGNIFICANCE OF DIFFERENCES BETWEEN EXPERIMENTAL PERIODS IN PROBLEM 31A

	Scheffé Intervals		
Comparison	Overall	Ideal	Good
1 vs. 2	5.622 -- 53.937***	2.788 -- 79.034***	4.192 -- 45.343*
1 vs. A	6.466 -- 56.410**	19.121 -- 80.190***	-4.996 -- 51.476
2 vs. A	-20.362 -- 23.680	1.650 -- 15.839*	-33.174 -- 30.114

	1	2	A
Ideal vs. Good	-00 -- 16.400	-00 -- 6.140	-00 -- -4.318**

* $p < .05$
** $p < .01$
*** $p < .001$

icantly from question 2 and the answer beyond the .001 level and the .01 level respectively. The question 2 mean and the answer mean were not significantly different. 2) The same pattern of significant differences is observed in the ideal-tactic group, plus a difference between question 2 and the answer significant beyond the .05 level. 3) For the good-tactic group, the only significant contrast between period means, was between the first and the second questions at the .05 level. 4) The only significant individual comparison between groups was between the answer period means, beyond the .01 level. Thus the results seem to indicate that the difference between the groups is mainly due to the lower answer period mean in the ideal-tactic group. Therefore the results in problem 31A are seen to provide support in favor of the hypothesis that there would be differences between the time scores of subjects using different cognitive approaches to the solution of a problem.

The results of the analysis of variance for problem 31B are presented in Table 6. Regarding their approach to the solution of this problem, the subjects were divided into good-tactic group (n = 14) and bad-tactic group (n = 10). Two subjects followed the ideal tactic but they were not included in the analysis: The small number of cases would hardly make them representative of a group. However, their profile means are included in Figure 4 to show a general trend found in all the problems. The results are similar to those obtained in problem 31A: 1) Though the F ratio showed no difference between the groups (F = 1.281, df = 1, 22), a directional t-test for uncorrelated means indicated that the good-tactic group mean time was significantly lower beyond the .05 level (t = -1.960, df = 22) as shown in Table 4. 2) There is no groups-by-periods interaction (F = 1.213, df = 2, 44), i.e., the profile means are parallel. 3) The

TABLE 6

ANALYSIS OF VARIANCE OF TIME SCORE MEANS OF "GOOD" AND "BAD" GROUPS FOR THREE EXPERIMENTAL PERIODS IN PROBLEM 31B

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Between Subjects	174463.493	23		
Groups	9598.297	1	9598.297	1.281
Subjects within Groups	164865.196	22	7493.873	
Within Subjects	308213.740	48		
Periods (1, 2, A)	69863.601	2	34931.801	6.804**
Periods x Groups	12456.752	2	6228.376	1.213
Periods x Subjects within Groups	225893.387	44	5133.941	
Total	482677.233	71		

** $p < .01$

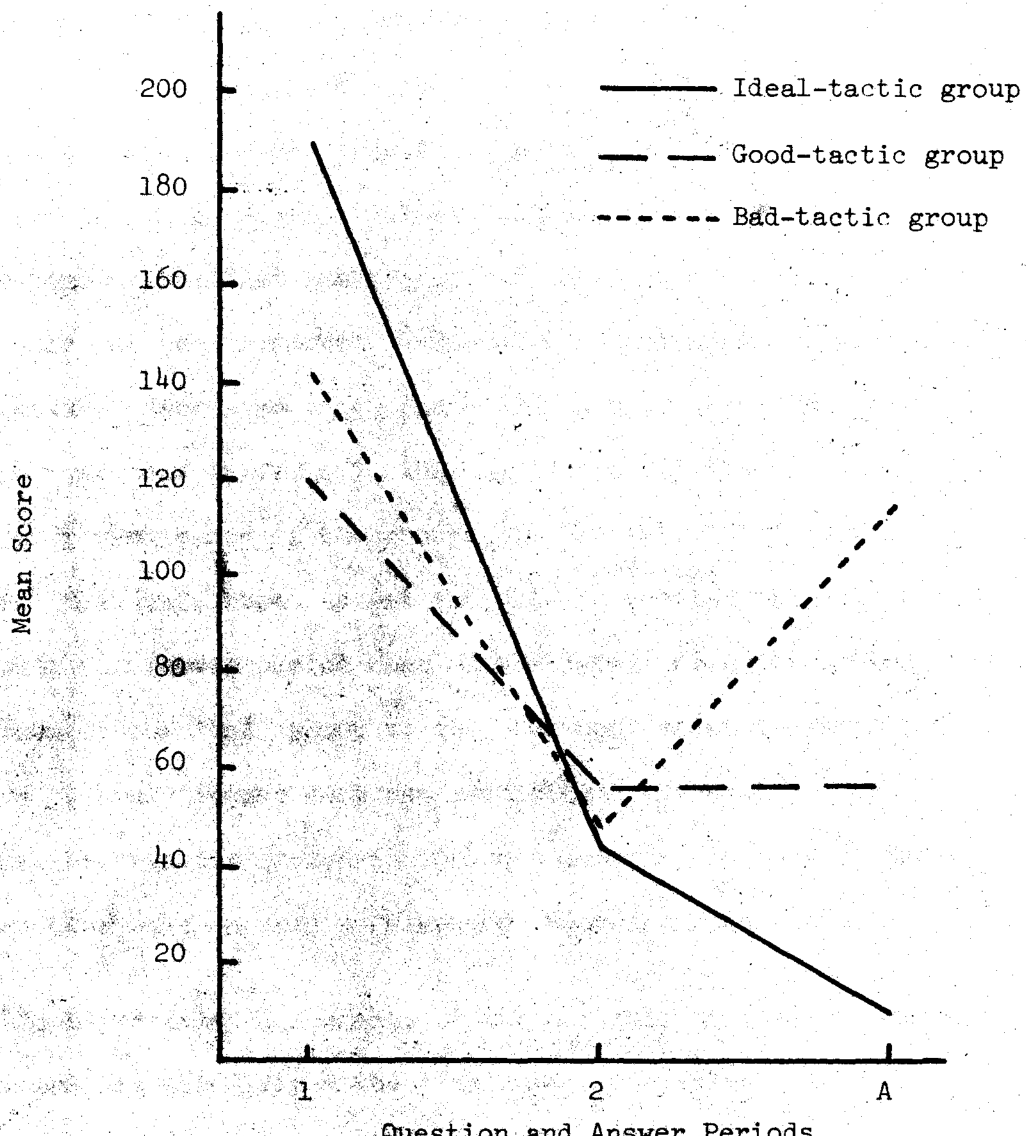

Figure 4. Problem 31B: Mean time score profiles for three experimental periods -- Ideal-, good- and bad-tactic groups.

experimental periods differed significantly beyond the .01 level ($F = 6.804$, $df = 2, 44$). As shown in Table 7, multiple comparisons among the period means indicated that the contrast responsible for the significant F ratio was that between the first and the second questions ($p < .01$). 4) Comparisons among the periods within each group indicated that periods 1 and 2 also differed significantly in both the good-tactic and the bad-tactic groups. 5) In the good-tactic group alone, period 1 was found to differ from the answer period at the $p = .05$ level of significance. Other comparisons within the groups did not reach customary levels of confidence. 6) Given that the hypothesis of equal group levels had been rejected, a one-sided simultaneous confidence interval set was used to determine which individual period means were significantly different. As seen in Table 7, the confidence interval for the difference in the answer period means of the groups, is the only interval where zero is not included. This indicates, as was the case in problem 31A with the ideal-tactic group, that the answer period mean of the 'good' group is smaller than the answer mean of the 'bad' group at the 5 percent joint significance level. Therefore it would appear that the significant one-tailed t tests for over-all difference between the groups in both problems 31, is largely due to the readiness with which a more parsimonious approach leads to solving the problem.

Table 8 presents the results of the analysis of variance of the period means in problem 35A. Since the ideal tactic to solve this problem, as well as the ideal tactic of problem 35B has three questions, two interquestion periods were considered in the analysis of problem 35, viz., question 2 period and question 3 period. Comparison of these two periods provided a further test of the main hypothesis of this study. Two groups were distinguished in problem

TABLE 7

SCHEFFÉ INTERVALS FOR THE DIFFERENCES BETWEEN EXPERIMENTAL PERIODS IN PROBLEM 31B

Within Subjects and Groups

Comparison	All Subjects	Good-tactic Group	Bad-tactic Group
1 vs. 2	23.374 -- 127.709***	0.502 -- 124.840**	22.479 -- 164.641**
1 vs. A	-16.341 -- 110.491	12.394 -- 110.449*	-138.720 -- 192.700
2 vs. A	-98.562 -- 41.629	-59.522 -- 57.022	-228.564 -- 95.424

Between Groups

Comparison	Good-tactic	vs.	Bad-tactic
1	-00	--	2.005
2	-00	--	28.254
A	-00	--	-0.758*

* $p < .05$
** $p < .01$
*** $p < .001$

TABLE 8

ANALYSIS OF VARIANCE OF TIME SCORE MEANS OF "IDEAL" AND "GOOD" GROUPS FOR FOUR EXPERIMENTAL PERIODS IN PROBLEM 35A

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Between Subjects	26639.067	27		
Groups	6122.984	1	6122.984	7.760**
Subjects within Groups	20516.084	26	789.080	
Within Subjects	107096.328	84		
Periods (1, 2, 3, A)	60981.515	3	20327.172	34.962***
Periods x Groups	764.413	3	254.804	.438
Periods x Subjects within Groups	45350.399	78	581.415	
Total	133735.395	111		

