

70-15,464

PRICE, Alan Dale, 1939-

CREATIVE THINKING, PROBLEM SOLVING, AND HEART
RATE VARIABILITY: A PSYCHOPHYSIOLOGICAL APPROACH
TO THE STUDY OF COGNITIVE PROCESSES.

The City University of New York, Ph.D., 1970
Psychology, general

University Microfilms, A XEROX Company, Ann Arbor, Michigan

CREATIVE THINKING, PROBLEM SOLVING, AND HEART RATE
VARIABILITY: A PSYCHOPHYSIOLOGICAL APPROACH
TO THE STUDY OF COGNITIVE PROCESSES

by

ALAN DALE PRICE

A dissertation submitted to the
Graduate Faculty in Psychology in partial
fulfillment of the requirements for the
degree of Doctor of Philosophy,
The City University of New York.

1969

This manuscript has been read and accepted for the
Graduate Faculty in Psychology in satisfaction of
the dissertation requirement for the degree of
Doctor of Philosophy.

Dec. 5, 1969
date

Gertrude R. Schmeidler
Chairman of Examining Committee

12/10/69
date

Walter Weiss
Executive Officer

Gertrude R. Schmeidler

William F. Oakes

Leo V. Dicara

Louis S. Dickstein

Supervisory Committee

ACKNOWLEDGEMENT

The author wishes to acknowledge the courtesy of The Psychological Corporation in making available the unpublished Test of Productive Thinking for use in this research.

TABLE OF CONTENTS

I.	INTRODUCTION	1
	Psychological Approaches to the Study of Cognitive Processes (1)--Psychophysiological Approaches to the Study of Cognitive Processes (6)--A Model of Thinking (11)	
II.	PROBLEM	15
	Research Objectives (15)--Instructional Set (15)--Creativity Test (17)--Multiplication Test (19)--Heart Rate Variability (19)--Hypotheses (23)	
III.	METHOD	25
	Design (25)--Subjects (25)--Apparatus (25)--Materials (26)--Procedure (26)	
IV.	TREATMENT OF DATA	31
	Scoring of Modified Bennett Test and Multiplication Problems (31)--Scoring of Physiological Data (36)--Preparation of Data for Analysis (37)	
V.	RESULTS	39
	Intersession Correlations Between Heart Rate Variability Measures (39)--Intersession Reliability of Multiplication Scores (40)--Intercorrelations Among Criterion Scales of Creativity (40)--Testing of Hypotheses (42)--Supplementary Analyses (45)	
VI.	DISCUSSION	50
	Interpretation of Results (50)--Suggestions for Future Research (60)--Concluding Remarks (66)	
	APPENDICES	68
A.	ROLE-INDUCING INSTRUCTIONS	68
B.	MODIFIED BENNETT TEST ITEMS	70
C.	MULTIPLICATION PROBLEMS, SCORING OF PERFORMANCE AND RELATED INSTRUCTIONS	71
D.	INSTRUCTIONS TO SCORERS OF PHYSIOLOGICAL DATA	74
E.	ADDITIONAL TABLES	76

REFERENCES	83
AUTOBIOGRAPHICAL STATEMENT	86

LIST OF TABLES

Table	Page
1. Order of Presentation of Role-Inducing Instructions and MBT Items	28
2. Frequencies of Response Categories Contained Within Novelty Categories for MBT Items (Normative and Dissertation Samples)	34
3. Interrater Reliability of MBT Scoring	36
4. Intercorrelations Among Criterion Creativity Scales for the Unregulated Condition (Spearman Rank Coefficients)	41
5. Intercorrelations Among Criterion Creativity Scales for the Regulated Condition (Spearman Rank Coefficients)	41
6. Correlations of Scores on Criterion and Overall Creativity Scales and Number of Responses with Measures of Heart Rate Variability for the Unregulated Condition	47
7. Correlations of Scores on Criterion and Overall Creativity Scales and Number of Responses with Measures of Heart Rate Variability for the Regulated Condition	47
8. Correlations of Multiplication Scores with Measures of Heart Rate Variability by Day and Difficulty Level	48
9. Split-Half Reliabilities (Odd-Even) Responses for Criterion Creativity Scales: Coefficients Derived from the Spearman-Brown Formula Using Spearman Rank Correlations as Estimates of Product-Moment Correlations	53
10. Distribution of Novelty Scores for Inappropriate or Trivial Responses by Condition	55
11. Percentage of MBT Responses in Creativity Categories for Regulated and Unregulated Conditions	56
12. Frequency of MBT Responses by Subject, Creativity Condition, and Creativity Category	76
13. Tabulation of Data for Day 1 by Subject and Condition . . .	77
14. Tabulation of Data for Day 2 by Subject and Condition . . .	79

Table	Page
15. Additional HR_v Data for Day 1 by Subject and Condition . . .	81
16. Additional HR_v Data for Day 2 by Subject and Condition . . .	82

LIST OF ILLUSTRATIONS

Figure	Page
1. Comparison of Two Patterns of Heart Rate Variability in Terms of Several Different Measures	21
2. Combination of Response Category Frequencies for MBT Items to Form Novelty Categories (Normative and Dissertation Samples)	33

I. INTRODUCTION

Psychological Approaches to the Study of Cognitive Processes

In recent years a number of individuals have argued convincingly that new concepts are needed to encompass the full range of human intellectual capability. In particular, those abilities or intellectual processes which distinguish the creative individual from his equally intelligent but uncreative peers have not been treated in most conceptualizations of human intellect.

The "structure of intellect" model proposed by Guilford (1965) posits five classes of intellectual operations--cognition, memory, divergent production, convergent production, and evaluation. Associated with these operations are four categories of informational content--figural, symbolic, semantic, and behavioral--as well as six categories of possible intellectual products--units, classes, relations, systems, transformations, and implications. The operation, content, and product dimensions are arranged in a cubical structure consisting of 120 cells, which presumably correspond to separate intellectual abilities.

Guilford (1962) points out that intelligence tests commonly emphasize the operations of cognition, memory, and convergent production, while ignoring divergent production and slighting evaluation. The abilities in the divergent production category, however, are regarded by Guilford as the most direct contributors to creativity. They provide the individual with the capacity for generating a wide variety of diverse

ideas or trains of thought in a situation where there exists no single correct answer, i.e., the capacity for producing multiple responses encompassing a variety of possibilities inherent in a stimulus situation. In contrast, the convergent production abilities are appropriate whenever there exists a single correct solution to a problem, necessitating a convergence of thinking in a particular direction.

Guilford also points out that intelligence tests greatly emphasize semantic content, give little attention to the product category of classes, and devote absolutely no attention whatsoever to the product categories of transformations and implications. The intellectual abilities associated with the transformations category are also regarded as important contributors to creativity.

Others like Kris (1950), Rapaport (1951), Schafer (1958), and Holt & Havel (1960) have suggested that the roots of the inventive, germinal, or inspirational phase of creative thinking lie in the capacity for assimilating and integrating primary process modes of thinking into secondary process thinking. According to Holt & Havel (1960), primary process thinking can be recognized by its preoccupation with libidinal and aggressive urges and by the presence of certain peculiar formal characteristics such as autistic logic and loose, nonsensical types of associative links. Time considerations are disregarded and logical contradictions abound. "When the primary process holds sway, ideas shift about, lose their identities through fusion or fragmentation, become concrete and pictorial, and are combined and associated in seemingly arbitrary or trivial ways. The course of thinking and remembering is dictated by the instinctual drives, while realistic considerations and the distinction between wish and reality is lost." In contrast, secondary

process thinking is characterized by its rationality, logic, and concern for realistic considerations.¹ According to Brenner (1957), secondary process thinking appears later in life than does primary process thinking, and evolves gradually as one aspect of ego development. It is ordinary, conscious thinking, following the usual laws of syntax and logic, and is adaptive to the demands and constraints of the external world.² Kris's (1952) concept of "regression in the service of the ego" proposed that the ego of a mature and healthy person can at times temporarily abandon the logical, rational and realistic standards of secondary process thinking and make creative and productive use of the freedom and fluidity of the primary process.

In general, there is considerable agreement among many theorists and researchers in the creativity field that the intellectual functions mediating creative thinking are different from or involve processes not used in the rational, logical, deductive kind of thinking so heavily emphasized by most intelligence and aptitude testing methods. However, Taylor (1960) has suggested that " . . . the question of what processes are involved in creative thinking and the question of whether these are the same as or different from the processes involved in such thinking as problem solving and decision making are questions to be solved not by definition, but by empirical investigation."

¹Holt & Havel base their discussion on Sigmund Freud's concepts elaborated in Chapter 7 of The Interpretation of Dreams (New York: Basic Books, 1955).

²Brenner also draws upon Freud's writings (See Sigmund Freud, Formulations regarding the two principles in mental functioning, trans. by M. N. Searl, Collected Papers [London: Hogarth Press, 1925], IV, 13-21).

There is some evidence of an indirect nature which supports the validity of such a distinction. Getzels & Jackson (1962) reported that the fantasy productions of "high creative" adolescents (those scoring in the upper 20% on a creativity test battery but not in the upper 20% in IQ) manifested more stimulus-free themes, unexpected endings, humor, incongruities, playfulness, and violence than those of the "high IQ" students (those scoring in the top 20% in IQ but not in the top 20% on the creativity battery).³

Pine & Holt (1960) found that quality scores on seven tests of imagination were related to measures of effectiveness of control and integration in the expression of primary process content on the Rorschach. In addition, Pine (1963) found that the quality of literary production (assessed in part on the basis of originality) was related to the expression, control, and integration of drive material within the production.

Utilizing the Holt & Havel (1960) concept of "adaptive regression," Wild (1965) found that a "creative group" (art students) gave significantly more adaptive original responses to an object sorting test, scored for pathology, drive, humor, response tone, and unusual property,

³It is possible that the differences between the two groups were related to differences in intelligence since Getzels & Jackson, unfortunately, did not report on two groups matched in IQ. The inference is that the high creative group produced stories differing in content from those of the high IQ group because they were intellectually inferior to the latter group. However, by the criterion of school achievement, it would seem that the high creative group was not intellectually inferior to the high IQ group since the two groups did not differ significantly in terms of overall achievement. It is, of course, also possible that the high IQ students were "underachieving"; However, it was reported that the high IQ students were liked significantly better by their teachers and were considered to be more ambitious and studious than the high creative students.

than did a group of teachers or a group of schizophrenics. Adaptive original responses were defined as either original responses without pathology or original responses exhibiting pathology, but also manifesting an adaptive feature such as humor, unusual property, or pleasant tone.

In addition, individuals judged to be highly creative on the basis of ratings by either peers, teachers, or psychologists have been found to score higher on tasks which measure the capacity for divergent thinking. Such individuals are more fluent, produce more original responses, and are much more flexible in their thinking than their less creative counterparts (Barron, 1965; Torrance, 1962).

These data are consistent with the notion that certain intellectual processes not present in the more rational, deductive, or convergent kinds of thinking are required for creative thinking. The operation of such processes, however, is considered to be necessary but not sufficient for creativeness. While identifying certain intellectual abilities as the most direct contributors to creativity, Guilford (1965) has pointed out that almost any intellectual ability may be involved in the total creative act. In a similar fashion, Maslow (1959) has written that the great works of art, philosophy, or science seem to result from an integration of a spontaneous, fanciful, receptive, uncritical phase of thinking, which provides the inspiration for the work, with a more deliberate, rigorous, critical, reality testing phase, which ensures that the product will be appropriate to its context and communicable to other individuals.

Psychophysiological Approaches to the Study of Cognitive Processes

Recent psychophysiological research provides some suggestions as to how more direct evidence of the hypothesized qualitative difference between creative thinking and other kinds of thinking might be obtained. Kagan & Rosman (1964) reported that heart rate variability in children was significantly lower during attention episodes (looking at a color wheel, listening to the tapping of a stick) than during rest periods. The measure of heart rate variability used was the interquartile range of trough to peak changes in interbeat heart rate; the criteria for defining peaks and troughs, however, were not reported. Related to this are some unpublished data from the laboratory of Singer and Antrobus at the City College. Subjects engaged in a tone detection task (simple decision making) evinced lower heart rate variability during tone periods than during rest periods. The measure used in this case was the mean difference between maximum and minimum interbeat heart rates within successive five second intervals.

Mandler & Mandler (1962) recorded heart rate while subjects were giving single word associations to nonsense syllables, adjectives, magazine photographs, and Rorschach blots. They reported a significant correlation of -0.37 ($p < .05$) between the largest continuous rise in heart rate occurring during the responses to the twenty stimuli (five of each kind) and the percentage of idiosyncratic associative responses given during this ten minute period. Idiosyncratic responses were defined as responses to a particular stimulus given by one and only one subject.

Obrist (1963) measured heart rate variability during several conditions. Two of these were periods requiring attention to environmental

stimulation (viewing colored landscape slides presented every fifteen seconds and listening to a semihumorous essay). Another condition involved finding hidden faces of people in a black and white drawing, while a fourth condition involved solving mental arithmetic problems. Heart rate variability was measured by calculating the mean peak to trough differences in heart rate. A peak was defined as the shortest interbeat interval between troughs that was at least .03 sec. shorter than the preceding trough. A trough was defined as the longest interbeat interval between peaks that was at least .03 sec. longer than the preceding peak. In terms of this measure heart rate variability was found to be significantly lower during each condition than during the preceding rest periods.

Hare (1968) found that in a group of inmates from a maximum security prison, "nonpsychopaths" manifested lower heart rate variability during an arithmetic period than during a resting period. However, he also found that "psychopaths" exhibited lower heart rate variability during the resting period than during the arithmetic period. Heart rate variability was measured by the standard deviation of the interbeat heart rates during each period. Since Hare did not report any data relative to the performance of each of the two groups, the differences are difficult to interpret.

These data suggest that the processing of information which requires a substantial degree of concentration or focused attention to proceed efficiently may be associated with cortical or central stabilization of the heart rate, i.e., damping of the heart rate variability. From such a conceptualization one can reasonably infer that diffuse, free-floating, or rapidly shifting attention to many different ideas or trains of thought might be associated with a different heart rate varia-

bility pattern from that associated with the state of focused attention to a sensory stimulus or the state of concentration involved in carrying out a complex central activity like decision making or problem solving. It is this diffuse, fluid kind of attention, associated with thinking dominated by the primary process, which has been hypothesized to be involved in the generation of creative ideas.

What pattern might be expected to be associated with the diffuse attention accompanying primary process thinking? Unfortunately, there are very few data to draw upon to formulate an hypothesis. However, it may be possible to glean something of value from what few do exist. It is known (Dement, 1965) that the rapid eye movement (REM) phase of the sleep cycle is associated with large fluctuations in heart rate. In addition, some writers have maintained that the dream mentation concomitant with this period reflects, more than that accompanying any other phase of sleep, the influence of primary process thinking with its characteristic diffuseness in attention.