** $p < .01$
*** $p < .001$

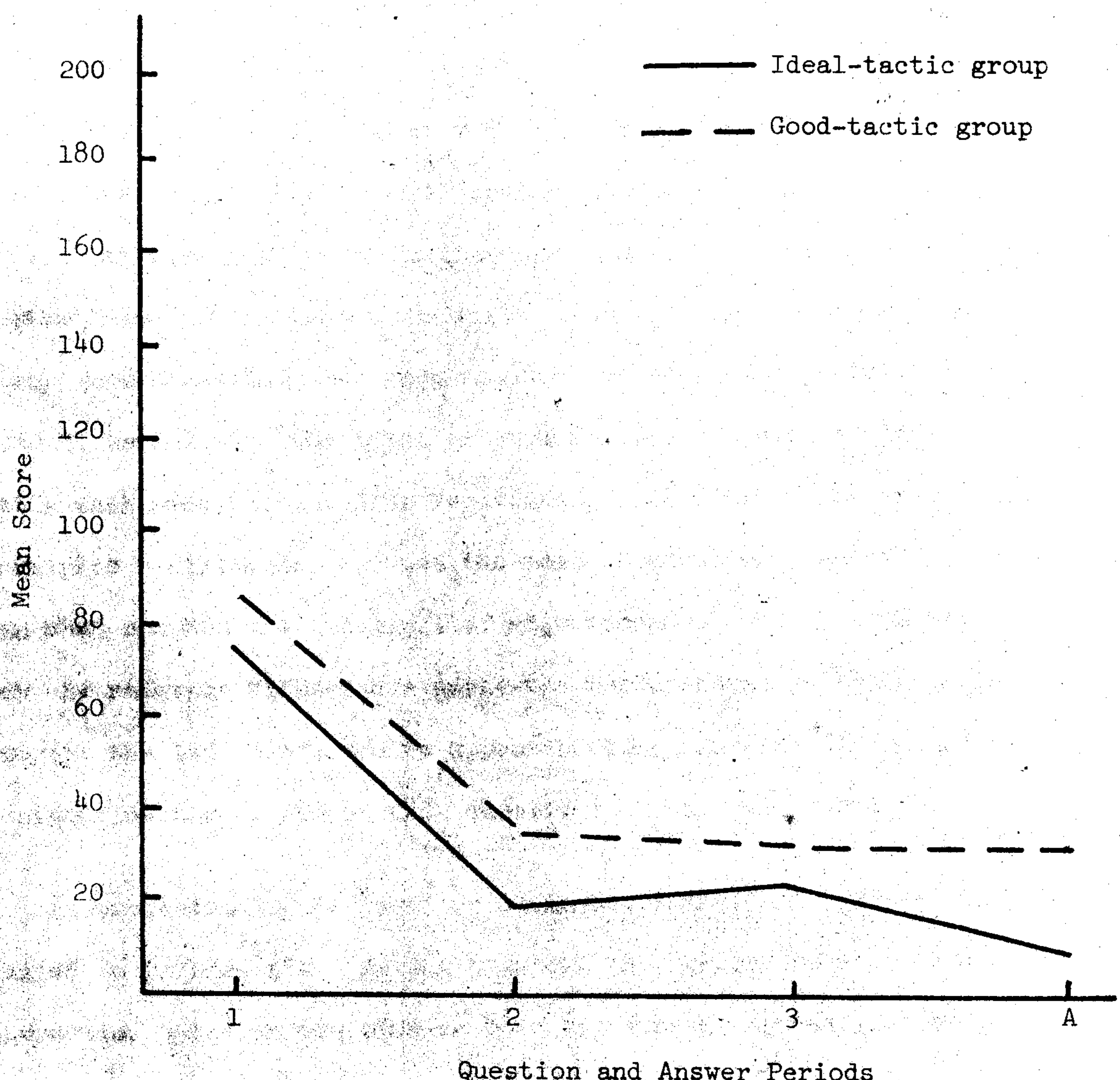

Figure 5. Problem 35A: Mean time score profiles for four experimental periods -- Ideal- and good-tactic groups.

35A: an ideal-tactic group which included 17 subjects, and a good-tactic group comprising 11 subjects. One of the two subjects who followed a bad tactic asked only two questions. Therefore, neither were considered in the analysis, nor have their profile means been plotted in Figure 5. Figure 5 shows the profile means for the "ideal" and "good" groups. Table 8 indicates that the hypothesis of parallel mean profiles in the population is indeed most tenable, the F ratio being 0.438 with df = 3, 78. The remaining F ratios indicate: 1) that the groups differ significantly beyond the .01 level (F = 34.962, df = 3, 78). As seen from Table 9, the Scheffé multi-comparison method for repeated measures indicated the first question period as significantly different from the answer and from the two interquestion periods, i.e., questions 2 and 3, beyond the .001 level of significance. A similar analysis performed within each group of subjects replicated those differences in the ideal-tactic group plus a difference between the mean of question 3 and the answer period mean that reached the .05 level of significance. The Scheffé method did not show any relevant differences among the period means in the good-tactic group. However, the less conservative approach of Newman-Keuls indicated question 1 as significantly different from questions 2 and 3 and the answer.

As proceeded in the previous analyses, individual differences were also studied in problem 35A. Having accepted the absence of a tactic-by-period interaction based on the time scores, the over-all gross conclusion of unequal mean vectors was resolved into differences between individual period means attributable to level or height of the profiles. Consistent with the one-sided hypothesis tested against the null hypothesis of difference between groups, directional tests were used to determine the significance of

TABLE 9

SCHEFFÉ INTERMALS FOR THE DIFFERENCES BETWEEN

EXPERIMENTAL PERIODS IN PROBLEM 35A

Within Subjects and Groups			
Comparison	All Subjects	Ideal-tactic Group	Good-tactic Group
1 vs. 2	15.555 -- 87.681***	2.954 -- 103.705***	-2.791 -- 100.736
1 vs. 3	14.194 -- 88.228***	.134 -- 98.490***	-4.308 -- 107.508
1 vs. A	18.672 -- 98.135***	12.732 -- 113.304***	-16.944 -- 119.490
2 vs. 3	-13.902 -- 11.088	-16.378 -- 8.343	-30.970 -- 36.224
2 vs. A	-10.400 -- 23.971	-3.413 -- 22.790	-48.193 -- 52.793
3 vs. A	-7.262 -- 23.648	2.498 -- 24.914*	-44.642 -- 43.987

Between Groups			
Comparison	Ideal-tactic	vs.	Good-tactic
1	-00	--	6.174
2	-00	--	-3.625****
3	-00	--	-1.754**
A	-00	--	-1.927****

* $p < .05$
** $p < .025$
*** $p < .001$
**** $p < .0005$

individual differences. As seen from Table 9, the 'ideal' group means on questions 2 and 3 and on the answer were significantly lower than the respective means for the 'good' group. There was no difference between groups regarding the average time they took to ask the first question.

Table 10 presents the results of the analysis of variance of the period means for problem 35B. There was a 'good' and a 'bad' group. Their profile means have been plotted in Figure 6. Only two subjects followed the ideal tactic in this problem. They were not included in the analysis of the data, but their profile means have been plotted in Figure 6. Neither significant groups-by-periods interaction (F = 1.212, df = 3, 69), nor difference between the groups (F = 1.329, df = 1, 23) were found. This led to the acceptance of both the parallelism hypothesis and the hypothesis of equal profile levels. The one-sided t test for the difference between the total group means did not show a significant departure in the predicted direction. Contrary to the expectations the total mean for the bad-tactic group was lower than the grand mean for the 'good' group as readily seen by inspection of the profiles in Figure 6. As had been the case in the analyses of both problems 31 and problem 35A, the hypothesis of equal response or period effects was also rejected in problem 35B (F = 22.583, df = 3, 69) at the .001 level of confidence. The Scheffé approach was used to set simultaneous confidence intervals and test for significance comparisons among the periods. As shown in Table 11 the first question period was significantly different from questions 2 and 3 and from the answer in the multiple comparison sense beyond the .001 level. Consistent with the finding of equal tactic effects and no tactic-by-period interaction, contrasts among the period means within each tactic-group showed the same pattern of

TABLE 10

ANALYSIS OF VARIANCE OF TIME SCORE MEANS OF "GOOD" AND "BAD" GROUPS FOR FOUR EXPERIMENTAL PERIODS IN PROBLEM 35B

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Between Subjects	135954.852	24		
Groups	7429.009	1	7429.009	1.329
Subjects within Groups	128525.843	23	5588.080	
Within Subjects	325031.438	75		
Periods (1, 2, 3, A)	156858.794	3	52286.265	22.583***
Periods x Groups	8418.228	3	2806.076	1.212
Periods x Subjects within Groups	159754.415	69	2315.281	
Total	460986.290	99		

*** $p < .001$

TABLE 11

SCHEFFÉ INTERVALS FOR THE DIFFERENCES BETWEEN EXPERIMENTAL PERIODS IN PROBLEM 35B

Comparisons	All Subjects Scheffé Interval	'Good' Group Scheffé Interval	'Bad' Group Critical Value	Total Differences
1 vs. 2	19.593 -- 154.414***	3.665 -- 182.277***	171.1	174.7*
1 vs. 3	44.349 -- 129.273***	38.198 -- 144.697***	191.5	200.6*
1 vs. A	41.614 -- 163.616***	34.851 -- 188.682***	138.6	172.7*
2 vs. 3	-44.427 -- 44.812	-59.541 -- 56.494	138.6	25.9
2 vs. A	-23.335 -- 54.557	-30.457 -- 68.047	138.6	2.0
3 vs. A	-28.212 --- 59.820	-35.879 -- 76.518	171.1	27.9