In a study of problem-solving and cardiac activity Blatt (1961) found that efficient problem solvers manifested significantly higher heart rate variability during problem solving periods than did inefficient problem solvers.⁴ There were, however, no significant differences between the groups during rest periods. Heart rate variability was measured by the standard deviation of the mean heart rates computed from thirty second intervals. In earlier research Blatt & Stein (1959) found that effi-

⁴Problems were presented on the John-Rimoldi Problem Solving Apparatus. This device requires subjects to request information which may be used in solving a given problem. For a description of the apparatus see E. R. John. Contributions to the study of the problem solving process. Psychol. Monogr., 1957, 71, No. 18 (Whole No. 447).

cient performance in the particular type of problem solving situation utilized in Blatt's (1961) study was positively correlated with a preference for esthetic values on the Allport-Vernon-Lindzey Scale of Values. This is a preference which has also been found to be related to high creativeness in other studies (Taylor, 1960). Blatt (1961) also reported that the spontaneous comments of inefficient problem solvers seemed to reflect a need to master, control, or impose their own preconceived structure on the problem, rather than a capacity for following the leads that emerged from the problem situation. On the other hand, the spontaneous comments of efficient problem solvers seemed to reflect a capacity for attending to and appreciating the nuances or subtleties of the problem, and also a capacity for "playful exploration." In general, efficient subjects reported more "feelings of discovery" and elation upon solution of a problem than did inefficient subjects. Such differences seem to be quite similar to the differences reported by Getzels & Jackson (1962) which differentiated "high creative" and "high IQ" students.

Along somewhat different lines, but still related to the question posed above, it is of interest to note that in the Kagan & Rosman (1964) study mentioned above, it was also found that mental elaboration episodes (silently making up stories, silently associating a picture to a phrase) manifested higher heart rate variability than did the attention episodes. However, this variability was still lower than the variability associated with rest periods.

Another course which recent psychophysiological research has followed suggests the interesting idea that individuals differing in terms of cognitive organization may also differ in terms of resting

heart rate variability. Lacey & Lacey (1958) have reported that variability in resting heart rate is a stable measure, reliable upon forty-eight hour retest, which is characteristic of the individual. Heart rate variability was measured by tabulating the maximum interbeat heart rate in each five second interval and then counting the number of half-minute intervals in which "cardiac bursts" occurred. A cardiac burst was defined as an increase of at least six beats per minute between maximum heart rates in successive five second intervals. Wilson & Dykman (1960) have confirmed this finding and also have reported that subjects with a large number of cardiac bursts had higher scores on the K scale of the MMPI (taken as a measure of psychological defensiveness or denial) and higher scores on the Taylor Manifest Anxiety Scale than did subjects having a small number of cardiac bursts. In addition, Barratt (1961), Hnatow & Lang (1965), and Lacey & Lacey (1958) have all reported finding a positive relationship between resting heart rate variability and impulsivity. The measure of heart rate variability used by Hnatow & Lang was the standard deviation of interbeat heart rates computed from a seven minute rest period. Barratt's work was cited by these investigators without mention of the measure of heart rate variability used.

Somewhat related to these data are the findings of Kagan & Rosman (1964) that boys who group pictures on the basis of an "analytic attitude" manifested lower heart rate variability during attention episodes (described above) than did subjects who grouped the pictures on the basis of some other attitude. While these investigators suggest that the difference may have been attributable to the fact that the nonanalytic boys were generally more restless than analytic boys, it is conceivable that such differences may have reflected individual differences in

cognitive activity. The analytic attitude is said to involve the grouping of pictures in terms of similarity in a differentiated characteristic of each picture. Presumably such functioning would be mediated by a state of concentration, since it requires the processing of new, unfamiliar information (see following section), and would be associated with a level of heart rate variability lower than that associated with the nonanalytic attitudes.

A Model of Thinking

If one tentatively accepts the account of thinking provided by the ego psychologists, thought processes may be characterized with respect to: (1) the extent to which they are regulated by the primary or secondary processes, i.e., the extent to which they are fluid, fanciful, and unbound by realistic considerations, or are logical, rational, and subject to the realistic constraints of the external world (Kris, 1950; Rapaport, 1951); and (2) whether they are associated with "involuntary-effortless attention" or "voluntary-effortful concentration" (Rapaport, 1951). In linking involuntary-effortless attention with both primary and secondary process thinking, and voluntary-effortful concentration with only secondary process thinking, Rapaport implies that there are three fundamental modes in which thinking may operate. In the interest of brevity, these three modes will be called concentrated secondary thinking, unconcentrated secondary thinking and primary thinking.

Rapaport states that effortless attention changes into a voluntary, effortful pursuit when there are intense, competing sensory stimuli, or when the subject matter to which one attends is complex or new, " . . . requiring organization of material or building of abstractions "

While he does not speak in informational terms, it is clear that such situations involve an increase in the information load, i.e., the amount of material which must be processed within a given interval of time. The organizing processes brought to bear on new or complex subject matter are said usually to create new quasi-stable thought patterns, which thereby extend the thinking process. Rapaport (1951, p. 717) writes:

Once such new patterns have been created and stabilized, and are in continuous use, their employment may become involuntary and effortless But when such patterns fall into disuse, or when the material to be apperceived is complex and hides rather than reveals them, meaning-discernment then becomes a matter of voluntary-effortful concentration. The difference between the two forms of meaning-discernment may be illustrated by that between reading a mystery story and reading Kant. The individual differences, however, are worth noting. For some people, the reading of a mystery story and of Thomas Mann's Faustus will be a contrast of attending and concentrating; for others, it may not. For a mathematician, the contrast in this respect between Faustus and a mathematical text may not be very great; for non-mathematicians, it is.

One can think of many other parallel examples of concentrated and unconcentrated secondary thinking. The solving of a multiplication problem "in one's head," requiring the storage of information low in meaning in short term memory and its subsequent retrieval after other operations have intervened, versus the planning of tactics which will solve a delicate interpersonal problem, requiring primarily the retrieval and manipulation of information high in meaning from long term memory, is one such contrast. Another is planning the day's general activities upon awakening, as opposed to outlining the procedures involved in the design and analysis of a complex experiment.

The model proposed here assumes that high creativity requires the integration of thinking which is dominated by the primary process with thinking which is predominantly regulated by the secondary process. Such an integration is facilitated by the "capability of making rapid or

at least appropriately rapid shifts in levels of psychic function" (Kris, 1952). In this regard, Rapaport's (1951) conception of an "inventive" phase of creative thinking, associated with primary thinking, and an "elaborative" phase, associated with concentrated secondary thinking, is much too gross to do justice to the dynamic interplay of primary and secondary thinking, which is here considered necessary for high creativeness. Rapaport's elaborative phase refers to thinking occurring across relatively long time periods, which accomplishes the arduous task of transforming an idiosyncratic product of primary thinking into a product which will have cultural or social significance. In contrast, the process of integration discussed above is conceived to occur over relatively brief periods of time.

It is also assumed that "moderate creativity" (see p. 35) results from the predominance of the concentrated secondary thinking mode of operation. By making an extended sequence of deductions from the premise of an item, an individual can generate responses which are sufficiently infrequent to be scored moderately creative. In addition, the predominance of this mode of thinking should lead to high performance on a task requiring convergent, logical thought, such as solving "mental multiplication" problems.

The core assumption of the model is that the operation of each of the three modes of thinking described above is reflected in the variability of the heart rate. For a given subject, the operation of each kind of thinking is assumed to be associated with a distribution of heart rate variability scores around a different mean variability. Concentrated secondary thinking is linked with a low mean level of variability, unconcentrated secondary thinking with a moderate mean level, and primary

thinking with a high mean level of variability (relative to the subject's own distribution).

II. PROBLEM

Research Objectives

The main objectives of this research were: (1) to determine whether a task presented with instructions presumed to encourage creative thinking would be reliably associated with a heart rate variability pattern differing from the pattern associated with the same task presented with instructions presumed to discourage creative thinking; and (2) to determine whether level of performance on a creativity task and on a problem solving task would be related to heart rate variability.

A second order objective of this research was to determine whether highly creative individuals differ in terms of resting heart rate variability levels from those individuals whose thinking rarely departs from stereotyped or conventional patterns.

Instructional Set

In order to achieve the first major objective mentioned above a modified version of the role playing technique employed by Wild (1965) was used to obtain set differences. Wild instructed her subjects to respond to both word association and object sorting tests in the manner in which they thought each of two very different hypothetical persons might respond to the tests. Modified versions of Wild's Regulated and Unregulated character sketches used in this study are reproduced below and complete instructions are presented in Appendix A.

Regulated Character: A reliable, cautious person who likes to live in an orderly, structured world and values good common sense. He is an efficient, competent individual who is suspicious of "wild,"

fanciful ideas, or of any ideas that seem inconsistent with commonly recognized knowledge and commonly held beliefs. In his opinion, those who would disregard the valuable "tried and true" approaches to problems in favor of unusual, fanciful, and unproven ideas are very impractical persons, who can never amount to much. He sees success as the natural reward of those who work hard and daydream little.

Unregulated Character: A clever, unconventional "loner" who typically has novel thoughts and fanciful yet acute perceptions that may startle other people. He is inclined to point to the contradictions which he sees in human experience, and his ideas attack conventional ways of thinking and perceiving; his thoughts literally force others to view reality in new and different ways. He has a good sense of humor and is not reluctant to engage in "far out" speculation; in fact, he enjoys fantastic ideas.

Wild evaluated the originality of the test responses of three different groups--students from a professional art school ("creative" group), elementary and high school teachers ("normal" group), and institutionalized schizophrenics "in good contact" (psychotic group). The creative and normal groups were matched with respect to sex, age, IQ, and education. The psychotic group was matched with the other groups in terms of sex and age, but it was not possible to match it to the other groups with respect to IQ and education. Wild found that the creative group was significantly more original when tested without role playing instructions (spontaneous originality) than the normal and psychotic groups. Furthermore, the former group showed a significantly greater shift in originality between the regulated and unregulated conditions than did the latter groups. The art students became far more original than the other groups under the unregulated condition as compared with the regulated condition, and their responses showed more adaptive features than those of the other groups. In none of the analyses were the normal and psychotic groups significantly different with respect to the originality or adaptiveness of their responses. In addition, the spon-

taneous level of originality was positively correlated ($r = 0.22$; $p < .025$) with shift scores (difference in originality scores between regulated and unregulated conditions) for both tests.

Creativity Test

Another variable in this study was creativity score on a modified version of Bennett's (1944) unpublished Test of Productive Thinking, henceforth called the Modified Bennett Test (MBT). The Bennett items consist of descriptions of imaginary situations to which the subject is instructed to respond with consequences which might conceivably follow, were the hypothetical situations to exist. The Bennett-type items used in this study are listed in Appendix B. Barron (1965) reports that when the Bennett test was used at the Institute of Personality Assessment and Research at Berkeley in a study of originality in graduate students, it proved to be an excellent predictor of faculty ratings of originality when scored for originality and "cosmicity".

Guilford's (1958) Consequences Test poses a similar task for the subject and has gained wide usage. The test is scored for the factors of originality and ideational fluency; originality is defined as the ability to produce clever, remotely associated, or uncommon responses. Barron (1965) reports a correlation of 0.35 between originality on the Consequences Test and an originality rating derived from three days of "living-in assessment" of 100 Air Force captains.

Thus, it would seem that there is enough evidence to indicate that a Bennett-type test stimulates a kind of thinking which can be characterized in terms of its originality, novelty, etc. However, certain theoretical discussions of creativity appearing in the literature

suggest that the use of additional criteria may be of value in assessing responses to the MBT.

Jackson & Messick (1965) propose four criteria to be used jointly in determining the creativeness of a product; unusualness, appropriateness, transformation, and condensation. Unusualness is to be judged in terms of a product's statistical infrequency with respect to certain norms; appropriateness, in terms of the extent to which the product fits the context; transformation, with respect to the strength and nature of the constraints on thinking which the product transcends; and condensation, in terms of the coalescence or concentration of meaning which leads one to re-examine and re-experience the product.

Koestler (1964), a well-known creative writer, develops a "bisociative" theory of the creative act in a book which is considered by many individuals to be a brilliant and sweeping treatise on the creative process. For Koestler, the basic pattern of the creative act is synthetic: "the sudden interlocking of two previously unrelated skills or matrices of thought".

Bruner (1962) also proposes that creativeness is the resultant of combinatorial activity, "a placing of things in new perspectives". According to this prominent psychologist, however, the hallmark of creative enterprise is its capacity for producing "effective surprise". In order to be effectively surprising, a product must be more than just unexpected; it must be non-trivial. Three kinds of effectiveness are proposed: (1) predictive effectiveness; (2) formal effectiveness; and (3) metaphorical effectiveness. Predictive effectiveness "pertains to the kind of surprise that yields high predictive value in its wake" (theoretical science). Formal effectiveness "consists of an ordering of

elements in such a way that one sees relationships that were not evident before, groupings that were not present, ways of putting things together not before within reach" (mathematics, logic, and perhaps music). And, metaphorical effectiveness pertains to the " . . . connecting (of) domains of experience that were before apart, but with the form of connectedness which is art."

These theoretical approaches suggest five criteria which could be used conjointly in evaluating the creativity of responses to the Modified Bennett Test items: Novelty, appropriateness, non-triviality, surprise and stimulation of thought, and synthesis of divergent domains of thought. Complete definitions of these criteria and methods for scoring are given in a scoring manual developed by the author. A method for combining the individual scores on each of these scales is described on pages 32-35.

Multiplication Test

Still another variable of interest in this study was the score derived from a mental multiplication test, consisting of problems which were to be solved without the use of writing aids of any sort. Multiplication problem sets, varying in level of difficulty, which were used in this study are presented in Appendix C. The system used for scoring performance is also given in the same appendix.

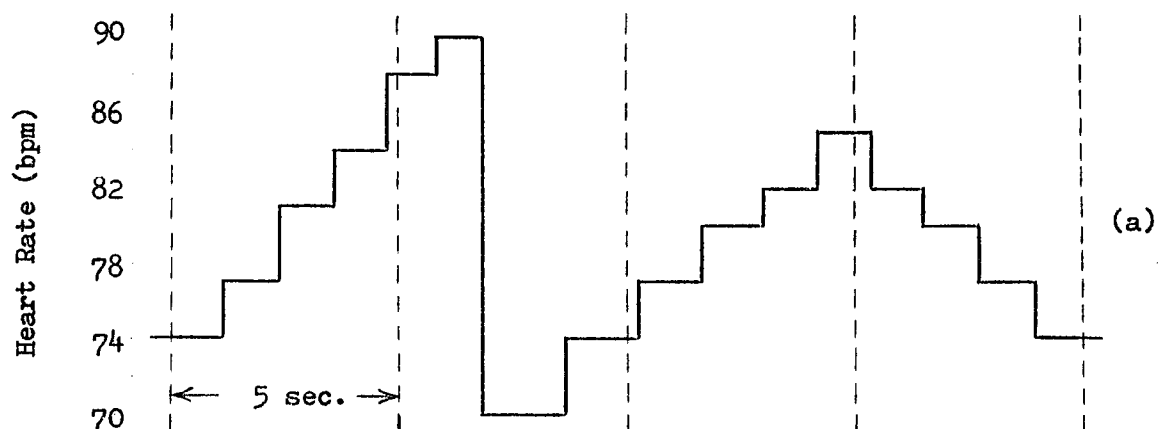
In both sessions each subject was given a set of ten problems to solve. The level of difficulty of the problem set was determined from the subject's performance on a series of practice problems.