* $p < .05$
*** $p < .001$

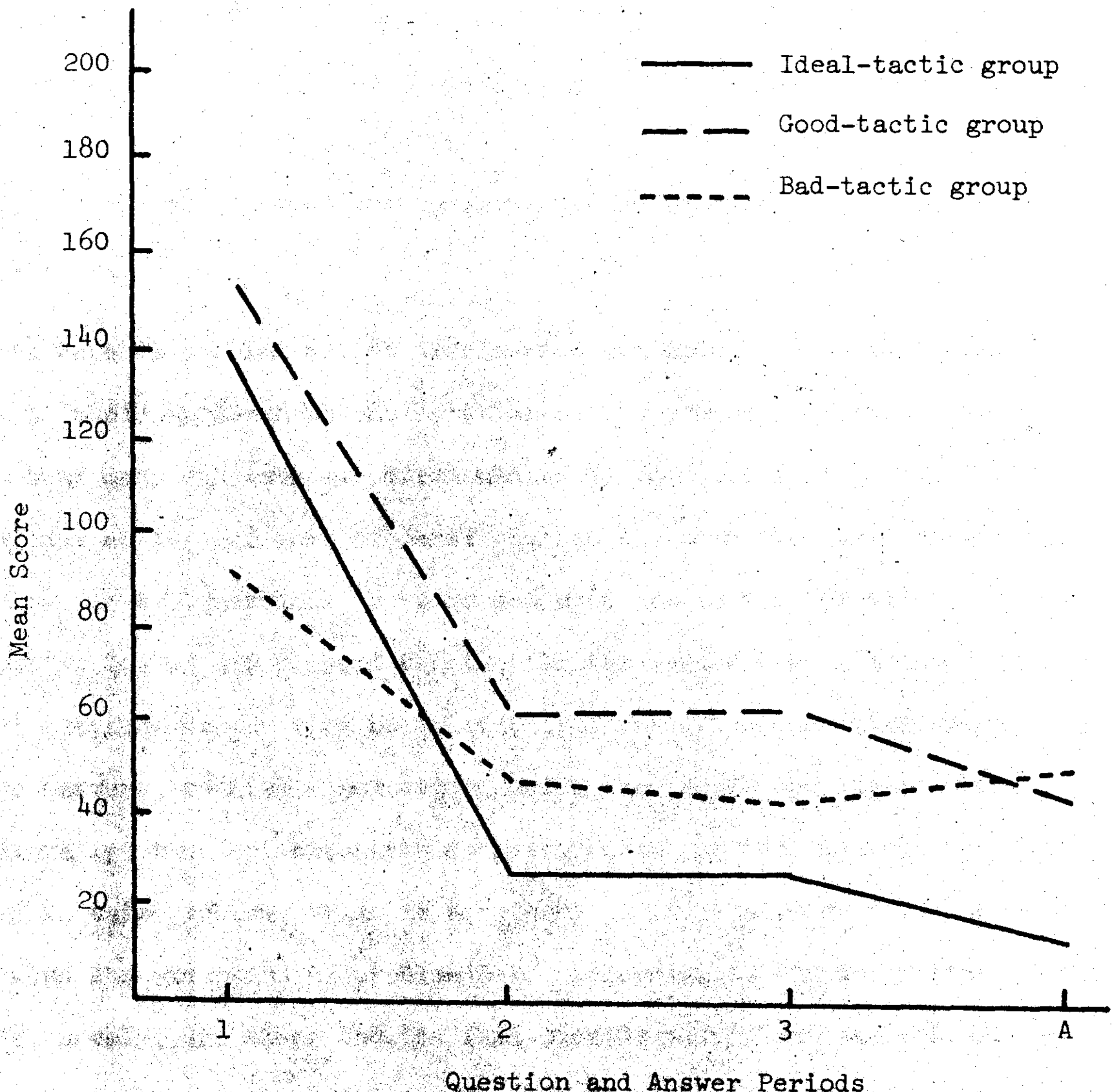

Figure 6. Problem 35B: Mean time score profiles for four experimental periods -- Ideal-, good- and bad-tactic groups.

differences, significant at the .001 level in the 'good' group and at the .05 level in the 'bad' group. In none of the three sets of comparisons were the remaining contrasts significant. The Scheffé method was used for the comparisons in the 'good' group, while the Newman-Keuls method (Winer, 1962) was utilized in probing the period differences in the bad-tactic group. The results of these comparisons, specifically the non-significant difference between the inter-question periods, i.e., the difference between the average times for asking the second and the third questions, provide further support to the major research hypothesis.

As regards problem 42, no distinction was made between the subjects relative to their approach to the solution of the problem. Previous research had shown that many subjects are often misled by the questions in this problem. Two situations arise: a) some subjects realize the adequate tactic after having asked one or two questions, b) some subjects ask most of or all the questions without following any planned tactic. In the second case a subject may either give a wrong answer or find no solution, or reviewing the information provided by the answers, realize a posteriori which the tactic and the solution are. Incidentally, the last situation is responsible for the high mean of the answer period in this problem, which is not found in the analysis of the verbal problems with the exception of problem 31B. According to our definition of a good tactic, namely, all those tactics that provide sufficient infommation to solve the problem, the subjects falling in both the situations above mentioned would be included in a "good" group. It was felt that such a group would not represent a unitary cognitive approach to the solution of the problem, and that the rigid application of a criterion might lead to irrelevant interpretation of the results. However, the fact that the ideal tactic has four questions and that subjects tend to ask many questions in this problem, made possible the determination of several interquestion periods, the contrasts among which provided a further test on the main hypothesis of constant rate.

For problem 42, then, two analyses of variance of the means of the time scores for the experimental periods were performed: one included all those subjects who had asked at least five questions, 28 subjects; the other comprised 17 subjects who has asked at least eight questions. Therefore, there were four interquestion periods in the first analysis, and seven in the second analysis. The results are reported in Tables 12 and 13 respectively, and the profiles have been plotted in Figure 7. In both analyses the F ratios reached the .001 level of significance (F = 12.258, df = 5, 135; and F = 11.741, df = 8, 128), indicating that there were some contrasts between the period mean times which would lead to rejecting the null hypothesis.

Two more analysis of variance were performed on the interquestion periods included in each of the previous analyses. The results, as seen in Tables 14 and 15 respectively, showed no differences between interquestion periods in any case (F = 1.223, df = 3, 81; and F = 0.641, df = 6, 96). These analyses were performed to substitute a single test for all possible contrasts among the interquestion periods considered in the two previous analyses. The results provide further support to the original t-tests computed on the difference between successive interquestion periods only. Again the main research hypothesis seems to be supported by the results. Application of the Scheffé method in connection to the analyses shown in Tables 12 and 13, indicated the following: 1) the time taken to ask the first question and the answer time are

TABLE 12

ANALYSIS OF VARIANCE OF TIME SCORE MEANS OF 28 SUBJECTS

FOR SIX EXPERIMENTAL PERIODS IN PROBLEM 42

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Between Subjects	157534.951	27		
Within Subjects	591635.008	140		
Periods (1, 2, 3, 4, 5, A)	184732.823	5	36946.565	12.258***
Residual	406902.185	135	3014.090	
Total	749169.959	167		

*** $p < .001$

TABLE 13

ANALYSIS OF VARIANCE OF TIME SCORE MEANS OF 17 SUBJECTS

FOR NINE EXPERIMENTAL PERIODS IN PROBLEM 42

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Between Subjects	93932.083	16		
Within Subjects	481658.689	136		
Periods (1, 2, 3, 4, 5, 6, 7, 8, A)	203854.309	8	25481.789	11.741***
Residual	277804.380	128	2170.347	
Total	575590.772	152		

*** $p < .001$

TABLE 14

ANALYSIS OF VARIANCE OF THE MEANS OF FOUR INTERQUESTION TIMES BASED ON 28 SUBJECTS WHO ASKED AT LEAST FIVE QUESTIONS IN PROBLEM 42

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Between Subjects	75065.680	27		
Within Subjects	79674.572	84		
Interquestion Periods	3451.804	3	1150.602	1.223
Residual	76222.768	81	941.022	
Total	154740.252	111		

F ratio not significant

TABLE 15

ANALYSIS OF VARIANCE OF THE MEANS OF SEVEN INTERQUESTION TIMES BASED ON 17 SUBJECTS WHO ASKED AT LEAST EIGHT QUESTIONS IN PROBLEM 42

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Between Subjects	40919.072	16		
Within Subjects	92942.186	102		
Interquestion Periods	3578.006	6	596.334	.641
Residual	89364.180	96	930.877	
Total	133861.258	118		

F ratio not significant

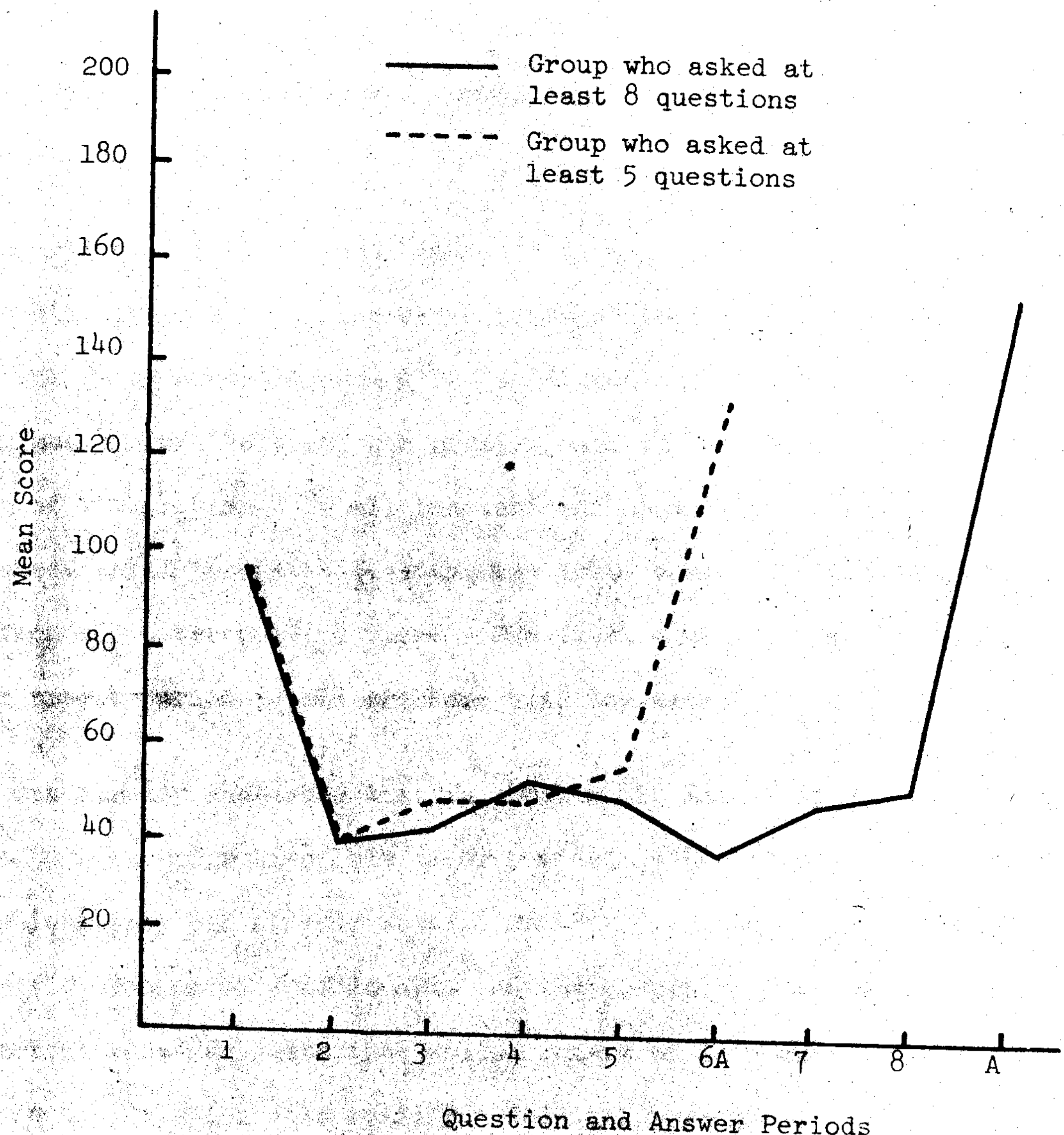

Figure 7. Problem 42: Mean time score profiles for six and nine experimental periods.

significantly different from the time elapsed between questions beyond the .01 level, but 2) they are not different between themselves.

A summary of the results obtained for the verbal problems is presented in Table 16 where a plus sign denotes significance and a minus sign denotes non-significance. All the individual comparisons that reached a customary level of significance are indicated.

Inspection of Table 16 and Figures 3 through 7 indicates that there is a definite difference between the three types of periods defined in this study, namely, the first question period or "understanding" the problem, the inter-question periods or "solving" the problem, and the answer period or finding the solution of the problem. In all problems and at all levels of approach, the time elapsed until the first question was asked stands as significantly different from all interquestion times. The first question time is also different from the answer period in all problems with the exception of 31B and 42.

It was already suggested that in problem 42, many subjects realize the tactic to solve the problem only after reviewing the information provided by the questions they had already asked. When this happens, the length of the answer period increases considerably and the resulting mean tends to obscure the effect of those subjects that follow a more or less straightforward tactic and get to the solution more readily. This interpretation is supported by the observation of the performances during the testing sessions. In problem 31B the "bad" group is responsible for the high total answer mean and the resulting non-significance of its contrast with the first question mean.

TABLE 16

SUMMARY OF RESULTS OBTAINED IN

THE VERBAL PROBLEMS

Problems		Interaction	Tactic Groups	Periods
31A	Over-all	-	+	+
	Individual Comparisons		A	All subjects: 1-2, 1-A Ideal Group: 1-2, 1-A, 2-A Good Group: 1-2
31B	Over-all	-	+	+
	Individual Comparisons		A	All Subjects: 1-2 Godd Group: 1-2, 1-A Bad Group: 1-2
35A	Over-all	-	+	+
	Individual Comparisons		2, 3, A	All Subjects: 1-2, 1-3, 1-A Ideal Group: 1-2, 1-3, 1-A, 3-A Good Group: 1-2, 1-3, 1-A
35B	Over-all	-	-	+
	Individual Comparisons		-	All Subjects: 1-2, 1-3, 1-A Good Group: 1-2, 1-3, 1-A Bad Group: 1-2, 1-3, 1-A

As to their approach to the solution of the problems, the time performance of all groups was similar within each problem. The parallelism hypothesis was accepted in all cases, as the pattern of differences between adjacent periods was alike in all groups. However, the profile heights were different in the sense that the group of subjects following a more parsimonious tactic had a total mean time score significantly lower. Individual comparisons of the periods between groups indicated that the over-all difference was mainly due to the answer period, which was significantly shorter in the more parsimonious group. These findings substantiate one of the hypothesis of the study, namely, that there would be differences between time scores at different levels of problem solving ability.

Groups within each verbal problem were further compared as regards their mean speed score. As previously stated, a mean speed score was defined for each subject as the average of the interquestion times. The mean speed score means, standard deviations and coefficients of variation for the different groups of subjects in each problem, as well as for the combined groups, are given in Table 17. The only significant difference was between the ideal-tactic and good-tactic groups in problem 35A beyond the .001 level ($\sigma_{D_M} = 4.169$, $t = 4.088$). This is totally consistent with the results obtained in the previous analyses, where problem 35A was the only problem in which the interquestion periods were different between the groups. Inspection of Table 17 indicates that the "ideal" and "good" groups in problem 35A are comparable in terms of absolute variability (coefficients of variation) of their mean speed scores, which results in enhancing the difference of central tendency between the groups.

TABLE 17

MEANS, STANDARD DEVIATIONS AND COEFFICIENTS OF VARIATION OF MEAN SPEED SCORES IN EACH PROBLEM

Problem		Tactic Groups			Groups Combined
		Ideal	Good	Bad	
31A	M	18.744	21.454	16.100	20.463
	σ	7.883	19.495	---	16.559
	CV	42.057	90.870	---	80.923
	N	9	20	1	30
31B	M	44.000	52.308	51.265	51.268
	σ	18.000	38.513	19.804	30.942
	CV	40.909	73.628	38.635	60.353
	N	2	14	11	27
35A	M	21.421	38.462	33.312	28.462
	σ	9.891	16.101	.687	14.726
	CV	46.173	41.862	2.064	51.739
	N	17	11	2	30
35B	M	26.525	65.748	64.107	62.654
	σ	5.175	41.707	31.180	39.761
	CV	19.510	63.434	48.638	63.462
	N	2	21	5	28
42	M	---	---	---	46.541
	σ	---	---	---	24.800
	CV	---	---	---	53.286
	N	---	---	---	30

The effect of degree of difficulty on different aspects of the time performance was studied in the verbal problems regardless of problem solving ability, given that subjects do not follow necessarily the same type of tactic throughout the problems. Since degree of difficulty of the problems has been assumed to be a function of logical structure and mode of presentation (language), 2 x 2 factorial designs with repeated measurements in both factors were utilized for the study of: 1) the first question period, 2) the answer period, 3) total time, and 4) mean speed.

As shown in Tables 18 through 21, the results of the analyses are similar for all the time measures with the only exception of the effect of structure on the answer period. The results indicate: 1) Parallel profiles regardless of time measure, i.e., there was no interaction between structure and language in any case. 2) Language affected significantly the four time measures: the answer period at the .01 level, and first question, total time and mean speed score beyond the .001 level of significance. 3) Degree of complexity of the logical structure produced changes significant at the .05 level in the time performance as measured in the first question period, total time and mean speed score. 4) The answer period was not affected by the structure of the problem.

In Figure 8 the mean of the first question period in the four problems was plotted twice so as to obtain the profile of each effect, structure and language at both levels of the other. The profiles at the left represent the effect of logical structure at both modes of presentation, language A and B. The profiles at the right indicate the effect of language at logical structure 31 and 35. Similar profiles have been plotted in Figures 9, 10, and 11 for the effect of

TABLE 18

ANALYSIS OF VARIANCE OF THE MEANS OF THE FIRST QUESTION

FOR 29 SUBJECTS IN FOUR VERBAL PROBLEMS

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Between Subjects	151441.455	28		
Within Subjects	228018.878	87		
Structures	5699.411	1	5699.411	4.323*
Structures x Subjects	36917.962	28	1318.499	
Languages	128291.805	1	128291.805	91.354***
Languages x Subjects	39321.368	28	1404.335	
Structures x Languages	1307.846	1	1307.846	2.222
Structures x Languages x Subjects	16480.486	28	588.589	
Total	379460.333	115		

* $p < .05$
*** $p < .001$

TABLE 19

ANALYSIS OF VARIANCE OF THE MEANS OF THE ANSWER

FOR 29 SUBJECTS IN FOUR VERBAL PROBLEMS

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Between Subjects	114382.804	28		
Within Subjects	341278.632	87		
Structures	8688.062	1	8688.062	2.635
Structures x Subjects	92308.145	28	3296.719	
Languages	30732.083	1	30732.083	8.352**
Languages x Subjects	103025.515	28	3679.483	
Structures x Languages	5848.980	1	5848.980	1.627
Structures x Languages x Subjects	100675.847	28	3595.566	
Total	455661.436	115		

** $p < .01$

TABLE 20

ANALYSIS OF VARIANCE OF THE TOTAL TIME MEANS

FOR 29 SUBJECTS IN FOUR VERBAL PROBLEMS

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Between Subjects	1433642.061	28		
Within Subjects	2568216.890	87		
Structures	75796.646	1	75796.646	6.397*
Structures x Subjects	331742.624	28	11847.951	
Languages	1108700.072	1	1108700.072	51.778***
Languages x Subjects	599550.548	28	21412.520	
Structures x Languages	.448	1	.448	.000
Structures x Languages x Subjects	452426.552	28	16158.091	
Total	4001858.951	115		

* $p < .05$
*** $p < .001$

TABLE 21

ANALYSIS OF VARIANCE OF THE MEAN SPEED SCORE MEANS

FOR 25 SUBJECTS IN FOUR VERBAL PROBLEMS

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Between Subjects	31904.354	24		
Within Subjects	78468.270	75		
Structures	2898.842	1	2898.842	6.400*
Structures x Subjects	10870.793	24	452.950	
Languages	26404.268	1	26404.268	38.343***
Languages x Subjects	16527.171	24	688.632	
Structures x Languages	62.861	1	62.861	.070
Structures x Languages x Subjects	21704.335	24	904.347	
Total	110372.624	99		

* $p < .05$
*** $p < .001$

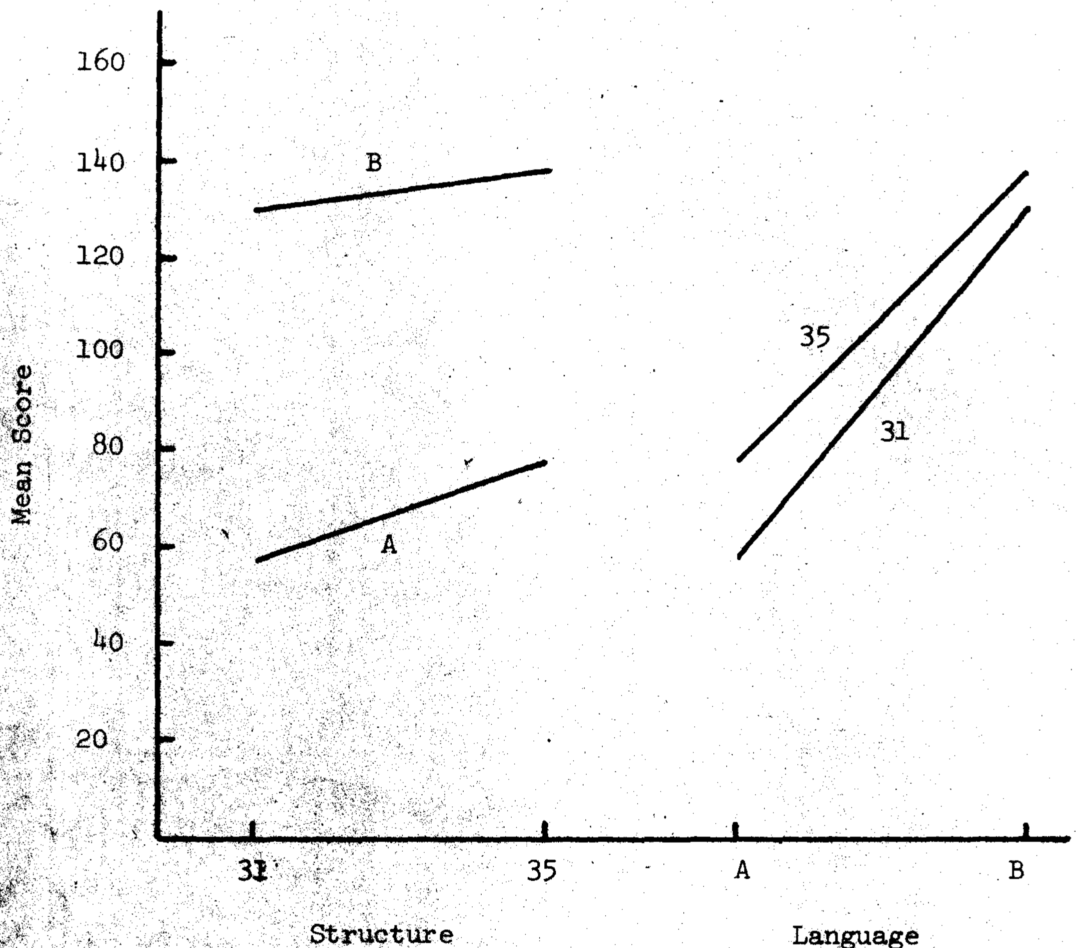

Figure 8. Effect of structure and language on mean time score for the first question period.