Heart Rate Variability

Several different measures of heart rate variability have been

reported in the literature, but none of these seemed satisfactory for use in this study. All of the following measures were obtained by using a cardiometer to convert beat to beat changes in heart rate to a running histogram of heart rate. The mean peak-trough difference is one measure which has been used by several investigators (Obrist, 1963; Welford, Lacey, & Peckham, 1964; Meyers, 1966). The method of defining troughs and peaks has been discussed above in connection with Obrist's work. Other methods are the interquartile range ($Q_3 - Q_1$) and the third quartile of peak-trough amplitude changes (Q_3) [Kagan & Rosman, 1964]. Still another method used in several studies is the "cardiac burst count," or the number of atypical fluctuations from the sinus arrhythmia, as defined above (Lacey & Lacey, 1958; Wilson & Dykman, 1960).

The last measure seems least appropriate for the purposes of this study, since the scoring of deviations from the sinus arrhythmia in both directions is desirable. The first three measures are also unsatisfactory because none of these consistently represents the characteristic of the cardiogram which is hypothesized here to be most closely related to cognitive activity. It is the degree of "flatness" or stability in the cardiogram which is thought to be most indicative of the type and efficiency of concomitant cognitive activity. Figure 1 illustrates the inconsistency of these measures in representing the degree of flatness in two hypothetical records. It may be observed, however, that the average maximum range of heart rate per five second interval is the same in both cases (as shown in the legend for Figure 1). Thus, it is assumed for the purposes of this study that a measure of the range of variability per unit of time gives a better representation of the stability of a cardiac record than that given by any of the other three

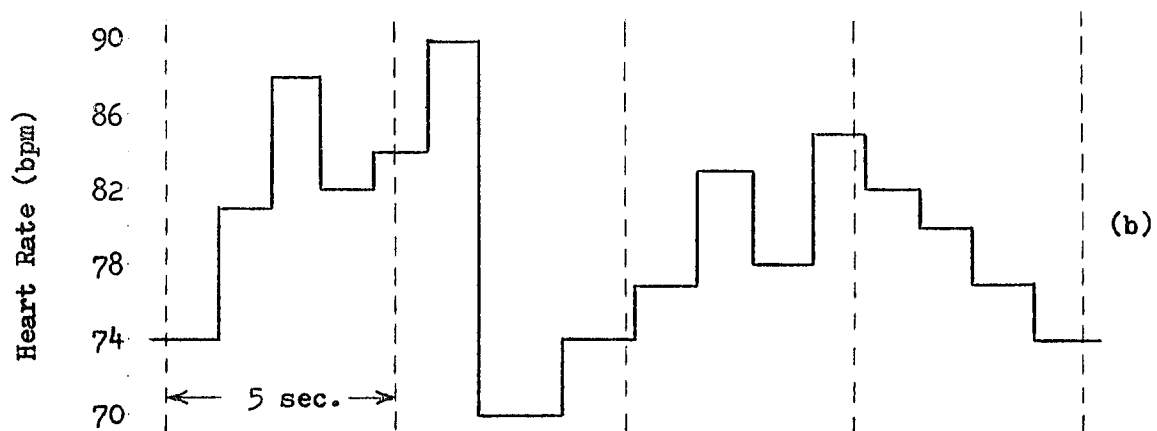


Q_{3-1} of peak-trough differences = 5.0

Q_3 of peak-trough differences = 18.0

Mean of peak-trough differences = 15.5

$\overline{HR}_v = 14.0$



Q_{3-1} of peak-trough differences = 7.0

Q_3 of peak-trough differences = 13.5

Mean of peak-trough differences = 10.5

$\overline{HR}_v = 14.0$

Fig. 1--Comparison of two patterns of heart rate variability in terms of several different measures.

measures discussed above. The measure called HR_v is defined here as the difference between the maximum and minimum interbeat heart rates within a five second interval. Mean HR_v ($\overline{HR_v}$), taken across two or more intervals, gives a representation of the average maximum change in heart rate per unit of time. Not only is the HR_v measure readily scored, but it also provides a means for avoiding the difficulties inherent in defining peaks and troughs in the heart rate cycle. The HR_v measure, in addition, has another feature which is not a characteristic of the first three measures; specifically, for equal time periods there will be an equal number of scores obtainable.

In the present research an attempt was made to identify the HR_v range corresponding to unconcentrated secondary thinking (described in Introduction). During a preliminary rest period each subject was asked to engage in some light reading. A frequency distribution of the HR_v scores occurring during this reading period was plotted and then smoothed by averaging the frequency for each HR_v value with the frequencies associated with the two HR_v values adjacent to it. The major modal value was then selected as best representing the HR_v level associated with unconcentrated secondary thinking, but only if it was greater than or equal to eight beats per minute (bpm). If it was less than eight bpm, then it was assumed that the reading period did not produce the desired unconcentrated secondary thinking, but rather produced concentrated secondary thinking.

Pilot data suggested the following partition of the total HR_v range. The moderate range (M) was defined as the range extending from two bpm below to two bpm above the major modal HR_v value of the reading period, as long as this value was not lower than eight bpm. The lowest

M range was thus six to ten bpm. The low range (L) was defined as the range extending five bpm below the moderate range, and the very low range (VL) was defined as comprising all values lying below the low range. The high range (H) was defined as the range extending five bpm above the moderate range, and the very high range (VH) was defined as comprising all values lying above the high range. If during the reading period the major modal HR_v value was less than eight bpm, then this mode was taken as representative of the center of the low range. In this case, the subject's L range was defined as the range extending from two bpm below to two bpm above this modal value; the M range was defined as extending five bpm above the L range; the H range was defined as extending five bpm above the M range; and the VH range was defined as comprising all values lying above the H range.

A given task period was classified according to the percentage of HR_v scores falling within each of the five HR_v ranges defined above. If at least 70% of the scores fell within the L and M ranges, and no other range contained more than 20% of the scores, then the period was categorized as an LM period. If at least 70% of the cases, subject to the same exception as above, fell within the M and H ranges, then the task period was categorized as an MH period. Any other combination was considered to represent a mixed pattern (MX) of heart rate variability.

Hypotheses

Hypothesis 1: Creativity scores will be higher under the unregulated (U) condition than under the regulated (R) condition.

Hypothesis 2: Mean $\overline{HR_v}$ will be higher during the U condition than during the R condition ($\overline{HR_v} = \text{mean } HR_v$ for a given subject).

Hypothesis 3: The frequency of creativity scores in the high range will be greater for MH periods than for LM periods.

Hypothesis 4: The frequency of creativity scores in the moderate range will be greater for LM periods than for MH periods.

Hypothesis 5: The frequency of creativity scores in the low range will be greater for MX periods than for LM periods.

Hypothesis 6: Performance scores on mental multiplication problems will be higher for LM periods than for MH periods.

Hypothesis 7: Resting $\overline{HR}_v$ will be positively correlated with overall creativity score in the U condition.

III. METHOD

Design

In each of two sessions Ss engaged in light reading while their resting heart rate variability was recorded. They were then given an instructional set which prepared them to assume the role of the Unregulated character in one session and the Regulated character in the other session (p. 15). Subsequent to the role-inducing instructions, they responded to a creativity test (Modified Bennett Test) while heart rate variability was monitored. The role-inducing instructions and the items of the creativity test were counterbalanced in a repeated measures design with each S serving as his own control. Finally, Ss were given a mental multiplication test, consisting of ten problems, and heart rate variability was monitored.

Subjects

Twenty-four students at the City College of New York, 13 males and 11 females who had volunteered for an ESP project, were used as subjects for this research. The subject sample ranged in age from 17-30 years, having a mean age of 21.0 years.

Apparatus

Electrophysiological recordings of cardiac rate and respiratory cycle were obtained by means of a Beckman Type R Dynograph Recorder, using standard Type 9857 and 9875 couplers. Each session was tape recorded, and verbal responses were marked on the Dynograph paper by

means of a "voice key". In addition, a memory drum, having a device which triggered one of the Dynograph marker pens each time the drum rotated, was used to present the multiplication problems.

Materials

The Modified Bennett Test used in this study is reproduced in Appendix B. The first three items were taken from Bennett's (1944) unpublished Test of Productive Thinking but have been somewhat reworded in order to make them less oriented to science and engineering students. The last three items were developed by the writer for the purpose of stimulating the more artistically-inclined individual.

Three paired lists of multiplication problems were constructed and are presented in Appendix C. Three levels of difficulty are represented.

Procedure

Each subject came for two sessions. In each session the appropriate transducing devices were connected to the subject, and a period for adaptation to the equipment and to the situation was provided before the collection of data was initiated. Each subject was told that the purpose of the investigation was to obtain measures of his physiological activity while he was engaged in certain kinds of thinking; no reference was made to the fact that a study of creativity was involved.

After the adaptation period in both sessions, resting heart rate variability was measured for ten minutes. It was intended that data obtained from each session would be scored relative to the resting variability obtained during that session. In an attempt to control the kind of thinking occurring during this resting period, subjects were asked to

choose two selections from either or both of the issues of Reader's Digest provided, and were instructed to read aloud for half of the period and silently for the other half. They were given strong assurance that at no time would there be any testing related to this material, and that the sole purpose for their reading was to give them something to occupy their thoughts during the resting period. Subjects were requested to select reading material which ostensibly required little concentration, was emotionally unarousing, and yet interesting to read, i.e., the kind of material which permits the reader to follow along in a passive, effortless manner. It was presumed that the reading of such material would lead to a high proportion of unconcentrated secondary thinking. The period of oral reading was intended to be used as a baseline for classifying a subject whenever the majority of HR_v scores during the U or R conditions was associated with periods of speech. The period of silent reading was intended for use in classifying a subject whenever the majority of HR_v scores during the U or R conditions was associated with periods of silence, and also in classifying the subject for the multiplication task. Since it was not clear to what extent talking might affect the frequency distribution of HR_v , the procedure just described appeared useful in providing some degree of control over the speech variable.

During the first session subjects 1-6 and 13-18 were instructed to respond to the items of the MBT in a way which they thought would be consistent with the Regulated Character, and subjects 7-12 and 19-24 were instructed to respond in a way which they thought would be consistent with the Unregulated Character. In the subsequent session the role-inducing instructions were interchanged for the two subgroups. In

each session following either the R or the U condition, each subject was given a series of ten multiplication problems to solve without using pencil and paper.

Three items of the MBT were utilized in the first session and three in the second; the entire six items were counterbalanced according to the plan shown in Table 1 so that each item occurred equally often under each condition, equally often at each position, and was preceded and followed the same number of times by each of the other items.

TABLE 1
ORDER OF PRESENTATION OF ROLE-INDUCING
INSTRUCTIONS AND MBT ITEMS

Day 1 R			Day 2 U			Day 1 U			Day 2 R			Day 1 R			Day 2 U			Day 1 U			Day 2 R																																																		
S1	ABC	DEF	S2	BCA	EFD	S3	CAB	FDE	S4	ACB	DFE	S5	CBA	FED	S6	BAC	EDF	S7	ABC	DEF	S8	BCA	EFD	S9	CAB	FDE	S10	ACB	DFE	S11	CBA	FED	S12	BAC	EDF	S13	DEF	ABC	S14	EFD	BCA	S15	FDE	CAB	S16	DFE	ACB	S17	FED	CBA	S18	EDF	BAC	S19	DEF	ABC	S20	EFD	BCA	S21	FDE	CAB	S22	DFE	ACB	S23	FED	CBA	S24	EDF	BAC

Subjects were told that they would have six minutes to respond to each of the test items, and were instructed to make use of all of the time allotted for each of the items. They were also encouraged to verbalize all of the ideas that occurred to them during each of the periods. Since a minimum of four responses to an item was considered desirable, slow or hesitant subjects were encouraged to give more responses as the end of the response period drew near. Tape recordings of the entire task period were obtained.

After a subject had finished responding to the three items of

the MBT in the first session, one of the three sets of multiplication problems (Appendix C) was selected as most appropriate for him in terms of degree of difficulty. The selection was made by quickly assessing the subject's ability for the task on the basis of his performance on two sample problems associated with each of the three sets of problems.

Following presentation of the instructions for the task (Appendix C), the subject was given the first practice problem from Set I (lowest difficulty) to solve. If an answer was given within ten seconds and was accurate for at least two of the three digits in the correct solution, or if it was given within fifteen seconds and was completely accurate, then the subject was informed that it would be necessary to proceed to another level of problems. With this, the first practice problem from Set II was presented. If this problem was solved within fifteen seconds and was accurate for at least two of the three digits in the correct solution, or if it was solved within twenty seconds and was completely accurate, then the subject was told that it would be necessary to proceed to still another level. If this did not occur, and the subject also failed to meet the criterion on the second practice problem, then Set II was selected as the test set. If the subject achieved the criterion level on either problem, then the first practice problem from Set III was given. If a response was given within the allotted ninety second period, then Set III was selected as the test set. If this did not occur, the subject was given the second practice problem from Set III. If he failed again or complained considerably about the difficulty of the problems, then Set II was selected as the most appropriate test set.

In the first session the sample testing procedure was immediately followed by the presentation of the first list of the set selected. In

the second session the creativity task was followed by a review of the instructions, and then the sample testing procedure was repeated using the first two problems in a problem set as both sample problems and test problems where necessary. Subjects were not led to expect practice problems in this session.

As mentioned previously, problems were presented by means of a memory drum, which was remotely activated by the experimenter. In this segment of the experimental procedure, as well as in the remainder of the procedure, subjects were situated in a sound-attenuating cubicle, while the experimenter was located in the monitoring room across the hall of the laboratory. Communication was maintained via an intercom system. As each problem was presented, one of the Dynograph marker pens was automatically activated to record the beginning of the response period. When the subject gave his response, the activation of a marker pen by the voice key recorded the end of the response period. Again tape recordings of the entire task period were obtained.

The experimenter did not respond to the subject's solutions to the problems or to his responses to the MBT items. If inquiries were made by the subject as to his performance, he was informed that the experiment required that this not be discussed until after all of the problems or all of the MBT items were completed, as the case might be.

IV. TREATMENT OF DATA

Scoring of Modified Bennett Test and Multiplication Problems

Responses to the Modified Bennett Test were transcribed from tape recordings, assigned an identifying code number, and then given to two judges for independent scoring. The judges scored the creativeness of the responses, without knowledge of the hypotheses or the physiological data, according to procedures outlined in a scoring manual developed by the author for the MBT.