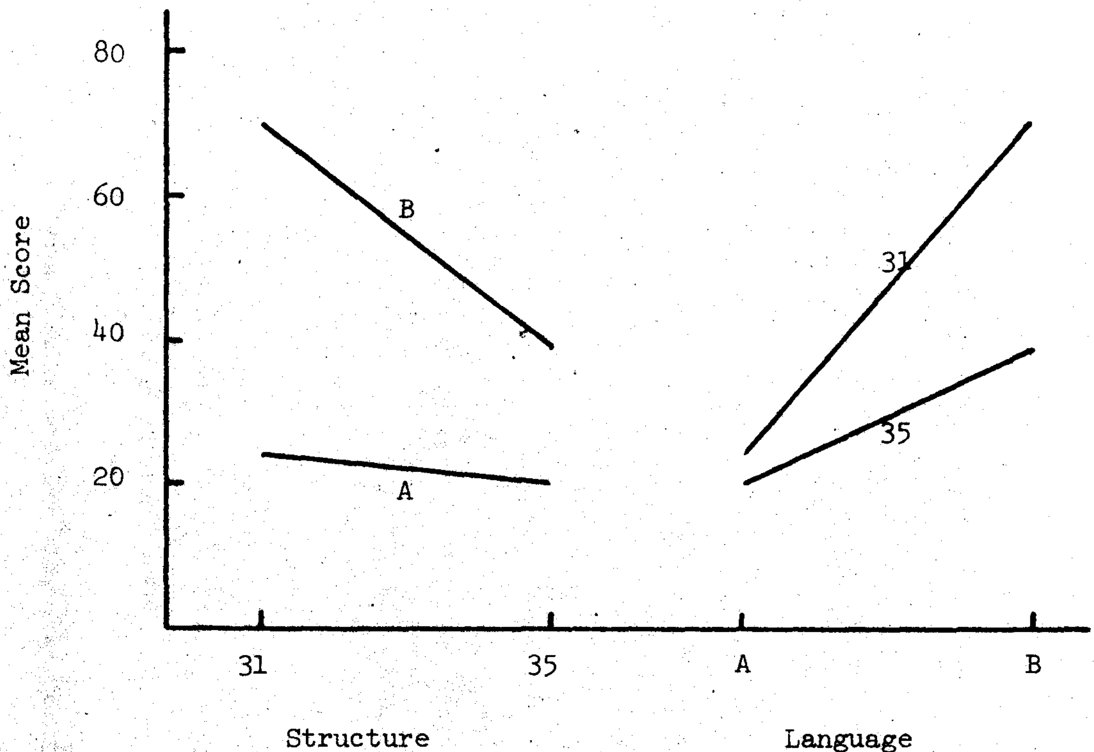

Figure 9. Effect of structure and language on mean time score for the answer period.

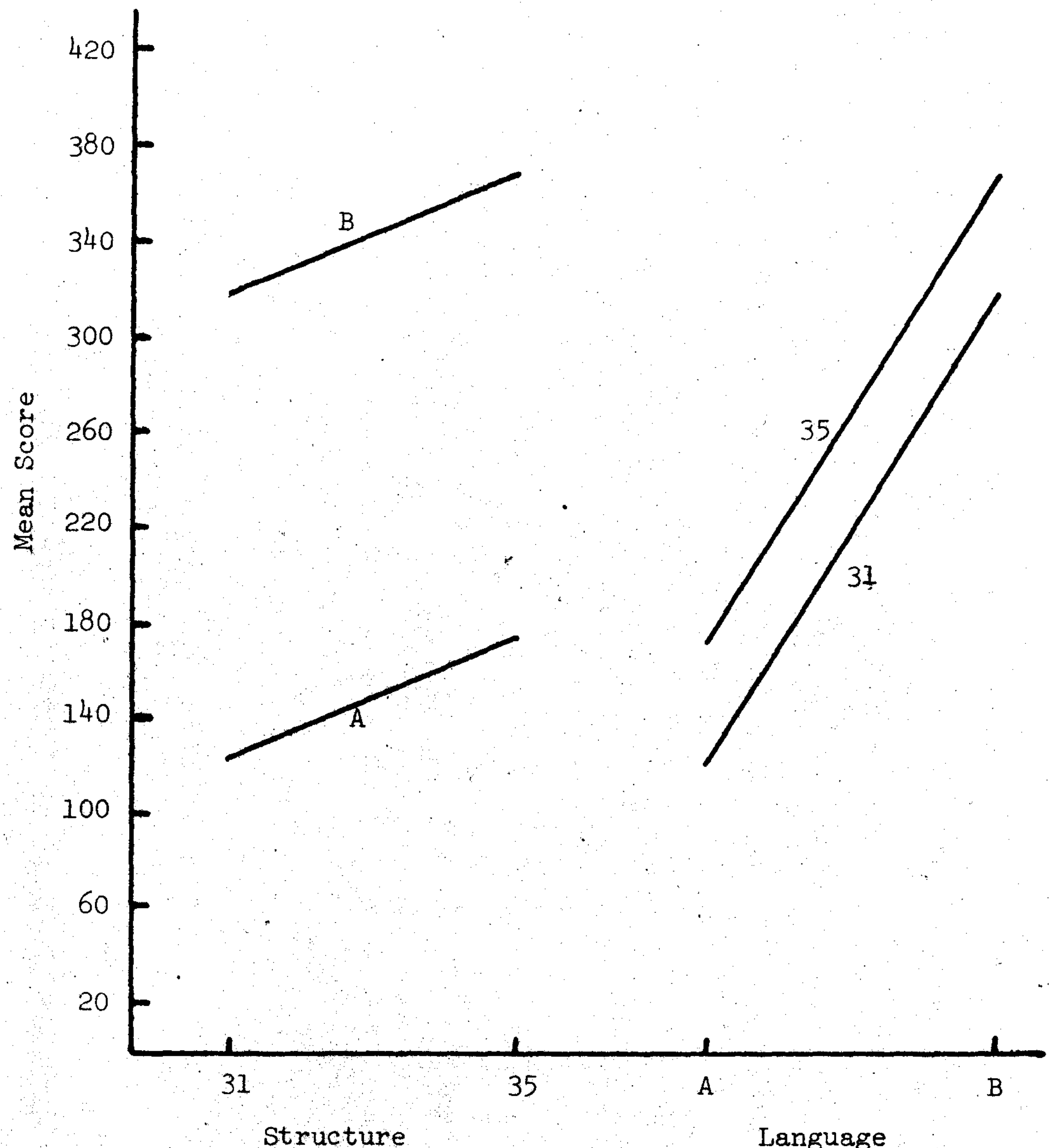

Figure 10. Effect of structure and language on mean total time.

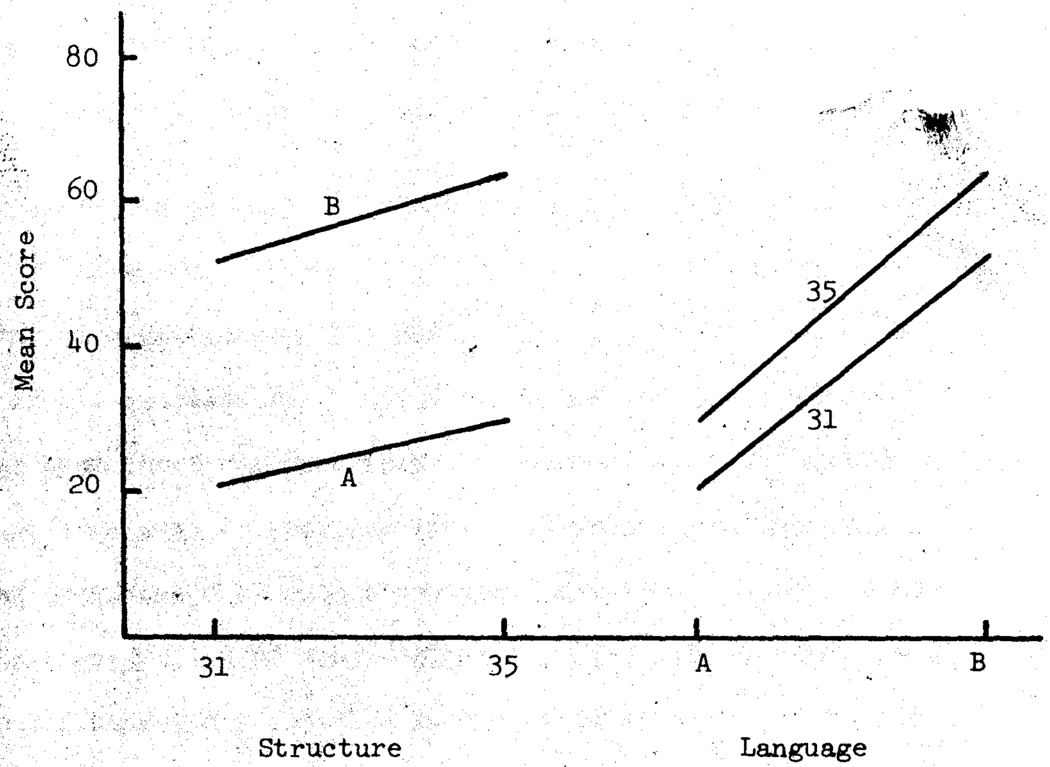

Figure 11. Effect of structure and language on the mean for mean speed scores.

both variables upon answer time, total time and mean speed respectively.

Inspection of the Figures makes apparent the results of the statistical analyses and indicates that the significant effects occurred in the expected direction. The logical frame involving more relationships, structure 35, and the mode of presentation using symbols to stand for objects, language B, go together with an increase in the mean value of all time measures, although the differences relative to language stand out as the most significant.