The manual proposes five criterion scales, in terms of which a given response is to be evaluated: (1) novelty, (2) appropriateness, (3) non-triviality, (4) surprise-stimulation of thought, and (5) synthesis of divergent domains of thought. Provided in the manual is a tabulation of response categories and their associated frequencies of occurrence in a normative sample of seventy-eight introductory psychology students at the City College of New York. The novelty of a response is scored by assigning it to one of the response categories. The scoring of a response with respect to the other four criterion scales is accomplished in each case by assigning it a rating on a three point scale (0-2). Separate examples are provided in the scoring manual for each test item and each numerical rating to be utilized in the scoring.

A twenty-two year old male, senior student in psychology and a twenty-seven year old female, former art student with a sizeable background in psychology served as judges for the evaluation of creativity. These individuals were selected from a number of potential judges as

those whose scoring agreed most closely with the author's scoring of a sample of responses not included in the present study. Subsequent to a training period which demonstrated that a substantial level of agreement could be reached between the two judges on all scales, independent scoring of the responses given by subjects in this study was initiated. Disagreements were resolved by establishing consensus scores, rather than by simply averaging the scores of the two judges. The former procedure seemed preferable since day-to-day variations in the mood, motivation, intellectual keenness, etc. of a judge could lead to his overlooking the intended meaning of a response which was detected by the other judge. Similarly, the intent of a response may be couched in language or involve connotations which are familiar to one judge but not to the other. In both cases discussion often produces ready agreement.

To determine a total creativity score for each response given by subjects in the present study, the following procedure was utilized. A new frequency tabulation of response categories was produced by combining the responses in this study with those in the normative sample. The frequencies of the response categories in the new tabulation were combined for each item of the MBT to form five novelty categories such that the sum of the frequencies in the five categories was negatively related to the novelty category, with the highest value of this function associated with the category containing the most infrequent responses (Figure 2). With this grouping of frequencies the curves for all items were as nearly linear and similar in slope as possible. A response falling in the novelty category containing the most infrequent responses was assigned a novelty score of six, whereas a response falling in the category containing the most frequent responses was assigned a novelty score of two. A

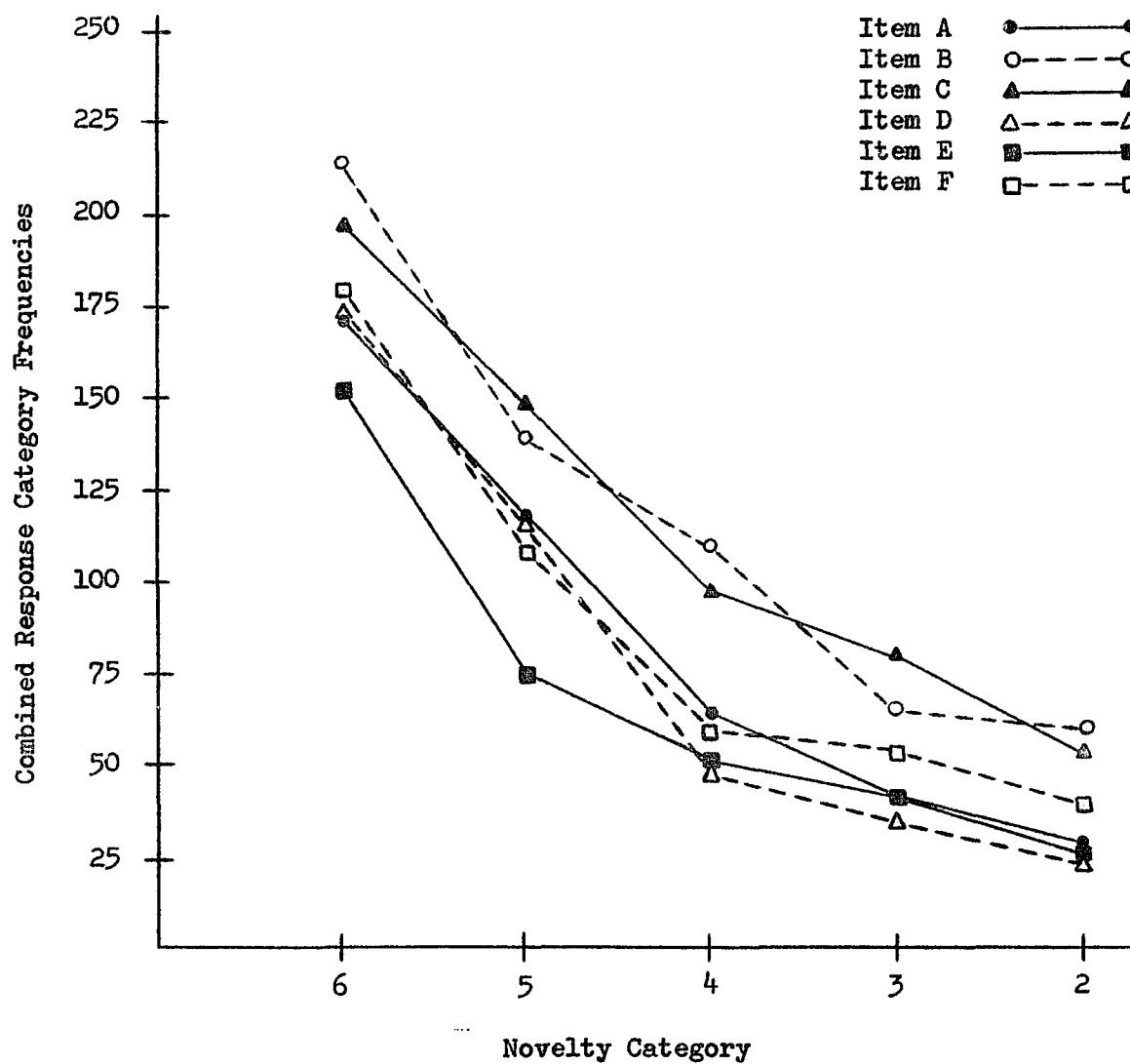


Fig. 2--Combination of response category frequencies for MBT items to form novelty categories (normative and dissertation samples).

tabulation of the frequencies of the response categories falling in each novelty category for each item of the MBT is given in Table 2.

TABLE 2
FREQUENCIES OF RESPONSE CATEGORIES CONTAINED
WITHIN NOVELTY CATEGORIES FOR MBT ITEMS
(NORMATIVE AND DISSERTATION SAMPLES)

Novelty Category	Item A	Item B	Item C	Item D	Item E	Item F
6	1-2	1-2	1-3	1	1-2	1
5	3-9	3-10	4-9	2-5	3-5	2-6
4	10-16	11-27	10-16	6-10	6-10	7-13
3	21	32-34	18-37	12-23	12-18	15-22
2	29	60	54	24	27	40

For further clarification of this procedure consider the function for Item B in Figure 2. The graph indicates that there were 214 responses which received the highest novelty score (novelty category 6). In conjunction with this, Table 2 shows that each of these responses was either unique or was placed in a category with only one other response in the combined normative and dissertation samples (102 subjects). Similarly, the graph for the same item indicates that 60 responses received the lowest novelty score (novelty category 2). By consulting Table 2 again, it can be observed that all of these responses were assigned to one response category having a frequency of 60.

Scores on the surprise and synthesis scales were added to the corresponding novelty score. If a response was judged to be totally inappropriate or trivial, the entire novelty score was subtracted. If the

response was judged to be somewhat inappropriate or trivial, the entire novelty score was subtracted and one point was added. Thus, a response receiving less than the maximum rating (two) on either the appropriateness or non-triviality scales was assigned a total creativity score of zero or one, since ratings greater than zero on the surprise and synthesis scales were not permitted in these cases.

In terms of this scoring system, total creativity score for a response could range from zero to ten. Scores of 8-10 were considered to represent high creativity, scores of 4-7, moderate creativity, and scores of 0-3, low creativity.

The degree of interrater reliability was assessed separately for each of the five criterion scales by computing contingency coefficients, where the data permitted, and also by determining the percentage agreement between the scores of the two judges (Table 3). All contingency tables were reduced to two-by-two tables so that the expected cell frequencies were each greater than five, and also so that the contingency coefficients derived from all tables could be compared with one another (McNemar, 1955). For the appropriateness and synthesis scales the scores of the two judges fell almost entirely within one cell, i.e., with few exceptions responses were deemed by both judges to be appropriate and without synthesis. Thus, for these sets of data no contingency coefficients could be computed.

It should be noted that the contingency coefficient is not comparable to a product-moment coefficient of the same magnitude, since its upper limit is a function of the number of categories. For a two-by-two table the upper limit is 0.71 (McNemar, 1955). In addition, the relatively low percentage agreement for the novelty scale requires a further

note. This percentage was computed on the basis of nineteen categories of information, as compared to three categories for the other four scales, and is thus understandably the lowest value.

TABLE 3
INTERRATER RELIABILITY OF MBT SCORING

Criterion Scale	Contingency Coefficient	Percentage Agreement
Novelty	0.64 [*]	82
Non-triviality	0.56	92
Appropriateness	-	94
Surprise	0.30	85
Synthesis	-	99

* All coefficients highly significant ($p < .0001$).

Performance on each multiplication problem was scored by the author on a scale ranging from one to eight developed in advance of the data collection (Appendix C). The highest scores were given to very fast, accurate responses, lower scores to slower or less accurate responses.

Scoring of Physiological Data

Heart rate variability (HR_v) was scored by four individuals, none of whom had knowledge of the creativity and multiplication data or the nature of the hypotheses. It was felt that several scorers were preferable because of the amount of data to be scored and the monotony involved; however, two of the individuals did the great majority of the scoring. Scorers were instructed to divide the record for each condition into successive five second intervals, scoring HR_v as indicated on page 22.

One of the aforementioned scorers did the scoring of all respiration data. For each five second interval the largest amplitude change between successive peaks and troughs in the respiration cycle (R_v) was scored.

Preparation of Data for Analysis

For the regulated and unregulated conditions frequency distributions of scores for each subject's responses to the MBT under each condition were compiled. From these distributions the number of responses in the high, moderate, and low creativity categories was determined. An overall creativity score was computed for each subject in each condition (C_u, C_r) by summing the twelve highest response scores in that condition. Such a score was considered desirable because it was conceivable that a highly creative individual might give several banal responses in warming up to his highly creative responses. This sort of pattern might result in a mediocre overall score if all responses were taken into consideration. However, the mean response creativity score for each subject in each condition was also computed for comparison. In addition, mean scores for each subject in each condition for each of the criterion scales were also computed. For the multiplication condition a total performance score was determined for each subject in each session by summing the scores for the ten problems in that session.

Frequency distributions of HR_v were compiled for each condition as indicated on page 22. However, in order to control for respiration effects, HR_v scores associated with atypical R_v scores were omitted. Where respiration data were not available because of technical difficulties, all HR_v scores were used in compiling the frequency distributions.

Atypical R_v scores were defined as those scores lying beyond the points at which the smoothed frequency distribution of R_v around the major mode either reached zero or turned upward to form a secondary mode, as long as (1) these scores represented no more than 50% of the total R_v distribution, and (2) the difference between the modes was not less than four half-millimeters along the smoothed R_v dimension. If either of the above two qualifications were applicable, then the procedure was extended to exclude fewer scores by omitting only those scores lying beyond points more remote from the major mode at which the smoothed distribution again either reached zero or turned upward to form another mode. Smoothing was again accomplished by averaging each frequency with its adjacent frequencies. In cases where these criteria did not lead to a clear cut decision, the typical R_v ranges for all conditions were made as similar as possible.

It should be noted that there were difficulties in the interpretation of the respiration data because of variation in the performance of the respiration transducer that was unrelated to the breathing cycle. Had this not been the case, controlling for the effects of respiration on HR_v would have been a much simpler matter. It would have then been possible to use only those HR_v scores associated with the same range of R_v in all conditions.

V. RESULTS

Inter-session Correlations Between Heart Rate Variability Measures

The correlation between $\overline{HR}_v$ in the silent reading conditions for the two sessions was 0.47 ($p < .05$). For the multiplication problems the correlation between $\overline{HR}_v$ scores for the two sessions was 0.58 ($p < .01$). For the U and R conditions the correlation between $\overline{HR}_v$ scores was 0.54 ($p < .01$).

The correlations reported in this section, as well as in the remainder of the paper, are Spearman rank order coefficients unless otherwise indicated.

It should be noted in interpreting these correlations that the reading material varied from day to day according to the subject's choice of selections from the Reader's Digest. Also, ten subjects (42%) were presented with multiplication problems which varied in level of difficulty for the two sessions. And, of course, the U and R conditions differed in terms of role-playing requirements, in addition to the fact that the order of presentation of conditions and the content and order of presentation of MBT items were varied for each condition (see Table 1). Finally, the interval between sessions was not held constant, but varied from 2 - 43 days. The median was 7.5 days with 71% of the intervals less than 11 days. The obtained measures of reliability for heart rate variability during the cognitive tasks were in the low to moderate range. However, the foregoing considerations suggest that these values might have been somewhat higher had conditions been more uniform across sessions.

Intersession Reliability of Multiplication Scores

Since there were three levels of difficulty for the multiplication problems, and also since a large proportion of subjects worked on problems which varied in level of difficulty for the two sessions, it would not be meaningful to report an overall correlation coefficient between scores for the two days. However, it is meaningful to report intersession correlations for those subjects who received problems of the same level of difficulty in both sessions. Seven subjects received the Set III problems in both sessions. The Kendall rank correlation coefficient between total performance scores for the two sessions was 0.86 ($p = .0034$). Five subjects received the Set I problems in both sessions. The Kendall rank correlation coefficient in this case was 0.60 ($p = .117$). Only one subject received the Set II problems on both occasions, and thus no correlation could be computed.

These results suggest that the multiplication problems of greatest difficulty provided a reasonably reliable means for assessing relative performance on the mental multiplication task; however, the easiest problems do not appear similarly commendable in this respect, and, of course, no information with respect to the problems of intermediate difficulty is available. On the other hand, the sample sizes are quite small, and thus the results should be considered cautiously.

Intercorrelations Among Criterion Scales of Creativity

The interrelationships among mean response novelty score, mean response non-triviality score, and mean response surprise-stimulation score for the U condition are given in Table 4. Appropriateness and synthesis scores are not included because of the extremely limited amount

of variation in these scores. A corresponding summary of intercorrelations for the R condition is given Table 5. Appropriateness and synthesis measures are again not included because of limited variation.

TABLE 4

INTERCORRELATIONS AMONG CRITERION CREATIVITY SCALES FOR THE
UNREGULATED CONDITION (SPEARMAN RANK COEFFICIENTS)

	Mean Response Novelty Score	Mean Response Non-triviality Score
Mean Response Non-triviality Score	-0.29	
Mean Response Surprise Score	0.35	0.26

TABLE 5

INTERCORRELATIONS AMONG CRITERION CREATIVITY SCALES FOR THE
REGULATED CONDITION (SPEARMAN RANK COEFFICIENTS)

	Mean Response Novelty Score	Mean Response Non-triviality Score
Mean Response Non-triviality Score	0.06	
Mean Response Surprise Score	0.57 [*]	0.08

^{*}
p < .01

Testing of Hypotheses

Since Hypotheses 1, 2, 6, and 7 are independent, the alpha level for the statistical test of each of these was set in advance at .05. In contrast, since Hypotheses 3, 4, and 5 are not independent, it was decided in advance that the conventional alpha level of .05 would be apportioned equally among the statistical tests associated with these hypotheses.

Hypothesis 1: An F test was used to test for homogeneity of variance of the overall creativity scores (C_r and C_u) in the R and U conditions. The variance for the R condition was 457, while the variance for the U condition was 47.5, yielding an F equal to 9.62 ($p < .002$; $df_1 = 11$, $df_2 = 11$). The departure from a situation of homogeneity of variance thus seemed sufficiently great to make the use of the t test inadvisable. Therefore, the nonparametric sign test, which makes no assumptions with regard to normality of distributions or homogeneity of variance, was used to test the hypothesis. The sign test assumes only that the difference between scores for a subject in two different conditions is independent of each of the differences for all other subjects, and that the differences are continuously distributed (Walker & Lev, 1953, p. 430). When the sign test was applied to the data, the hypothesis of higher creativity in the U condition as compared with the R condition was confirmed. The associated two-tailed probability value was .002.

Hypothesis 2: A two-tailed t test for correlated means was used to test the hypothesis that mean $\overline{HR}_u$ for the U condition would be greater than mean $\overline{HR}_r$ for the R condition. The data yielded a t equal to -3.62 ($p < .002$; $df = 23$) which did not support the hypothesis, but which indi-

cated that mean $\overline{HR}_V$ was significantly lower in the U condition than in the R condition. However, since the distribution of $\overline{HR}_V$ for the U condition seemed to depart from normality in the direction of bimodality, it was considered advisable to supplement this test with a nonparametric test.

In this case, the signed rank test was used because the differences between conditions were not quite so pronounced as in the case of the previous hypothesis. This test is more sensitive than the sign test in that both the direction and magnitude of the differences between conditions are taken into account rather than simply the direction of the differences alone. When the signed rank test was applied to the data, the hypothesis was also not confirmed by this method, but the two-tailed test again indicated that mean $\overline{HR}_V$ was significantly lower in the U condition than in the R condition ($p = .025$).

Hypothesis 3: In the U condition not a single subject manifested an $\overline{HR}_V$ distribution which could be classified in the MH category. Thus, the hypothesis that MH periods would be associated with more responses in the high creativity range than LM periods could not be tested for this condition. In the R condition three subjects manifested $\overline{HR}_V$ distributions which were classified in the MH category. Of the fourteen MH and LM periods, only one LM period was associated with a response in the high creativity range. Obviously, there was no significant difference between the groups; however, the data did not really permit an adequate test of the hypothesis since the R condition simply did not elicit high creativeness.

Hypothesis 4: Since there were no MH periods in the U condition, the hypothesis that LM periods would be associated with more responses

in the moderate creativity range than MH periods also could not be tested for this condition. For the R condition a t test for the difference between uncorrelated means yielded a t equal to 1.60, which was not significant ($p > .05$; $df = 12$). However, since the MH group was so small, the data again really did not permit a very satisfactory test of the hypothesis.

Hypothesis 5: The data from neither the R nor the U condition confirmed the hypothesis that MX periods would be associated with more responses in the low creativity range than LM periods. For the R condition a t test for uncorrelated means yielded a t equal to 0.41 ($p > .05$; $df = 19$). For the U condition a t equal to 0.76 ($p > .05$; $df = 22$) was obtained.

Hypothesis 6: Neither session one nor session two yielded data which supported the hypothesis that LM periods would yield higher multiplication performance scores than MH periods. For the first session a t test for uncorrelated means resulted in a t equal to 0.84 ($p > .05$; $df = 16$). For the second session a t equal to 0.50 ($p > .05$; $df = 12$) was obtained.

Hypothesis 7: Neither the R condition nor the U condition provided data which supported the hypothesis that resting heart rate variability would be positively correlated with overall creativity score in the U condition. Pearson product-moment correlations between C_u and $\overline{HR}_v$ for the silent reading period associated with the U condition, and between C_r and $\overline{HR}_v$ for the silent reading period associated with the R condition were computed. In the former case an r equal to 0.18 was obtained, while in the latter case an r equal to -0.32 was obtained. Neither of these correlations was significant at the .05 level.

Supplementary Analyses

There was no hypothesis formulated in advance which predicted a relationship between overall creativity score and HR_v classification. However, it was noted in the course of the preceding analyses that 19 out of 26 scores in the high creativity range over both the U and the R conditions were associated with an MX classification. Post hoc t tests were performed to compare C_u scores for LM and MX periods and C_r scores for the same periods. MX periods manifested significantly higher C_u scores than LM periods ($t = 2.07$; $df = 22$; $p < .05$). On the other hand LM periods appeared to be associated with higher C_r scores than MX periods, but the difference was not significant ($t = 1.41$; $df = 19$; $.10 < p < .20$). Of course, such results cannot be construed as providing evidence that HR_v classification is related to performance on the MBT, but they do provide some interesting suggestions for future research.

In addition to performing the tests on frequency scores for Hypotheses 3, 4, and 5, it seemed worthwhile to perform the same tests on percentage scores to determine whether individual differences in productivity were a factor in the results. The results of each individual test will not be reported here since there were no appreciable differences between these tests and the corresponding tests on the frequency scores, with the exception that in the U condition the mean percentage of low creativity scores was higher for LM periods than for MX periods ($t = 2.07$; $df = 22$; $p < .05$). This is, of course, not significant in terms of the pre-established alpha level of .0167, but it is suggestive of a possible relationship which could be sought in future research.

Since the procedure for classifying HR_v distributions did not yield support for the model proposed in this paper, it was considered

worthwhile to carry out some additional analyses of the data along more conventional lines. Table 6 gives for the U condition a summary of the correlations between scores on each of the criterion scales of creativity and each of three measures of heart rate variability. Also shown are the correlations between each of these three measures of variability and C_u , mean response creativity score, and number of responses. A corresponding summary for the R condition is given in Table 7.

Some comments should be made concerning the selection and meaning of the heart rate variability measures shown in these tables. Two types of measures are represented. One type is the kind of measure which could be called "autonomic tension"; the other is a measure which could be called "autonomic lability" (Lacey, Bateman, & Van Lehn, 1953). The former reflects the magnitude of the heart rate variability scores $\left[\overline{HR}_V, HR_V(Q_3) \right]$, whereas the latter reflects the dispersion of these scores $\left[HR_V(Q_{3-1}) \right]$. The notation $HR_V(Q_3)$ represents the third quartile of a subject's HR_V frequency distribution in beats per minute, and the notation $HR_V(Q_{3-1})$ represents the interquartile range of the distribution. The $HR_V(Q_3)$ and $HR_V(Q_{3-1})$ measures are very similar to the measures used by Kagan & Rosman (1964) which assessed the third quartile (Q_3) and the interquartile range (Q_{3-1}) of peak-trough amplitude changes in heart rate during a given period. $\overline{HR}_V$ in beats per minute is similarly analogous to the mean peak-trough amplitude change in heart rate, which was the measure used by Obrist (1963).

The $HR_V(Q_3)$ and $HR_V(Q_{3-1})$ measures were used because many of the subjects manifested HR_V distributions which tended to be positively skewed. The $HR_V(Q_3)$ measure, unlike the median, is sensitive to high but not extreme scores, and thus was considered more appropriate to the task

of detecting differences in moderately high HR_v . The $HR_v(Q_{3-1})$ measure was also used because it provided another more conventional means for detecting possible relationships between cognitive performance and the "shape" or dispersion of the HR_v distribution which were not detected by the classification procedure used in testing Hypotheses 3-5.

TABLE 6

CORRELATIONS OF SCORES ON CRITERION AND OVERALL CREATIVITY SCALES
AND NUMBER OF RESPONSES WITH MEASURES OF HEART RATE
VARIABILITY FOR THE UNREGULATED CONDITION

	Mean Response Novelty Score	Mean Response Non- triviality Score	Mean Response Surprise Score	Mean Response Creativity Score	Sum of 12 Highest Response Creativity Scores (C_u)	Number of Responses
$\overline{HR}_v$	0.02	0.20	-0.002	0.13	0.25	0.39
$HR_v(Q_3)$	0.004	0.16	0.01	0.12	0.26	0.40*
$HR_v(Q_{3-1})$	0.06	0.08	0.09	0.10	0.35	0.49*

*
p < .05

TABLE 7

CORRELATIONS OF SCORES ON CRITERION AND OVERALL CREATIVITY SCALES
AND NUMBER OF RESPONSES WITH MEASURES OF HEART RATE
VARIABILITY FOR THE REGULATED CONDITION

	Mean Response Novelty Score	Mean Response Non- triviality Score	Mean Response Surprise Score	Mean Response Creativity Score	Sum of 12 Highest Response Creativity Scores (C_r)	Number of Responses
$\overline{HR}_v$	-0.38	-0.25	-0.21	-0.30	-0.23	-0.14
$HR_v(Q_3)$	-0.38	-0.22	-0.13	-0.31	-0.26	-0.14
$HR_v(Q_{3-1})$	-0.17	-0.23	-0.07	-0.21	-0.12	0.002

A summary of correlations between multiplication performance scores and several measures of heart rate variability by session and difficulty level is given in Table 8. The coefficients are Kendall rank correlations (τ) except in the case of Set III-2 where Spearman rank correlations (ρ) are given. It should be noted that τ and ρ are not comparable, but for samples of $N < 10$ the t test of the significance of ρ is not satisfactory (McNemar, 1955, p. 210). In order to search for relationships between performance and both magnitude and dispersion of HR_V , the same HR_V measures used in connection with Tables 6 and 7 are repeated in Table 8. The measure $HR_V(Q_1)$, which represents the first quartile of the HR_V distribution, is also included because this measure, unlike the median, is sensitive to low but not extreme scores.

TABLE 8
CORRELATIONS OF MULTIPLICATION SCORES WITH MEASURES
OF HEART RATE VARIABILITY BY DAY
AND DIFFICULTY LEVEL

	n	$HR_V(Q_{3-1})$	$HR_V(Q_3)$	$\overline{HR}_V$	$HR_V(Q_1)$
Set I-1 (τ)	9	-0.19	0.25	0.19	0.14
Set II-1 (τ)	7	-0.57*	-0.43	-0.38	-0.48
Set III-1 (τ)	8	0.11	0.25	0.11	0.25
Set I-2 (τ)	8	-0.36	0.04	0.14	0.39
Set II-2 (τ)	5	0.50	-0.50	-0.50	-0.70
Set III-2 (ρ)	11	-0.24	-0.42	-0.37	-0.60*

*
 $p < .06$

Since the C_u and C_r scores were derived from an arbitrary combination of the scores on the criterion scales, it seemed advisable to test for differences between corresponding criterion measures for the U

and R conditions. Using the mean score for each subject in each condition, signed rank tests were used to test for differences between novelty, non-triviality, and surprise scores. The appropriateness and synthesis scales yielded so little variation that tests on these measures would not have been meaningful. Mean novelty was significantly higher in the U condition than in the R condition ($p < .01$). Mean non-triviality was also significantly higher in the U condition ($p < .01$), as was mean surprise ($p < .01$). A test of the difference between mean response creativity scores in the two conditions was also made. The signed rank test revealed that mean response creativity scores were significantly higher in the U condition ($p < .01$).

One final bit of supplementary observational data remains to be reported. It had been hoped that the reading periods would be predominantly associated with unconcentrated secondary thinking, since the reading material provided did not appear to be particularly difficult or unusual in content. However, informal questioning of some subjects about their mental states during the reading periods suggested that often there was a predominance of cognitive activity which could not be considered to represent unconcentrated secondary thinking. Subjects reported engaging in such activities as concentrating intently on the reading material, relating it to themselves, thinking about the material, and disagreeing with it, etc. Thus, if heart rate variability were to be related to cognitive activity as hypothesized by the model presented here, the reading periods would not be expected to consistently reflect the heart rate variability range associated with unconcentrated secondary thinking.

VI. DISCUSSION

Interpretation of Results

In view of the arbitrary characteristics of the total creativity score assigned to a response to the MBT, it is important to consider the interrelationships among the criterion scales. For both the U and R conditions the patterns of correlations obtained suggested that the criterion scales did not overlap appreciably. The correlations were low and only the relationship between mean novelty and mean surprise-stimulation in the R condition was significant. Such an interpretation, of course, assumes that the scales were reasonably reliable. The interrater reliabilities for the novelty and non-triviality scales were quite good, as can be seen from the contingency coefficients given in Table 3. Coefficients of 0.61 and 0.56 were obtained; the upper limit for a two-by-two table is 0.71. On the other hand, the coefficient for the surprise scale was 0.30, which indicated that the agreement between judges was considerably less for the surprise scale than for the novelty and non-triviality scales.

While the above-mentioned coefficients give information regarding the level of agreement between the judges' scores, they do not provide indications of the reliabilities of the consensus scores. Ideally, a measure of reliability computed from comparable alternate forms of the MBT would have been most desirable; however, this information was not available from previous research. In addition, test-retest reliability could not be determined, since subjects responded to three items of the

MBT under the R condition in one session and to the other three items under the U condition in the other session. The only measure of reliability which seemed available was a measure of internal consistency. The determination of inter-item consistency by correlating the odd items with the even items was not possible since there were only three items in each condition; however, it was possible to determine a measure of inter-response consistency in each condition by correlating the mean of the odd-numbered responses with the mean of the even-numbered responses.

Since conditions, item sets, and order of administration were counterbalanced in the design, it was considered important to determine whether all subjects in a condition could be pooled for computing the reliability of each of the criterion scales used in the assessment of creativity. For this purpose, analyses of variance were computed for each scale in each condition and also for the mean response creativity scores in each condition. Again, the appropriateness and synthesis scales were not used because of the extremely limited amount of variation in the scores for these scales. The analyses indicated that there were no significant effects due to order of administration with one exception. Mean response creativity scores in the R condition were significantly higher on Day 2 than on Day 1. There were also no significant effects due to item set with two exceptions. For the surprise scale in the U condition the DEF items produced significantly higher scores than the ABC items, and mean response creativity scores in the U condition were significantly higher for DEF items than for ABC items. There were, in addition, no significant interaction effects. Thus, a single correlation between odd and even responses was determined for each measure in each condition, except for (1) the surprise scale in the

U condition and (2) the mean response creativity score in the U condition, in which cases two correlations were calculated (one for ABC items and one for DEF items), and (3) for the mean response creativity score in the R condition, in which case two correlations were also calculated (one for Day 1 and one for Day 2).