One exception is readily noticeable, namely, the effect of structure on the length of the answer period. The respective F ratio does not reach even the .10 level of significance ($F = 2.635$, $df = 1, 28$) as shown in Table 19. Inspection of the profiles in Figure 9 indicates that the means for structure 35 are lower than those for structure 31, and that such difference is more pronounced at the level of problems presented in abstract language. Since there was no significant structure-by-language interaction in any case, and the order of presentation of the problems was 31A, 31B, 42, 35A and 35B, the results for the answer may possibly be explained in terms of practice effect and/or in terms of the phase of the cognitive process identifiable in the answer period.

In summary, the results of these analyses, as shown in Tables 18 through 21, and Figures 8 through 11, substantiate the hypothesis of effect of difficulty on the first question period, i.e., understanding the problem, and indicate a significant effect of difficulty on total time, mean speed score and time to answer as well.

For the discussion of the hypothesis of consistency of rate of work, the reader is referred to Figure 12. Similar to the approach followed by Rimoldi (1951), we calculated for each subject the mean, standard deviation and coefficient of variation of his mean speed scores throughout the problems. Then, the obtained means were plotted against the respective coefficients of variation. The rationale is that in fast subjects, higher speed tends to go together with a small coefficient of variation, while in slow subjects, mean variation may be high or low. Inspection of Figure 12 shows that this is also the case in the present study. Notice that the lower the mean speed score, the speedier the subject. To determine whether consistency is related to problem solving ability, a rough selection was made of those subjects who had followed at least one ideal tactic, one good tactic without irrelevant questions and at most, one good tactic with up to two irrelevant questions. It was assumed that these subjects represented a group of good problem solvers. Identification of the 12 subjects showed that they were not necessarily the most consistent subjects in the whole sample. Although some indication of consistency was found, the findings suggest that consistency does not bear a one to one relationship with problem solving ability.

As previously indicated, the study of the relationship between rate of cognitive work as measured by the mean speed score, i.e., the mean of the interquestion periods, and the tempo variables was preceded by a factor analysis of the correlation matrix between the tempo tests. Thurstone's (1947) centroid method of factoring was used. The orthogonal solution was then rotated obliquely using hand graphical rotations, until the criterion of simple structure was met. The correlation matrix and the unrotated centroid

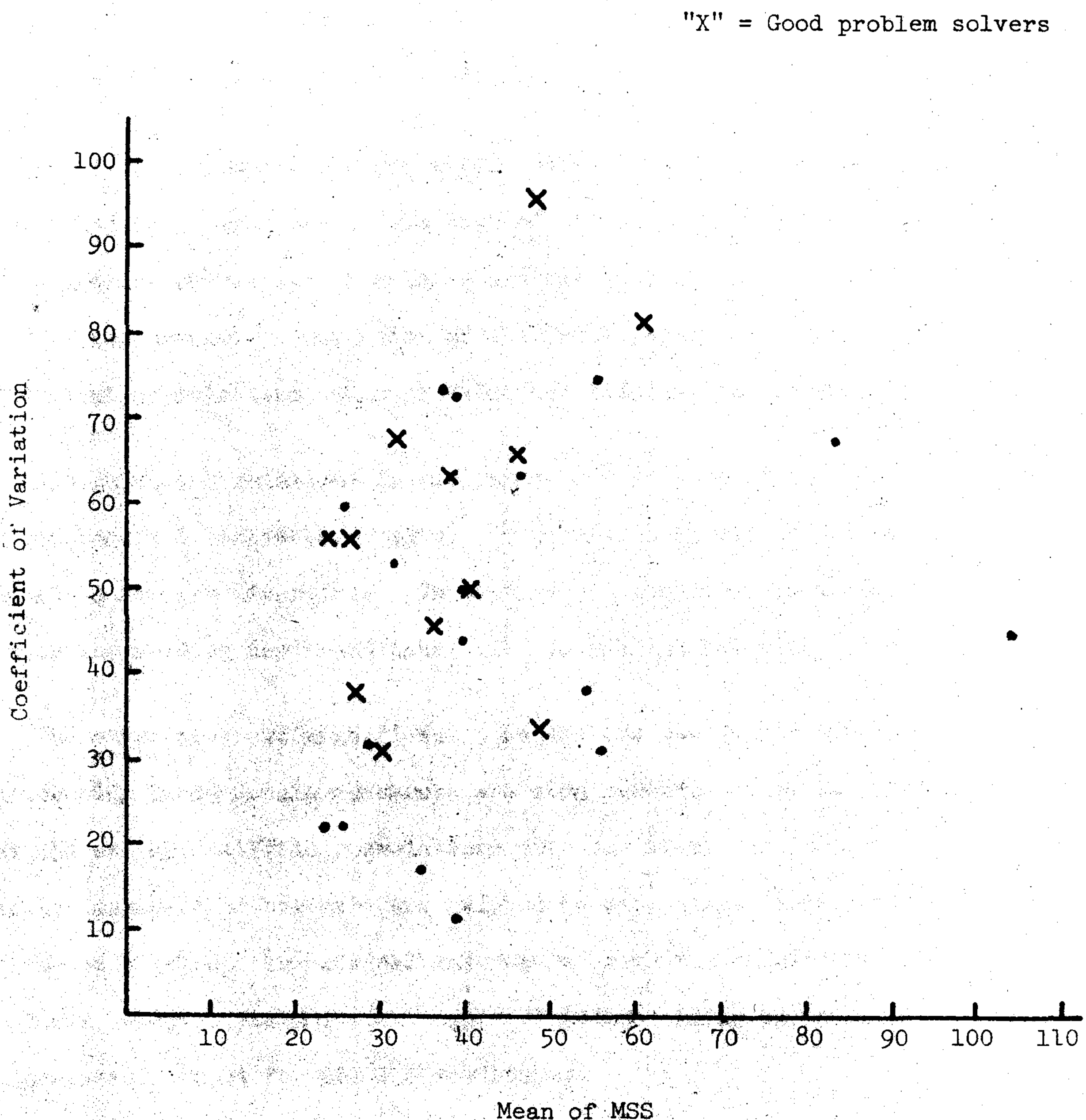

Figure 12. Relationship between the mean and coefficient of variation of the mean speed scores on five problems for each subject.

factor solution are presented in the Appendix as well as the final rotated oblique solution, the matrix of transformation and the matrix of cosines of the reference vectors. As expected, the three factors were recovered and once more the high reliability of tempo measurements became apparent.

Table 27 presents the correlations between the four time measures on each problem and the tempo tests. The sign of all the correlations is an artifact of the scoring procedure: the lower the value of a time score, the higher the speed of performance. Inspection of the Table indicates that there are several significant correlations, some of which are difficult to interpret.

A significant relationship was found between some of the time measures in the problems and the reading tests. In problem 31A, mean speed score was related to Reading Literature. In problem 35B the first question was related to both the reading tests and total time to reading literature only.

The other group of significant correlations was found between the tests representing large muscle movements and some measures of mental speed in problems 35A and 42. All the correlations were negative. In the two problems parallel movement of the arms was related to mean speed score and total time. In problem 42 alone, symmetrical movement of arms was related to total time and the first question period, i.e., speed in understanding the problem. No explanation is found for these correlations.

There was no significant association between measures of mental speed and the tests representing the drawing factor in any of the problems.

TABLE 27

CORRELATIONS OF MEAN SPEED SCORE (MSS), FIRST QUESTION (Q.1),

TOTAL TIME (TT) AND ANSWER (A) IN EACH PROBLEM,

WITH TEMPO TESTS (1, 2, 3, 4, 5, 6), PROBLEM SOLVING SCORE, (PSS)

AND CORRECT ANSWER (CA)

		1	2	3	4	5	6	PSS	CA
31A	MSS	11	12	-29	-39*	22	22	-24	00
	Q.1	-17	-15	-11	-30	01	04	-02	-17
	TT	10	14	-18	-27	20	26	-47**	01
	A	25	25	-04	05	19	23	-44*	03
31B	MSS	28	38	19	20	27	21	-03	06
	Q.1	-16	-08	-14	-08	10	-03	12	-01
	TT	03	13	17	08	17	21	-12	00
	A	-01	23	05	01	20	15	-15	-20
35A	MSS	46*	23	-14	-04	20	16	-52**	-13
	Q.1	01	03	-01	-08	-14	25	-13	17
	TT	41*	21	-23	-06	06	24	-70**	09
	A	33	23	-31	-06	13	15	-68**	-03
35B	MSS	13	21	-15	-22	05	14	-15	-02
	Q.1	04	-14	-38*	-47**	-11	04	05	28
	TT	11	05	-30	-37*	-06	12	-19	-06
	A	18	07	-21	-14	-35	13	-14	-43*
42	MSS	37*	32	02	04	11	25	34	30
	Q.1	21	-02	-33	-29	-24	15	15	-09
	TT	44*	49**	-13	01	32	35	-32	35
	A	20	36*	-03	20	29	28	-38*	32

* $p < .05$
** $p < .01$

Note: Decimal points have been ommitted.

Table 27 also presents the point biserial correlations between time measures and correct answer. Correct answer is what many authors refer to as quality of the response or accuracy of solution to the problem. Only one significant correlation is observed, viz., between answer time and correct answer in problem 35B, indicating that correct answers are associated with high speed in the answer period at least in this problem.

Finally, Table 28 presents the relationship between correct answers in the different problems as determined by using the phi coefficient. Problems 31A and 35A are the only ones significantly related in this respect ($p < .001$).

TABLE 28

CORRELATIONS BETWEEN

CORRECT ANSWER IN DIFFERENT PROBLEMS

	31A	31B	35A	35B	42
31A					
31B	32				
35A	66***	34			
35B	17	06	33		
42	31	17	26	24	

*** $p < .001$

Note: Decimal points have been omitted.

CHAPTER V

DISCUSSION

Since a great part of the findings have been discussed already in the previous chapter, this section will deal with the overall integration of the results.

The results of the present study seem to provide evidence in support of the major hypothesis. It was proposed that there is a constant rate at which distinct steps occur in the cognitive process of a subject engaged in the solution of a problem.

Studies bearing on the relationship between speed and intellectual ability have used a variety of measures for rate and altitude. Among others, the work of Bennett (1941) represents a standard approach to the problem. She defined a speed or rate score on the basis of average amount of time spent on items done correctly in a speed test of intelligence. Her altitude measure was the score obtained in the same test when all time limits were removed. The altitude score, as is usually the case, was based on the items solved correctly.