Spearman rank correlations (ρ s) were computed in each case because the data violated the assumptions necessary for use of the product-moment correlation (r). Since ρ is equivalent to the product-moment correlation of the ranks (Walker & Lev, 1953, p. 281), and since the ρ for two normally distributed variables is less than 0.02 lower than the corresponding r (McNemar, 1955, p. 209), ρ was used as an approximation for r in order that the Spearman-Brown prediction formula could be used to estimate the reliability coefficients for the entire test (Walker & Lev, 1953, p. 310).

It was determined for the surprise scale in the U condition and the mean response creativity score in the U condition that the ρ in each case for both sets of items was identical with the average of the ρ s obtained for each item set, when the latter was computed by considering each ρ as an estimate of a corresponding r , transforming the r 's to Fisher's z scores (McNemar, 1955, pp. 147-149), averaging the z 's, and then transforming the average z back to an r . For the mean response creativity score in the R condition the same procedure revealed that the average ρ for the two days was -0.024 less than the ρ computed for both days combined. The latter value was used in computing the whole test reliability. Thus, Table 9 gives an estimate of the reliability coefficients which could be computed for each condition for combined item sets and sessions. For the surprise scale in the R condition there

was too little variation to compute a reliability value.

TABLE 9

SPLIT-HALF RELIABILITIES (ODD-EVEN RESPONSES) FOR CRITERION CREATIVITY
 SCALES: COEFFICIENTS DERIVED FROM THE SPEARMAN-BROWN FORMULA
 USING SPEARMAN RANK CORRELATIONS AS ESTIMATES
 OF PRODUCT-MOMENT CORRELATIONS^a

	Unregulated	Regulated
Novelty	0.39	0.61
Non-triviality	0.58	0.66 *
Surprise	0.74 **	—
Composite (C)	0.71 **	0.78 ***

^aSignificance values given for rank correlations computed for the means of the odd and even-numbered responses (half-test).

*
p < .05

**
p < .01

p < .001

All of the criterion scales, with the exception of the novelty scale in the U condition seem to exhibit a moderate degree of internal consistency, as does the composite measure (C). C represents a combination of all the criterion scale scores for a given response, and is the basis for the C_u and C_r scores and the mean response creativity scores in each condition. Since the reliability coefficients for C given in Table 9 are computed from the mean scores of the odd and even responses, these coefficients are more closely related to the latter two scores than to the former two.

At first sight, the difference between conditions for the novelty measurement was puzzling, but it became understandable in terms of the following considerations. A response which received the highest

novelty score was a response given extremely infrequently by subjects in the combined normative and dissertation samples. Highly creative responses would be expected to receive high novelty scores and uncreative responses would be expected to receive low novelty scores. However, some very uncreative responses received the highest novelty score simply because they were so trivial or inappropriate that few, if any, other subjects gave the same or highly similar responses. It may be argued that such a situation should hold for both the U and R conditions and should affect the internal consistency of the novelty measure to a similar degree in both conditions. However, if the responses judged to be trivial or inappropriate in the U condition were to be more novel than the responses judged to be trivial or inappropriate in the R condition, then the novelty measure would be expected to be less consistent in measuring a single variable in the U condition, since high scores could be assigned to both highly creative and uncreative responses. Table 10 suggests that such was the case. In order to test these data by means of a chi-square analysis, adjacent novelty categories were combined (three with four and five with six) to produce expected values in each cell which were greater than five. A chi-square equal to 84.0 was obtained, which with one degree of freedom is highly significant ($p < .0001$).

It is now possible to draw some better conclusions with regard to the degree to which the criterion scales measure separate functions. The rank correlations given in Tables 4 and 5 were again used as estimates of corresponding product-moment correlations and were then corrected where possible for attenuation due to errors of measurement (Walker & Lev, 1953, pp. 299-301). The following corrected correlations were obtained: mean novelty and mean surprise-stimulation scores in the U con-

TABLE 10
DISTRIBUTION OF NOVELTY SCORES FOR INAPPROPRIATE OR
TRIVIAL RESPONSES BY CONDITION

	Novelty Scores				
	Two	Three	Four	Five	Six
Responses in U condition receiving C scores of zero or one	0	7	2	13	40
Responses in R condition receiving C scores of zero or one	0	22	7	19	28

dition, $r = 0.66$; mean non-triviality and mean surprise-stimulation scores in the U condition, $r = 0.39$; mean novelty and mean non-triviality scores in the U condition, $r = -0.60$; mean novelty and mean non-triviality scores in the R condition, $r = 0.08$. These results suggest that in the U condition the novelty scale was measuring a function which was related to but not identical with the functions measured by the surprise-stimulation and non-triviality scales. In the R condition it would appear that the novelty and non-triviality scales were measuring essentially unrelated functions. The difference between the correlations for mean novelty and mean non-triviality in the two conditions is also consistent with the analysis of the data of Table 10 reported above.

Turning now to a consideration of the results of this research concerning possible relationships between cognitive and autonomic variables, it is important to keep in mind that subjects gave remarkably few responses which received creativity scores in the high range, i.e., scores of 8-10. The total 1083 responses given by all subjects in both the U and R conditions were distributed among creativity categories as

shown in Table 11. Most of the responses tabulated in the high creativ-

TABLE 11
PERCENTAGE OF MBT RESPONSES IN CREATIVITY CATEGORIES
FOR REGULATED AND UNREGULATED CONDITIONS

Condition	Low	Moderate	High
Regulated	32.1	67.1	0.8
Unregulated	21.1	75.3	3.6
Combined	25.9	71.7	2.4

ity category received scores of eight; only eight responses received scores of nine (0.7% of total), and not a single response received a score of ten. This situation resulted from the fact that scores greater than zero on the synthesis scale were rarely given by the judges, and when they were, they were scores of one rather than two. On a theoretical basis the synthesis criterion is assumed to distinguish the highest levels of creativeness on the MBT from lower levels.

It is conceivable that the judges were, perhaps, excessively conservative in assigning surprise and synthesis ratings to the responses, but on the other hand, the relative infrequency of highly creative responses is consistent, on theoretical grounds, with the fact that only 3 of the 48 MBT periods were classified as MH with respect to heart rate variability. The model proposed above suggests that a preponderance of HR_v scores in the moderate and high ranges should lead to more responses in the high creativity category. However, the three periods having MH classifications all occurred in the R condition and provide some embarrassment for the model in that none of the responses in these periods were scored in the high creativity category.

With these considerations in mind, attention will now be directed to the major results of this research. On the basis of confirmation of Hypothesis 1 and the results of the supplementary tests using scores on the criterion scales and the mean response creativity scores in the U and R conditions, it would seem justifiable to conclude that the role-inducing instructions used in this study were effective in producing differences in creativity. The results are consonant with those of Wild (1965) discussed earlier. However, it is important to bear in mind that the higher creativity scores of the U condition relative to the R condition were not generally very high, with the great majority of scores falling in the moderate range.

From the perspective of the model moderate creativity is conceived to result from the predominance of concentrated secondary thinking; thus, since the greatest difference between the U and R conditions is the difference between the percentage of moderately creative responses in the two conditions (See Table 11), one would expect the U condition to be associated with more concentrated secondary thinking than the R condition. It should be remembered in this connection that the model assumes that concentrated secondary thinking is associated with low heart rate variability. Thus, one can deduce that the mean level of heart rate variability should have been lower in the U condition than in the R condition. This is, of course, exactly what was found in testing Hypothesis 2. The hypothesis was formulated with the expectation that the unregulated instructions would lead to a predominance of responses in the high creativity range, whereas the regulated instructions would lead to a predominance of responses in the moderate creativity range. It appears now that this expectation was unrealistic, particularly when

one considers that highly creative individuals tend to be rather rare.

The foregoing interpretation, while making good theoretical sense, is not, however, the only available explanation for these results. It is altogether possible that the R condition stimulated more emotionality and was, therefore, associated with higher heart rate variability than the U condition. However, one would, perhaps, logically expect that the demand characteristics of the U condition would be more anxiety-arousing than those of the R condition. It would seem plausible that the "uncreative" individual or, perhaps, the individual who has doubts about his own intellectual capacities would tend to be more threatened by a situation which demands that he function in a free-wheeling, imaginative manner than by one which demands only that he function in an orderly, conventional manner.

The model suggested that the different modes of thinking identified earlier are associated with frequency distributions of HR_v having different means which are superimposed upon one another to form the frequency distribution for a given period. It was deduced from the model that a preponderance of high creativity would be associated with a distribution which reflected a predominance of moderate and high HR_v . If this were the case, then one would expect that the shape of the distribution or the location of the distribution relative to the HR_v level of unconcentrated secondary thinking would be important in determining the relationship between heart rate variability and creativity. For example, two subjects could manifest the same $\overline{HR_v}$ for a given period, and yet the distribution of one subject might approach normality, while the distribution of the other might approach rectangularity. In other words, the first subject might receive an MH or an LM classification, whereas the

second would almost certainly receive an MK classification. The tests of Hypotheses 3-5 which could be performed, however, did not support the model. The correlations in Tables 6 and 7 are suggestive or significant only when uncorrected for selection.

Neither the data related to Hypothesis 6 nor the correlations of Table 8 provide evidence in support of the model. However, it was noted that the multiplication task elicited higher heart rate variability than did any other condition of this study. Complementary to this fact was the observation that subjects in general showed great distaste for the task, and many were noticeably bothered by the situation. Thus, it had been anticipated that anxiety might be a significant determiner of the amount of variability in the heart rate, and that it could obscure any pattern associated with differences in thinking because of the magnitude of its effect on the heart rate.

There was, in addition, no evidence provided by the test of Hypothesis 7 for a relationship between resting level $\overline{HR}_V$ and creativity. However, it seems likely that $\overline{HR}_V$ for the reading condition was a poor index of resting heart rate variability. It had been hoped that the reading material provided and the demand characteristics of the situation would produce a predominance of unconcentrated secondary thinking (moderate HR_V). However, $\overline{HR}_V$ during the reading condition was for many subjects at a level which in the writer's experience is quite low and would presumably correspond to a state of focused rather than relaxed attention (see p. 49).

What conclusions may then be drawn from the results of this study? The MBT seems to have a reasonable degree of reliability and validity as a measure of creativity, as evidenced by the data of Table 9

and by the significant differences in the predicted direction between the scores on the criterion and overall creativity scales in the U condition and the corresponding scores in the R condition. Also, the results suggest that there was low to moderate reliability in the measurement of heart rate variability. Thus, it seems necessary to conclude that the predictions from the model regarding relationships between heart rate variability and creativity were not confirmed.

The multiplication task seemed to provide a reasonably reliable means for assessing the ability to do mental multiplication, but the fact that the level of difficulty of the problems varied in an uncontrolled fashion from subject to subject and session to session raises some serious doubts as to the adequacy of the formal test of Hypothesis 6 and the supplementary correlations of Table 8 for assessing the validity of the model.

Suggestions for Future Research

The data of this study, as a whole, suggest that the model is inadequate for representing the complex cognitive and physiological processes under study. There are certainly few data which provide a rationale for retaining the model. As discussed above, the significant results obtained in the direction opposite to that predicted by Hypothesis 2 were consistent with the model in connection with the results related to Hypothesis 1, since there were extremely few highly creative responses, with the great majority of responses receiving creativity scores between four and seven. However, such results would also be consistent with a model which predicted simply that originality would be associated with highly focused attention or concentration, and thus, with low heart rate

variability relative to a resting period. The suggestive, but unconvincing, post hoc finding that MK periods were associated with higher creativity scores in the U condition than were LM periods is also not consistent with the model.

On the other hand, a case can be made for the argument that the form of the hypotheses and the methodology employed did not provide an optimal situation for testing the validity of the model. In addition to methodological deficiencies noted previously, such as the unreliability of the respiration measure, the uncertainty in delineating the resting level, and the failure to elicit a substantial proportion of high creativeness, it must be noted that the classification technique leaves much to be desired. If it is to be useful, its crude arbitrary criteria need to be replaced, if possible, by empirical criteria derived from an intensive study of individual subjects.

Before the model can be adequately evaluated it seems necessary to await the results of further research which can provide information regarding the existence of the hypothesized ranges of heart rate variability corresponding to distinctly different patterns of cognitive functioning. For example, one might attempt to identify the hypothesized high HR_v range by studying the REM stage of sleep, which has been said to be characterized by the predominating influence of primary process thinking. In addition, HR_v data from situations which encourage "stream of consciousness" reporting in an environment of reduced sensory stimulation could be studied in connection with an assessment of the extent of primary thinking in the reports, perhaps, by some technique similar to that of Holt & Havel (1960) for assessing primary process in Rorschach protocols. In addition, it might be possible to identify the HR_v levels

of concentrated and unconcentrated secondary thinking for a given subject by varying reading material and instructions and then eliciting extensive introspective reports from the subject pertaining to his cognitive activity.

Subjects should be studied intensively in a number of different situations so that the presumed HR_v ranges for each subject could be precisely defined. Reliable measurements of respiration are essential to this task. Each subject should be initially studied with the goal of establishing a relationship which would permit allowances for the effect of respiration on HR_v to be made. Such a relationship would enable the investigator to determine what values each of the presumed HR_v ranges might assume in conditions differing substantially in respiration amplitude or rate. One of the major deficiencies of the present study is to be found in the fact that the respiration data were so unreliable, and that there was insufficient information for making the kinds of allowances discussed above.

The correlational analyses also do not seem entirely adequate for testing the validity of the model. If it is assumed, for purposes of illustration, that the model is valid in its suggestion that moderately high creativity can result from processes which are different from those mediating high creativity (i.e., secondary thinking vs. combined secondary and primary thinking), then there could very well be intersubject as well as intrasubject variation in the kind of cognitive activity employed in a given situation. In other words, some subjects might use almost exclusively secondary thinking to produce responses to the MBT, whereas others might rely almost entirely upon an integration of primary and secondary thinking. In addition, a given subject might use inte-

grated primary and secondary thinking to produce some responses and then switch to exclusively secondary thinking to produce others. Thus, if the model is also valid in proposing different heart rate variability correlates for different kinds of cognitive functioning, then the magnitude of obtained correlations between creativity and heart rate variability would be a function of the degree of homogeneity in the kind of cognitive functioning used to produce responses.

If specific ranges of heart rate variability corresponding to different kinds of thinking were not identified, then correlational analyses could be used in situations where the kind of cognitive functioning leading to the highest creativity scores would presumably be more homogeneous. For example, highly creative subjects could be identified by means of a battery of measures which have been shown to be related to creativity. These individuals could then be matched in terms of intelligence and other significant variables with another group which was identified as low in creativity by the creativity battery. The correlation between performance on the MBT and heart rate variability could then be computed separately for the two groups. If the model is generally valid, then the correlation should be positive for the high creatives and negative for the low creatives. Subjects could also be studied individually over an extensive period of time and correlational analyses could be performed within subjects.

The possibility of wide individual differences in cardiac functioning which might not be related to cognitive activity suggests that within subject analyses may be superior to across subject analyses. For example, in Tables 13 and 14 of Appendix E it can be seen that $\overline{HR}_v$ for Subject 12 varied between 16.46 and 18.59 bpm on Day 1 and between

15.65 and 19.08 bpm on Day 2. In contrast, $\overline{HR}_V$ for Subject 9 varied between 4.16 and 8.32 bpm on Day 1 and between 4.64 and 6.44 bpm on Day 2.

Another suggestion for future research is related to the elicitation and measurement of creative thinking. The subjects of this study seemed to produce fewer highly creative responses than the subjects comprising the normative sample. This apparent difference is somewhat difficult to interpret in that the writer scored the responses of the latter group. However, there is a hint in this that the conditions of the present study may have been less favorable for eliciting creative responses than those for the normative sample. The subjects in the normative group were not asked to play a role while giving their responses. In addition, they gave their responses anonymously in written form. It is conceivable that the role playing requirement introduced into this study encouraged the development of a mental set, which was less favorable for the higher levels of creativity, i.e., it predisposed subjects, perhaps, to rely more upon concentrated secondary thinking than would otherwise have been the case. Also, it is possible that the subjects of the present study may have felt self-conscious in being "on stage," so to speak, and thus functioned in a more constrained, intellectualized way than the subjects in the normative group. Such functioning would also appear to predispose subjects to rely to a great extent upon concentrated secondary thinking. Therefore, one might hypothesize that the MBT would elicit higher creativity if (1) subjects were asked to give their own responses rather than those that they think might be given by a prescribed type of individual, and if (2) they were requested to write rather than to say their responses aloud. Since writing might involve a

good proportion of concentrated secondary thinking, thinking periods and writing periods could be analyzed separately.

The system for scoring the MBT also needs to be improved so that higher reliability can be achieved. In selecting judges careful attention should be given to such factors as compatibility, cognitive complexity, and perhaps even creativeness. Large differences in personality characteristics such as dominance, self-confidence, etc. may invalidate the consensus procedure since the ratings of one of the judges may predominate in the consensus scores. Each of the judges must be sufficiently complex in cognitive organization to be prepared, as Bruner (1962) writes, ". . . to discern what is trivial improbability and what is effective surprise." In addition, the valid assessment of synthesis in the scoring procedure may depend upon the judge's capacity for flexible, divergent thinking, or his ability to abandon temporarily the critical, exacting standards of secondary process thinking, in short, upon his own capacity for creative thinking.

Since the reliabilities of the C_u and C_r scores were not available, these need to be determined for future research. While a certain advantage in using the C_u score was mentioned previously, the score also has certain disadvantages, and a better measure is clearly needed for assessing creativity. One such negative feature will be briefly mentioned. Consider the hypothetical distributions of response creativity (C) scores for two subjects given below. These distributions are qualitatively different, yet it may be noted that the C_u score in both cases would be equal to 71.

Subject A: C = 10 (3 responses)
C = 9 (4 responses)

C = 2 (1 response)
 C = 1 (3 responses)
 C = 0 (5 responses)

Subject B: C = 6 (11 responses)
 C = 5 (5 responses)
 C = 4 (2 responses)

It may also be worthwhile to look at the HR_v distribution associated only with high creativity scores for a given subject and to compare it with the distribution associated with moderate scores and also the distribution associated with low scores. Similarities and differences across subjects in the HR_v patterns associated with the different ranges of scores could then be explored.

Concluding Remarks

The psychophysiological literature has provided little information about possible relationships between heart rate variability and performance on cognitive tasks. The present study represents an attempt to expand the amount of knowledge in this area, but, unfortunately, the results provide only suggestive hints as to a direction which subsequent research might follow. In summary, it is argued that this study provides no evidence for the model presented; however, it is also argued that the design of the research and the specific hypotheses formulated did not permit an adequate test of the model. Thus, it is proposed that a decision to retain, reject, or modify the model be postponed until further information is available.

It must be admitted that this study has not provided even the most tentative answer to the question of whether creative thinking involves the same or different processes from other kinds of thinking (e.g., problem solving and decision making). Only additional research can in-

dicade whether the utilization of psychophysiological methods may eventually yield information from which a sound answer to this question can be derived.

APPENDIX A

ROLE-INDUCING INSTRUCTIONS

Instructions for Regulated Condition
(First Session)

Now, let's find out something about body changes occurring during certain kinds of thinking. Later, I'll tell you about some imaginary situations, and I'll ask you to list the consequences or results which might follow each of these. However, before I tell you more, let me describe a certain kind of person which I'd like you to imagine yourself being when you hear about these hypothetical situations.

The kind of person which I have in mind is a reliable, cautious person who likes to live in an orderly, structured world and values good common sense. He is an efficient, competent individual who is suspicious of "wild," fanciful ideas or of any ideas that seem inconsistent with commonly recognized knowledge and commonly held beliefs. In his opinion, those who would disregard the valuable "tried and true" approaches to problems in favor of unusual, fanciful, and unproven ideas are very impractical persons, who can never amount to much. He sees success as the natural reward of those who work hard and daydream little.

Now, suppose that this orderly, sensible person is giving a list of consequences, which might result from each of the imaginary situations which I'll describe in a few moments. Remember, he's not supposed to give causes, but just a list of the results. What would his list be?

You will be given six minutes for each situation to give the consequences which this person might think of, and I'll tell you when this

time is up. Any questions?

Instructions for Unregulated Condition
(Second Session)

Now, let's continue with the gathering of information concerning body changes occurring during other kinds of thinking. Again, I'll describe some imaginary situations, and I'll ask you to list the consequences or results which might follow each of these. However, before I do this, let me describe another type of person which I'd like you to imagine yourself being when you hear about these hypothetical situations.

The type of person which I have in mind this time is a clever, unconventional "loner," who typically has novel thoughts and fanciful, yet acute perceptions that may startle other people. He is inclined to point to the contradictions which he sees in human experience, and his ideas attack conventional ways of thinking and perceiving; his thoughts literally force others to view reality in new and different ways. He has a good sense of humor and is not reluctant to engage in "far out" speculation; in fact, he enjoys fantastic ideas.

Now, suppose that this clever, unconventional person is giving a list of consequences that might result from each of the imaginary situations, which I'll describe in a few moments. Remember, he's not supposed to give causes, but just a list of the results. What would his list be?

You will be given six minutes for each situation to give the consequences which this person might think of, and I'll tell you when this time is up. Any questions?

APPENDIX B

MODIFIED BENNETT TEST ITEMS

Item A: The average level of the world's oceans has dropped five feet during the period of a month. The water has simply disappeared, and there have been no significant changes in the tides. What have been the consequences?

Item B: Over a period of twenty years the average height of Americans has risen to seven feet and the average weight has increased to three hundred pounds. What have been the consequences?

Item C: Through some accident the average distance between the earth and the sun has been reduced to $3/4$ of its original size. What have been the consequences?

Item D: All vegetation on the earth has slowly changed until it is now predominately red rather than green in color. What have been the consequences of this development?

Item E: During the course of several centuries the sense of touch in humans has developed to the point that objects can be felt at a distance, i.e., actual contact with the body is not required to produce the sensation of touch. What have been the consequences?

Item F: What would be the consequences of every color having a distinct smell?

APPENDIX C

MULTIPLICATION PROBLEMS, SCORING OF PERFORMANCE,
AND RELATED INSTRUCTIONSProblem Sets

The three sets of multiplication problem lists used in this study are reproduced below. Each set varies in difficulty from each of the other sets. For Set I, carrying is required for each of the first two steps, that is, if the multiplications are done in the conventional manner. For Set II, no carrying is required for any step in the conventional multiplication procedure. For Set III, carrying is required for two of the multiplication steps, but for none of the addition steps, if the problem is solved in the conventional, routinized fashion.

<u>Set I</u>	<u>Set II</u>	<u>Set III</u>
List 1	List 1	List 1
173 X 4 = 692	52 X 14 = 728	16 X 54 = 864
124 X 6 = 744	43 X 13 = 559	26 X 34 = 884
138 X 7 = 966	32 X 14 = 448	27 X 36 = 972
186 X 4 = 744	61 X 13 = 793	18 X 48 = 864
164 X 4 = 656	23 X 21 = 483	27 X 29 = 783
143 X 6 = 858	41 X 18 = 738	17 X 47 = 799
126 X 7 = 882	23 X 13 = 299	24 X 37 = 888
119 X 6 = 714	31 X 21 = 651	29 X 34 = 986
129 X 7 = 903	62 X 12 = 744	19 X 47 = 893
147 X 4 = 588	31 X 16 = 496	26 X 28 = 728
139 X 6 = 834	53 X 13 = 689	27 X 34 = 918
197 X 4 = 788	81 X 12 = 972	16 X 47 = 752

List 2	List 2	List 2
174 X 4 = 696	51 X 13 = 663	24 X 36 = 864
137 X 7 = 959	61 X 14 = 854	27 X 28 = 756
169 X 4 = 676	32 X 21 = 672	18 X 49 = 882
134 X 6 = 804	54 X 14 = 756	28 X 34 = 952
119 X 8 = 952	73 X 13 = 949	13 X 74 = 962
148 X 6 = 888	41 X 17 = 697	26 X 29 = 754
196 X 4 = 784	32 X 24 = 768	27 X 37 = 999
142 X 7 = 994	21 X 17 = 357	14 X 63 = 882
178 X 4 = 712	42 X 13 = 546	24 X 39 = 836
117 X 6 = 702	71 X 12 = 852	16 X 49 = 784

Scoring of Performance on Multiplication Problems

Digits Correct	Solution Time Category	Score
3	very fast	8
3	fast	7
2	very fast	7
3	moderately fast	6
2	fast	6
3	moderately slow	5
2	moderately fast	5
1	very fast	5
3	slow	4
3	very slow	4
2	moderately slow	4
1	fast	4
2	slow	3
2	very slow	3
1	moderately fast	3
1	moderately slow	2
1	slow	2
1	very slow	2
0	-	1

Time categories were determined by dividing the distribution of solution times for each problem set into sextiles.

Instructions for Multiplication Problems

Now, you can forget about the person I described above, and we'll move along to another kind of thinking. The mechanical device on the table will be used to show you a series of multiplication problems, which you will solve in your head without pen or pencil. Soon after you have solved a problem, another problem will appear. Work as rapidly as you can without sacrificing accuracy. You should not go back to check your work before giving me your answer; however, by working carefully you should be reasonably sure that your answer is correct. Continue working on each problem until you have the solution or until I tell you to stop. Please do not speak except to give your answers, so that we may move along quickly from problem to problem. Only one answer per problem will be accepted--your first one--so be sure to give the entire answer all at one time from left to right, rather than to give each digit alone as you obtain it. Remember! Work as rapidly and as carefully as you can. If you have any questions, please ask them now. If not, we will begin at this point with some practice problems.

APPENDIX D

INSTRUCTIONS TO SCORERS OF PHYSIOLOGICAL DATA

Scoring of HR_v

Mark off successive five second intervals from the beginning of a condition. Each centimeter in the horizontal direction represents two seconds. If the last interval is three seconds or longer, add the necessary time period to complete the interval; if less than three seconds, then omit it. Score HR_v by finding the difference in beats per minute between the maximum and minimum levels of the heart rate for each five second interval. Each millimeter division in the vertical direction corresponds to two beats per minute.

Observe the following conventions in your scoring. Score to the nearest beat per minute. If any white space appears between the pen line and a millimeter line, then consider the heart rate to be the odd number, whereas if no white space appears between the pen line and the millimeter line, then consider the heart rate to be the even number. If a change in heart rate occurs exactly on an interval line, then consider the next level which the heart rate reaches in the succeeding interval as falling in both intervals.

If a large, abrupt change appears in the record, then the inter-beat interval given by the electrocardiogram should be checked to determine whether this was a legitimate heart rate change, or an artifact produced by the instrumentation.

Scoring of R_v

Mark off five second intervals corresponding to those for the heart rate. Score R_v by measuring the amplitude of the largest peak to trough change in half-millimeters. If the respiration tracing goes beyond the limit of the channel, indicate that R_v could not be scored for a given interval by entering a dash on the data sheet.

If, because of irregularities, it is not clear what should be called a peak and what a trough, then a potential amplitude change should be compared by inspection with the amplitude changes in the five preceding intervals. If the presumed change is obviously at least half as large as the average of the above-mentioned changes, and if the period of the change is at least half as long, then it should be scored as a legitimate amplitude change. If such a comparison cannot be made by inspection, then the average amplitude change discussed above should be computed. Highly erratic segments of a record should be omitted and their omission indicated by dashes on the data sheet.

Periodic checks should be made throughout to ensure that the intervals for HR_v and R_v are the same.

APPENDIX E
ADDITIONAL TABLES

TABLE 12
FREQUENCY OF MBT RESPONSES BY SUBJECT, CREATIVITY
CONDITION, AND CREATIVITY CATEGORY

Subject	Creativity Categories					
	Regulated Condition			Unregulated Condition		
	Low	Mod.	High	Low	Mod.	High
1	10	15	0	4	16	4
2	7	10	0	2	13	3
3	9	21	0	4	33	0
4	11	1	0	4	12	0
5	7	17	0	4	13	0
6	7	11	0	2	17	0
7	5	9	1	12	13	0
8	2	6	0	8	21	1
9	5	19	0	6	15	0
10	0	15	0	3	10	0
11	3	10	0	4	12	0
12	9	19	0	8	39	0
13	7	2	0	6	22	2
14	5	7	0	6	21	0
15	9	3	0	8	16	1
16	2	6	1	8	26	1
17	4	9	0	6	15	0
18	1	7	0	3	20	1
19	9	19	0	3	12	2
20	9	36	1	3	12	3
21	11	39	0	14	26	1
22	5	3	0	3	16	1
23	9	24	1	2	34	2
24	8	14	0	4	20	0
Totals	154	322	4	127	454	22

TABLE 13

TABULATION OF DATA FOR DAY 1 BY SUBJECT AND CONDITION

Subject		Reading $\overline{HR}_v$		Creativity				Multiplication			
No.	Sex	Silent	Oral	$\overline{HR}_v$ Class.	C_u	C_r	$\overline{HR}_v$	$\overline{HR}_v$ Class.	$\overline{HR}_v$	Total Score	Problem Set
1	M	9.07	11.00 ^a	MX		69	11.64	MX	12.11	48	I
2	F	7.03		LM		55	7.71	LM	7.65	55	I
3	M	9.47	12.02	LM		72	11.16	MH	10.71	25	III
4	F	9.42	8.34	MX		12	14.86 ^b	MH	10.96	42	I
5	M	7.66		LM		66	9.66	MH	11.31	76	III
6	M	13.89		MX		56	18.19	MH	13.48	56	III
7	F	6.84		LM	60		6.80	LM	9.43	45	III
8	M	15.92	13.56	MX	78		13.21 ^b	MX	17.62	58	II
9	M	4.16	4.85	LM	63		8.32	LM	6.46	35	III
10	F	9.67		LM	66		8.93	LM	8.51	44	I
11	M	11.92		LM	68		9.54	MX	11.92	44	III
12	F	16.59		MX	72		16.46	MX	18.59	55	II
13	F	10.86		LM		17	9.39	LM	8.80	56	II
14	M	6.17		LM		55	7.04	LM	8.48	62	II
15	M	13.70		MX		23	12.25	MX	15.51	49	II
16	M	8.31		MX		44	14.04	LM	10.26	51	I
17	F	13.15	11.76	LM		51	12.52 ^b	MH	15.31	68	I

TABLE 13--CONTINUED

Subject		Reading $\overline{HR}_v$		Creativity				Multiplication			
No.	Sex	Silent	Oral	HR_v Class.	C_u	C_r	$\overline{HR}_v$	HR_v Class.	$\overline{HR}_v$	Total Score	Problem Set
18	F	13.28		MH		38	14.90	LM	9.43	60	II
19	F	13.15		MX	73		13.42	MX	12.56	49	II
20	M	6.63		LM	83		7.41	LM	8.33	63	III
21	M	9.14	9.11	LM	77		7.72	MX	10.00	44	III
22	M	8.14		LM	78		11.96	LM	11.91	48	I
23	F	9.18	11.60	MX	86		12.05	LM	8.33	47	I
24	F	10.50		MX	71		14.58	MH	11.48	60	I

^aThe HR_v frequency distribution for the oral reading condition was used for classifying the HR_v frequency distribution for the oral periods of the creativity condition. This procedure was used whenever oral periods were more numerous than silent periods.