The approach followed in this study was independent of correctness of the final answer. The measure of ability, problem solving score, was based on the dynamic aspect of thinking, the process, rather than on its end product, the final answer.

In the Rimoldi (1967, 1968) technique used in this study, the notion of structure is the core. The subject is given a problem that has a set structure, upon which is superimposed various contents, and the process is recorded directly as he takes each step in his structuring activity.

Accordingly, using Rimoldi's technique for the characterization of problem solving processes, various units of performance were defined, which corresponded to the asking of questions and giving the answer to the problem. A distinction should be made, however, between those units or periods as previously defined. It was assumed that the processes involved in the different periods, although related to one another, were not necessarily the same.

In the first question period, reading and viewing the problem were implied. This involves reading the questions, associating them with the problem, and sorting them as to the relevant or irrelevant information they might provide, and decision on which question to ask first. This last step may include, among efficient problem solvers, decision on the complete tactic to be followed so as to reach the solution of the problem. The first question period would seem to be best characterized by the "relation of likeness"... which "makes possible the extension of conceptual thinking to levels of high complexity" (Rimoldi, 1951).

The following periods, interquestion periods, imply incorporation of the information supplied by the answer to the previous question, assimilation and association of this to previous information, and decision on which questions to ask next. Viewing all the interquestion periods as a whole, i.e., as <u>the</u> question period in the solving process, it would seem that although analysis and synthesis are involved, the process is mainly analytical. Therefore it may be characterized as centered upon discovering relationships and educing correlates in Spearman's sense (1927).

In turn, the answer period seems to be primarily one of grand synthesis of all the information, involving the ability of "bringing the parts together into a meaningful solution" and perceiving the "relations necessary for the construction of a whole." (Rimoldi, 1951) Related to the synthetic, Rimoldi (1951) found a factor of plasticity, interpreted as the capacity of bringing together conflicting Gestalts, and probably related to personality. Plasticity is also present in the "relation of likeness and its opposite", though to a lesser extent.

If the inference from time to process is valid, the results of the analyses of the period means in the various problems indicate that the processes involved therein are different.

The temporal characterization of the periods, when studied in each of the problems, showed that the interquestion periods did not differ among themselves, either considering the total sample, or subgroups of subjects differing in their approach to the problem. The findings support the major hypothesis of this study and suggest that: if it is at the level of processes that are mainly analytical that constancy is found, any appreciation of "cognitive tempo" should be based on the analytical phase of cognitive activity.

Other hypothesis of the study was posited basically to estimate the effect of problem solving ability on the time scores of the experimental periods. On the basis of research findings reported in the literature, it was expected that subjects using a more parsimonious approach would be faster. According to the tactic followed in a specific problem, the subjects were divided into "ideal", "good", and "bad" groups for that problem. The results of the analyses of the data, as summarized in Table 16, substantiated the hypothesis in the predicted direction. It was also found that regardless of difficulty of the problems, the group profiles were similar and could be considered as parallel to each other. Inspection of Figures 3 through 6 indicates that the profile for the different groups follow the same general trend in all the problems. However, the profile for the "ideal" group shows smaller means than the remaining groups for the interquestion times and a sudden decrease in time at the answer period. As regards the first question, the mean for the "ideal" group is higher in problems 31, but lower in problems 35 than the respective mean for the "good" group. This general trend appears consistently throughout the problems. It seems to be pointing to a true difference between time scores at different levels of problem solving ability. The paucity of number of subjects in the "ideal" groups for the two problems with abstract language, 31B and 35B, makes impossible any comparison between "ideal" and "good" groups beyond the concrete language problems.

Further inspection of Table 16 shows that whenever a comparison was made, the over-all significant difference between the "good" and the "poor" group in each problem was mainly due to the difference in the answer period.

Inspection of the correlations in Table 27 may clarify these findings. In problems 31A and 35A, total time to solve the problem and time to give the answer are significantly related to the problem-solving score. A similar relationship is found in problem 35A between mean speed score and problem solving score.

When correct answer to the problem is considered, the only significant correlations relate correct answer to answer time in problem 35B, and correct answer between problems 31A and 35A.

All these findings, as shown by the correlations, would indicate the sensitivity of the answer time to problem-solving ability, at least in problems presented in a concrete language, and in problem 42 where a perceptual factor is in play. In this respect a factorial study (Paiva, 1967) has previously found that problems 31A, 35A, and 42 are heavily loaded in a factor characterized as a low difficulty-perceptual factor.

The hypothesis of effect of difficulty of the problem upon the length of period taken to understand the problem, establishing relations of likeness, was supported by the results. The effect of difficulty of the problem was also studied in relation to the answer period, total time and mean speed score throughout the problems. It was found that complexity of the logical structure of the problem, intrinsic difficulty, affected significantly the length of all but one of the periods, namely the answer period. Degree of abstractness of the language in which the problem is presented, extrinsic difficulty, affects all the variables considered for above expectation: the four F ratio tests were significant beyond the .001 level. The lack of any interaction between language and structure indicates that the differences in time to "understand" the problem, in rate of work, total time, and therefore in the processes therein, and the answer period are due only to parallel or independent effects of both components of difficulty.

The findings support the hypothesis of the effects of difficulty upon time to understand the problem and suggest that while the analytical phase of the process is affected by the complexity of the logical relationships and the language, the phase of synthesis involved in the answer period, is selectively affected only by the language used. Since people vary as to their handling of sets of abstract symbols, ability which is probably related to "plasticity", their performance in problems of the B type is unequally affected. This may partially explain the vanishing of correlations found in the concrete-language problems, when the performance in abstract-language problems is considered. If the reasoning that the question period and its measure, the mean speed score, represent an index of the mental tempo of the subject is correct, then it would be justifiable to say that mental tempo is affected in a selective way by the structure of the problem and its language.

If the assumption regarding the type of processes mainly involved in each experimental period is valid, the results would indicate that the component of the synthetic process, which is affected by difficulty of the problem, is the same that is sensitive to problem solving ability. It is suggested that this component is the analytical activity involved in "the ability of bringing the parts together into a meaningful solution" (Rimoldi, 1951). It is present to a lesser extent in the performance of easy tasks and to a greater extent when the problems become more difficult and complex. As the tasks grow harder, the influence of speed seems to be independent of cognitive ability and the significant relationship found in the low difficulty problems disappears.

Concerning the relationship between tempo variables and speed of mental processes, it would be of interest to perform a factorial study using a greater variety of problems and tempo tests. The negative correlation between some measures of speed in the problems and tests representing large muscle movements are in line with Rimoldi's (1951) findings. This author found a negative correlation of speed of cognition with two factors, namely, speed of large muscle movements and speed of small muscle movements, "indicating a split in speed of performance for motor versus non-motor activities."

CHAPTER VI

SUMMARY

The purpose of this study was to determine whether a relationship exists between tempo and complex cognitive processes involved in problem solving behavior. Thirty female subjects were divided into groups according to their performance on the Rimoldi problems. Measures of time were taken everytime the subject asked a question and when he gave the answer. The results were analyzed and indicated the following:

1) The rate at which the subject asks questions is constant for a given problem, independent of his problem-solving ability and the difficulty of the problem.

2) The first question period, "understanding" or viewing the problem, stands as significantly different from the rest of the periods.

3) For a given problem, the pattern of time performance is similar in all groups of subjects.

4) Subjects using a more parsimonious approach are significantly faster in the answer period.

5) Structure and language of the problem affect significantly the first question period, rate of work and total time.

6) The answer period is affected by language only.

7) There is no interaction between structure and language regarding their effect on the first question period, mean speed, answer period and total time.

8) Only at a low level of difficulty a relationship was found between speed and problem-solving ability. The correlation was significant in:

a) problems presented in every day language, regardless of structure, when speed is measured as a function of total time and time to answer; and

b) in the figure problem, regarding time to answer.

9) There was no significant relationship between any measure of speed and problem solving ability in difficult problems with difficulty defined as a function of language.

10) There were some significant correlations between time measures in the problems and tests representing large muscle movements and reading or perceptual speed.

11) Indication of consistency of speed was found.

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Appendix A

TABLE 22

MATRIX OF CORRELATIONS BETWEEN TEMPO TESTS

	1	2	3	4	5	6
1						
2	65					
3	-06	26				
4	-09	35	69			
5	24	33	08	18		
6	13	23	02	43	39	

TABLE 23

CENTROID FACTORIAL MATRIX

	Factor		
Variable	I	II	III
1	45	57	41
2	76	25	34
3	50	-65	17
4	70	-55	-17
5	47	25	-22
6	50	13	-54

Note: Decimal points have been omitted.

TABLE 24

ROTATED FACTORIAL MATRIX

Variable	Factor A	Factor B	Factor C
1	78	-22	-22
2	73	19	05
3	07	83	-18
4	-05	77	22
5	17	-04	44
6	-12	02	69

TABLE 25

FINAL TRANSFORMATION MATRIX

	A	B	C
I	47	46	35
II	45	-87	32
III	76	18	-88

TABLE 26

MATRIX OF COSINES OF REFERENCE VECTORS

	A	B	C
A	1.00		
B	-04	1.00	
C	-36	-28	1.00

Note: Decimal points have been omitted except in diagonals of Table 26.

Appendix C

Problem 31 A

John has 20 horses. There are black rabe horses and white race horses. There are black farm horses and white farm horses. I want you to figure out how many black farm horses there are?

Questions	Answers
1. How many horses does John ride?	1. 10
2. How many white horses does John have?	2. 7
3. How many brown horses does John have?	3. 0
4. How many white racing horses does John have?	4. 5
5. How many black racing horses does John have?	5. 5
6. How many brown racing horses does John have?	6. 0
7. How many white farm horses does John have?	7. 2
8. How many brown farm horses does John have?	8. 0
9. How many horses did John sell?	9. 0
10. How many ponies does John have?	10. 0

Ideal tactic: 2-5

Solution: 8

Appendix D

Problema 31 A

José´tiene 20 caballos. Hay caballos blancos de carrera y caballos negros de carrera. Hay caballos blancos de tiro y caballos negros de tiro. Cuántos caballos negros de tiro tie ne José?

Preguntas	Respuestas
1. Cuántos caballos cabalga José?	1. 10
2. Cuántos caballos blancos tiene José?	2. 7
3. Cuántos caballos marrones tiene José?=	3. 0
4. Cuántos caballos blancos de carrera tiene José?	4. 5
5. Cuántos caballos negros de carrera tiene José?	5. 5
6. Cuántos caballos marrones de carrera tiene José?	6. 0
7. Cuántos caballos blancos de tiro tiene José?	7. 2
8. Cuántos caballos marrones de tiro tiene José?	8. 0
9. Cuántos caballos vendió José?	9. 0
10. Cuántos caballos percherones tiene José?	10. 0

Appendix E

Problem 31 B

We have 50 objects called C. There are two kinds of C's. One kind is called B; the other kind is called G. Any B can be an R or a T, and any G can be an R or a T. No B can be a G, and no R can be a T. Will you find out how many of the G objects are also called T?