^bMean HR_v based on silent periods was used in comparing the heart rate variability for the U and R conditions (Subject 4 - 14.02; Subject 8 - 15.16; Subject 17 - 12.39).

TABLE 14

TABULATION OF DATA FOR DAY 2 BY SUBJECT AND CONDITION

Subject		Reading $\overline{HR}_v$		Creativity				Multiplication			
No.	Sex	Silent	Oral	HR_v Class.	C_u	C_r	$\overline{HR}_v$	HR_v Class.	$\overline{HR}_v$	Total Score	Problem Set
1	M	10.46	12.67 ^a	MX	86		13.07	MX	13.98	51	I
2	F	8.64		MX	82		7.10	LM	7.59	49	II
3	M	6.61	7.91	MX	75		9.81	LM	8.25	38	III
4	F	4.76		LM	65		6.95	LM	7.78	49	II
5	M	8.74		MX	71		8.10	LM	10.27	64	III
6	M	7.31	10.16	MX	72		11.42 ^b	LM	7.19	58	III
7	F	9.57		MX		60	9.83	LM	9.11	58	III
8	M	12.21		MX		33	12.07	MX	14.81	39	III
9	M	4.75	6.44	LM		77	6.42	LM	4.64	47	III
10	F	10.35		LM		69	9.80	MX	12.09	45	I
11	M	8.68		MH		64	9.78	MH	11.72	61	I
12	F	15.97		LM		72	15.65	MX	19.08	67	I
13	F	7.47	8.25	MX	81		11.86 ^b	LM	10.00	37	III
14	M	5.66	7.49	LM	70		8.72 ^b	LM	8.63	67	II
15	M	11.60		MX	73		14.30	MX	16.82	62	I
16	M	10.30	13.41	MX	77		14.43 ^b	MX	10.43	52	I
17	F	7.74		LM	78		8.70	LM	10.62	67	I

TABLE 14--CONTINUED

Subject		Reading $\overline{HR}_v$		Creativity				Multiplication			
No.	Sex	Silent	Oral	HR_v Class.	C_u	C_r	$\overline{HR}_v$	HR_v Class.	$\overline{HR}_v$	Total Score	Problem Set
18	F	10.48		LM	73		11.13	MH	14.80	44	III
19	F	12.30		MX		69	15.47	MX	15.30	39	III
20	M	8.43	9.38	LM		83	9.37 ^b	LM	5.67	66	III
21	M	6.82	11.38	LM		78	8.56	MX	10.91	55	III
22	M	11.42		MH		18	12.67	MX	15.59	36	II
23	F	8.78	12.90	MX		79	14.32	MX	13.12	66	I
24	F	10.93		MX		60	10.90	MH	11.13	48	II

^aThe HR_v frequency distribution for the oral reading condition was used for classifying the HR_v frequency distribution for the oral periods of the creativity condition. This procedure was used whenever oral periods were more numerous than silent periods.

^bMean HR_v based on silent periods was used in comparing the heart rate variability for the U and R conditions (Subject 6 - 13.17; Subject 13 - 8.22; Subject 14 - 7.15; Subject 16 - 10.09; Subject 20 - 7.70).

TABLE 15
 ADDITIONAL HR_v DATA FOR DAY 1 BY SUBJECT AND CONDITION

Subject	Creativity			Multiplication		
	$HR_v(Q_3)$	$HR_v(Q_1)$	$HR_v(Q_{3-1})$	$HR_v(Q_3)$	$HR_v(Q_1)$	$HR_v(Q_{3-1})$
1*	14.27	7.75	6.52	15.81	7.38	8.43
2*	9.43	5.36	4.07	9.58	5.42	4.16
3*	13.45	7.98	5.47	12.32	8.38	3.94
4*	19.00	10.50	8.50	13.38	8.75	4.63
5*	11.86	6.17	5.69	13.92	9.17	4.75
6	24.62	11.05	13.57	15.81	9.25	6.56
7	7.55	3.98	3.57	12.88	6.92	5.96
8	17.06	7.94	9.12	23.88	11.62	12.26
9	10.05	4.43	5.62	7.31	3.75	3.56
10	10.97	6.01	4.96	10.05	5.68	4.37
11	11.60	6.72	4.88	14.62	9.08	5.54
12*	20.88	10.58	10.30	22.35	13.25	9.10
13*	11.62	6.34	5.28	10.25	6.88	3.37
14*	8.61	4.40	4.21	11.25	5.67	5.58
15*	17.25	6.62	10.63	20.75	9.88	10.87
16*	19.38	7.95	11.43	10.75	6.45	4.30
17*	14.66	10.34	4.32	16.50	12.83	3.67
18	17.55	11.22	6.33	11.38	6.75	4.63
19	16.71	8.89	7.82	18.67	7.60	11.07
20	9.02	5.20	3.82	10.31	4.94	5.37
21	9.12	3.45	5.67	13.62	5.38	8.24
22	13.07	7.05	6.02	14.00	8.17	5.83
23	15.92	7.41	8.51	10.75	5.11	5.64
24	17.25	11.52	5.73	13.75	7.75	6.00

* Subjects receiving regulated instructions on Day 1.

TABLE 16
 ADDITIONAL HR_v DATA FOR DAY 2 BY SUBJECT AND CONDITION

Subject	Creativity			Multiplication		
	$HR_v(Q_3)$	$HR_v(Q_1)$	$HR_v(Q_{3-1})$	$HR_v(Q_3)$	$HR_v(Q_1)$	$HR_v(Q_{3-1})$
1	16.30	8.25	8.05	16.38	10.12	6.26
2	9.15	4.69	4.46	9.29	5.21	4.08
3	12.38	5.89	6.49	10.05	5.19	4.86
4	8.35	4.55	3.80	10.58	4.69	5.89
5	11.08	4.75	6.33	13.12	4.75	8.37
6*	14.34	7.04	7.30	8.47	4.75	3.72
7*	13.31	5.92	7.39	10.88	5.81	5.07
8*	15.88	7.25	8.63	20.25	9.55	10.70
9*	8.20	3.29	4.91	5.75	2.80	2.95
10*	11.50	7.00	4.50	16.38	7.12	9.26
11*	11.84	7.43	4.41	14.19	9.25	4.94
12	18.02	12.96	5.06	22.88	14.92	7.96
13	15.17	8.00	7.17	12.59	7.34	5.25
14	11.02	6.54	4.48	11.62	4.75	6.87
15	17.75	9.20	8.55	20.75	9.88	10.87
16	17.93	10.50	7.43	13.13	5.42	7.71
17	10.89	6.53	4.36	12.20	8.60	3.60
18*	12.78	7.71	5.07	17.35	11.79	5.56
19*	20.83	9.50	11.33	18.75	8.25	10.50
20*	11.80	5.81	5.99	6.94	3.25	3.69
21*	10.21	3.74	6.47	16.00	3.25	12.75
22*	14.45	9.00	5.45	17.29	11.95	5.34
23*	17.69	10.96	6.73	15.75	10.25	5.50
24	13.83	7.25	6.58	12.25	8.81	3.44

* Subjects receiving regulated instructions on Day 2.

REFERENCES

- Barratt, E. S. ANS activity related to intraindividual variability. Unpublished terminal report of Project M-4534, National Institute of Mental Health, 1961. Cited by M. Hnatow & P. J. Lang, Learned stabilization of cardiac rate. Psychophysiol., 1965, 1, 330-336.
- Barron, F. The psychology of creativity. In New directions in psychology. New York: Holt, Rinehart, & Winston, 1965. Pp. 1-134.
- Bennett, G. K. Test of productive thinking. Unpublished test. New York: The Psychological Corp., 1944.
- Blatt, S. J. Cardiac arousal during mental activity. J. abnorm. soc. Psychol., 1961, 63, 272-282.
- Blatt, S. J. & Stein, M. I. Efficiency in problem solving. J. Psychol., 1959, 48, 193-213.
- Brenner, C. An elementary textbook of psychoanalysis. Garden City, N. Y.: Doubleday Anchor, 1957.
- Bruner, J. S. The conditions of creativity. In H. E. Gruber, G. Terrell, & M. Wertheimer (Eds.), Contemporary approaches to creative thinking. New York: Atherton Press, 1962. Pp. 1-30.
- Dement, W. C. An essay on dreams: The role of physiology in understanding their nature. In New directions in psychology. New York: Holt, Rinehart & Winston, 1965. Pp. 137-257.
- Getzels, J. W. & Jackson, P. O. Creativity and intelligence. New York: Wiley, 1962.
- Guilford, J. P. Consequences test. Beverly Hills, Calif.: Sheridan Supply Co., 1958.
- Guilford, J. P. Factors that aid and hinder creativity. In J. C. Gowan, G. D. Demos, & E. P. Torrance (Eds.), Creativity: Its educational implications. New York: Wiley, 1962. Pp. 106-123.
- Guilford, J. P. A psychometric approach to creativity. In H. H. Anderson (Ed.), Creativity in childhood and adolescence. Palo Alto, Calif.: Science & Behavior Books, 1965.
- Hare, R. D. Psychopathy, autonomic functioning, and the orienting response. J. abnorm. Psychol. Monogr. Suppl., 1968, 73(3), Part 2.

- Hnatiow, M. & Lang, P. J. Learned stabilization of cardiac rate. Psychophysiol., 1965, 2, 330-336.
- Holt, R. R. & Havel, Joan. A method for assessing primary and secondary process in the Rorschach. In Maria A. Rickers-Ovsiankina (Ed.), Rorschach psychology. New York: Wiley, 1960. Pp. 263-315.
- Jackson, P. W. & Messick, S. The person, the product, and the response: Conceptual problems in the assessment of creativity. J. Pers., 1965, 33, 309-329.
- Kagan, J. & Rosman, Bernice L. Cardiac and respiratory correlates of attention and an analytic attitude. J. exp. child Psychol., 1964, 1, 50-63.
- Koestler, A. The act of creation. New York: Macmillan, 1964.
- Kris, E. On preconscious mental processes. Psychoanal. Quart., 1950, 19, 540-560.
- Kris, E. Psychoanalytic explorations in art. New York: International Universities Press, 1952.
- Lacey, J. I., Bateman, D. E., & Van Lehn, R. Autonomic response specificity: An experimental study. Psychosom. Med., 1953, 15, 8-21.
- Lacey, J. I. & Lacey, Beatrice. The relationship of resting autonomic activity to motor impulsivity. In Proceedings of the Association for Research in Nervous and Mental Disease. The brain and human behavior. Baltimore: Williams & Wilkins, 1958, 36, 144-209.
- McNemar, Q. Psychological statistics. (2nd ed.) New York: Wiley, 1955.
- Mandler, G. & Mandler, Jean M. Associative behavior and somatic response. Canad. J. Psychol., 1962, 16, 331-343.
- Maslow, A. H. Creativity in self-actualizing people. In H. H. Anderson (Ed.), Creativity and its cultivation. New York: Harper & Brothers, 1959.
- Meyers, W. J. Heart rate fluctuations and fixed foreperiod reaction time. Psychophysiol., 1966, 3, 40-45.
- Obrist, P. A. Cardiovascular differentiation of sensory stimuli. Psychosom. Med., 1963, 25, 450-459.
- Pine, F. Thematic drive content and creativity. In M. T. Mednick & S. A. Mednick (Eds.), Research in personality. New York: Holt, Rinehart, & Winston, 1963. Pp. 563-574.
- Pine F. & Holt R. R. Creativity and primary process: A study of adaptive regression. J. abnorm. soc. Psychol., 1960, 61, 370-379.

- Price, A. D. Scoring manual for the Modified Bennett Test. (Mimeographed.)
- Rapaport, D. Toward a theory of thinking. In D. Rapaport (Ed.), Organization and pathology of thought. New York: Columbia University Press, 1951. Pp. 689-730.
- Schafer, R. Regression in the service of the ego: The relevance of a psychoanalytic concept for personality assessment. In G. Lindzey (Ed.), Assessment of human motives. New York: Rinehart, 1958.
- Taylor, D. W. Thinking and creativity. Ann.N. Y. Acad. Sci., 1960, 91, 108-127.
- Walker, Helen M. & Lev, J. Statistical inference. New York: Holt, 1953.
- Welford, N. J., Lacey, Beatrice, & Peckham, C. Computer identification and measurement of cardiac activity. Psychophysiol., 1964, 1, 111-114.
- Wild, Cynthia. Creativity and adaptive regression. J. pers. soc. Psychol., 1965, 2, 161-169.
- Wilson, J. W. D. & Dykman, R. A. Background autonomic activity in medical students. J. comp. physiol. Psychol., 1960, 53, 405-411.

AUTOBIOGRAPHICAL STATEMENT

The author is currently an Instructor in Psychology at Monmouth College, West Long Branch, New Jersey, a position he has held since September 1968. He received the Bachelor of Arts degree from the University of California at Los Angeles in 1962, and also the Master of Arts degree from the same institution in 1963.

As an undergraduate the author was a physics major for three years before turning to the study of psychology. He has been employed as an engineering psychologist in the aerospace industry and also as a counselor in a narcotics rehabilitation program.

The author is thirty years of age, married, and has one child. At present, he resides at 20 Monmouth Drive in Deal, New Jersey.