Questions	Answers
1. How many K's are there?	1. 11
2. How many R objects are also called G?	2. 15
3. How many T objects are also called B?	3. 10
4. How many N objects are there?	4. 10
5. How much is K times C?	5. 550
6. Are there more G than B objects?	6. No
7. How many R objects are there?	7. 35
8. Are there more R objects than T objects?	8. Yes
9. Are there any objects called M?	9. No
10. How many R objects are also called B?	10. 20

Ideal Tactic: 7-3
Solution: 5

Appendix F

Problema 31 B

Tenemos 50 objetos llamados C. Hay dos clases de C: una de las clases se llama B y la otra clase se llama G. Cualquier B puede ser R o T y cualquier G puede ser R o T. Ninguna B puede ser G y ninguna R puede ser T. Cuántos objetos G son también T?

Preguntas	Respuestas
1. Cuántas K hay?	1. 11
2. Cuántos objetos R son También G?	2. 15
3. Cuántos objetos T son también B?	3. 10
4. Cuántos objetos N hay?	4. 10
5. Cuánto es K multiplicado por C?	5. 550
6. Hay más objetos G que objetos B?	6. No
7. Cuántos objetos R hay?	7. 35
8. Hay más objetos R que objetos T?	8. Sí
9. Hay objetos llamados M?	9. No
10. Cuántos objetos R son también B?	10. 20

Appendix G

Problem 35 A

Joe and his two friends Peter and Mark went to the store to buy some marbles. Each one of them bought some green ones, some red ones, and some blue ones. Altogether they bought 45 marbles. How many blue marbles did Mark buy?

Questions	Answers
1. How many green marbles did the three of them buy?	1. 15
2. How many red marbles and green marbles did Peter buy?	2. 10
3. Did they use the marbles right away?	3. Yes
4. How many green marbles did Mark buy?	4. 5
5. How many red marbles did Peter buy?	5. 5
6. Did Peter buy more marbles than Joe?	6. No
7. Are the red marbles larger than the green ones?	7. No
8. How many blue marbles did Joe and Peter buy?	8. 10
9. Did they buy anything else besides marbles?	9. No
10. How many red marbles did the three of them buy?	10. 15

Ideal Tactics: 1-10-8 and 10-1-8
Solution: 5

Appendix H

Problema 35 A

Juan, Pedro y Santiago fueron a comprar bolitas. Cada uno de ellos compró algunas verdes, otras rojas y otras azules. Los tres Juntos compraron 45 bolitas. Cuántas bolitas azules compró Santiago?

Preguntas	Respuestas
1. Cuántas bolitas verdes compraron los tres Juntos?	1. 15
2. Cuántas bolitas rojas y bolitas verdes compró Pedro en total?	2. 10
3. Cuántas bolitas amarillas compró Juan?	3. 0
4. Cuántas bolitas verdes compró Santiago?	4. 5
5. Cuántas bolitas rojas compró Pedro?	5. 5
6. Compró Pedro más bolitas que Juan?	6. No
7. Son las bolitas rojas más grandes que las verdes?	7. No
8. Cuántas bolitas azules compraron Juan y Pedro?	8. 10
9. Qué compraron a más de las bolitas?	9. Nada más
10. Cuántas bolitas rojas compraron los tres Juntos?	10. 15

Appensix I

Problem 35 B

We have three kinds of T objects. One kind is called M, another kind is called N, and another kind is called P. Further, each M, N, or P can also be called either a Q, an R, or an S. Altogether there are fifty objects. How many of the N objects are also called S?

Questions	Answers
1. How many Q objects and R objects are called P?	1. 15
2. How many M objects and P objects are also called S?	2. 5
3. Are there more Q objects than S objects?	3. Yes
4. How many N objects are called Q?	4. 5
5. How many objects are called Q?	5. 25
6. How many M objects are called A?	6. 0
7. How many objects are called R?	7. 15
8. Are there more P objects than R objects?	8. Yes
9. How many objects are called K?	9. 0
10. How many P objects are also called R?	10. 5

Ideal Tactics: 1-10-8 and 10-1-8

Solution: 5

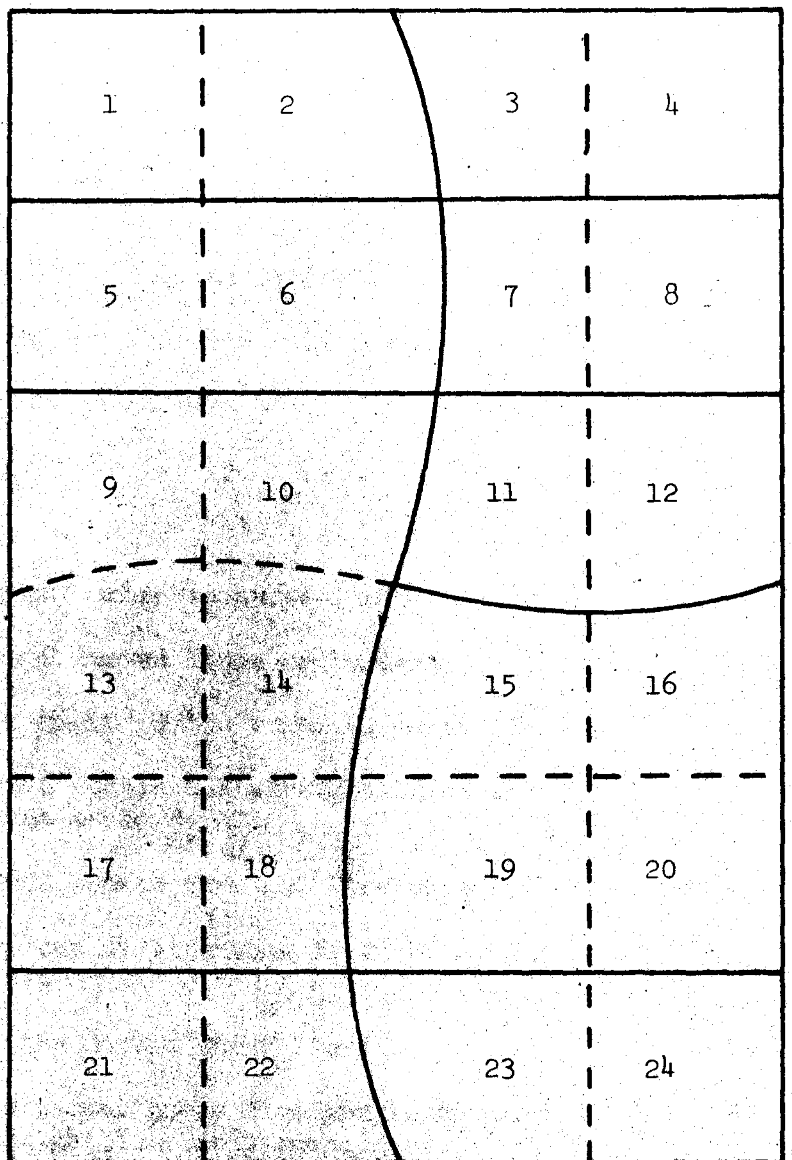
Appendix J

Problema 35 B

Hay tres clases de objetos T. Una de las clases se llama M, otra clase se llama N, y otra clase se llama P. Cada M, N, o P puede ser una Q, una R, o una S. Hay 50 objetos en total. Cuántos objetos N son también S?

Preguntas	Respuestas
1. Cuántos objetos Q y objetos R son P?	1. 15
2. Cuántos objetos M y objetos P son S?	2. 5
3. Hay más objetos Q que objetos S?	3. Sí
4. Cuántos objetos N son Q?	4. 5
5. Cuántos objetos son Q?	5. 25
6. Cuántos objetos M son A?	6. 0
7. Cuántos objetos son R?	7. 15
8. Hay más objetos P que objetos R?	8. Sí
9. Cuántos objetos son K?	9. 0
10. Cuántos objetos P son R?	10. 5

Appendix K



Problem 42

Appendix L

Problem 42

This figure is composed of 24 areas. The numbers in the areas are merely for the purpose of identifying a particular area and have no bearing on the solutions of the problem whatsoever.

One of the areas has been selected. Your task is to discover the selected area. You may discover this area by using any of the questions you like to arrive at the answer.

Questions	Answer
1. Is it above the unbroken curve line?	1. No
2. Does it have 2 curved lines or borders?	2. No
3. Is it to the right of the vertical curve line?	3. Yes
4. Does it have 2 continuous straight lines and 2 broken lines as borders?	4. No
5. Does it have 2 broken straight line borders?	5. No
6. Does it have any combinations of 2 broken and 2 curved sides?	6. No
7. Is it below the dotted curve line?	7. No
8. Does it have 3 continuous straight lines and 1 broken straight line as borders?	8. No
9. Does it have a broken curved line as a border?	9. No
10. Does it have at least 1 continuous straight line and 2 continuous curved lines as borders?	10. No

Ideal Tactic: 3-1-5-8
Solution: 23

Appendix M

Problema 42

La figura está compuesta de 24 áreas. Los números en las áreas sólo se utilizan para identificar las mismas y no tienen conexión con la solución del problema. Se ha seleccionado una de las áreas. Su tarea consiste en descubrir cuál es el área selecionada, em pleando las preguntas que Ud. Desee para arrivar a la solución.

Preguntas	Respuestas
1. Está arriba de la línea curva continua?	1. No
2. Tiene de bordes 2 líneas curvas?	2. No
3. Está a la derecha de la línea curva vertical?	3. Sí
4. Tiene de bordes 2 líneas rectas continuas y 2 líneas punteadas?	4. No
5. Tiene 2 bordes rectos punteados?	5. No
6. Tiene alguna combinación de 2 bordes punteados y 2 bordes curvos?	6. No
7. Está debajo de la línea curva punteada?	7. No
8. Tiene de bordes 3 líneas rectas continuas y una línea recta punteada?	8. No
9. Tiene un borde curvo punteado?	9. No
10. Tiene al menos un borde recto continuo y 2 bordes curvos continuos?	10. No

APPROVAL SHEET

The dissertation submitted by Rosalia E. Paiva has been read and approved by 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.

Feb 6, 1969
Date

Signature of Adviser