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NAME OF AUTHOR/*NOM DE L'AUTEUR* DAVID ARTHUR PEARSON

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NAME OF SUPERVISOR/*NOM DU DIRECTEUR DE THÈSE* Dr D.W.R. WILSON

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DATED/*DATÉ* 28/4/[illegible]5 SIGNED/*SIGNÉ* D A Pearson

PERMANENT ADDRESS/*RÉSIDENCE FIXÉ* 9830-105 STREET, #706
EDMONTON, ALBERTA, CANADA

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THE UNIVERSITY OF ALBERTA

THE HYPOTHESIZING ABILITIES OF ELEMENTARY SCHOOL STUDENTS

by

DAVID PEARSON

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "The Hypothesizing Abilities of Elementary School Students" submitted by David A. Pearson in partial fulfilment of the requirements for the degree of Master of Education.

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Supervisor

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Date ....April.......... 1975

ABSTRACT

The main purpose of this study was to determine the abilities of elementary school students with respect to the formulation of hypotheses. To this end, three tasks which required the demonstration of such abilities were devised and administered, the task modes and pupil groupings taking the following forms: visual-mechanical mode (individual administration); visual mode preceded by visual-mechanical mode (individual administration); and visual mode, not preceded by visual-mechanical mode (group administration).

The principal sample, which was involved in the individually administered procedures, consisted of one hundred and twenty-five students. The secondary experimental sample, which was presented with the group visual task, consisted of two hundred students drawn from outside the principal experimental sample.

All students within the principal experimental sample were assigned to high, average or low intelligence levels within each grade, these levels being determined on the basis of the results of the S.R.A. Test which was administered as part of the study.

During performance of the individual visual-mechanical task students were encouraged to formulate as many hypotheses as possible in explanation of the phenomena generated by means of the 'Hypothesis Machine.'

During performance of the individual visual task students were encouraged to formulate as many hypotheses as possible in explanation of relationships depicted on printed representations of the machine

and its contents.

The group visual task was designed and conducted in a manner similar to that of the individual visual task.

Complete audio-tape and written records were kept of the students' responses to the tasks.

Analysis of the resulting data indicated the following:

1. Significant relationships exist between the Formulation of Hypotheses Scores obtained from the two individually administered tasks.

2. Significant relationships exist between the Formulation of Hypotheses Scores (both individual visual-mechanical and individual visual) and age, grade, general intelligence, verbal meaning ability and number facility.

3. Significant differences exist between grade three and four boys and girls in their ability to formulate hypotheses.

4. With respect to general intelligence, the high I.Q. group, in general performed significantly better on individually administered Formulation of Hypotheses Scores than did the low I.Q. group.

5. Significant differences in the Formulation of Hypotheses Scores (both individual visual-mechanical and individual visual) exist between grades one and four, one and six, and between grades two and six. Generally a growth in the ability to formulate hypotheses as indicated by the scores obtained in the tasks administered, occurred with increase in grade level, the low scores achieved by grade five students on the individual visual-mechanical task, providing an exception to this trend.

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Chapter 1

INTRODUCTION AND BACKGROUND

One of the newer trends which has arisen in Elementary School Science is epitomized by 'Science—A Process Approach' (SAPA)—a curriculum formulated by the American Association for the Advancement of Science (AAAS). Unlike other science programs which have tended to emphasize the content or product of science, SAPA as the title implies, has created a curriculum which emphasizes the processes [illegible] procedures associated with the scientific endeavour.

In 1968, the implementation of a new science curriculum based upon the precepts of the SAPA program was initiated within the Province of Alberta. Unlike the SAPA program which, in emphasizing the development of the processes, correspondingly de-emphasized the acquisition of content, the new Alberta program views science as both a process of inquiry and a body of knowledge. Accordingly equal emphasis is given in the Alberta program to the development of inquiry skills and the acquisition of content.

THE PROBLEM

The evaluation of the effectiveness of any program depends heavily upon whether or not the objectives of that program are clearly defined, are testable, and are tested objectively.

Student achievement within the SAPA program is defined entirely on the basis of behavioural objectives. Student achievement within the Alberta program is defined in terms of specified behavioural objectives, acquisition of specified content, and adoption of specified attitudes.

How, then, are such objectives evaluated? The SAPA program utilizes instruments to determine a student's performance with respect to a specified process immediately following the completion of a series of lessons specifically designed to develop that process.

Although the majority of SAPA instruments are designed for individual student evaluation only, evaluation capabilities on a group basis are claimed for certain instruments for the simple or 'basic' processes, and a further instrument provides a basis for long term assessment of progress in the basic processes. Up to the present, however, no instrument has been available for the evaluation of ability or achievement in any complex or 'integrated' process on a group basis.

The Alberta science program does not set out any standardized evaluation techniques or procedures. The Alberta Curriculum Guide (1969) suggests that teachers themselves design and implement instruments capable of evaluating processes and attitudes effectively.

It can be seen that an urgent need exists for the development of effective, valid and reliable individual and group tests, capable of evaluating basic and integrated processes.

In recent years, a series of studies has been carried out under the auspices of the Department of Elementary Education, University of Alberta. Such studies have determined the abilities of elementary school children in the performance of tasks associated with the processes of classification (Blackford, 1970), quantification (Kellough, 1971) and inference (Plester, 1972).

THE PURPOSE

The present study is an attempt to extend the range of these studies in order to establish further valid evaluation measures of process. Accordingly, this study will attempt to determine the behavioural characteristics and process skills of students with respect to one of the integrated processes—namely that of the 'Formulation of Hypotheses.'

SIGNIFICANCE OF THE STUDY

It is hoped that this study will:

1. Establish criteria which may provide the basis for the evaluation of children's abilities in formulating hypotheses.

2. Indicate at which level(s) an emphasis on instruction in formulating hypotheses may be most productive.

3. Indicate any relationships which may exist between the ability to formulate hypotheses on the basis of mental manipulation of visual data only, and the ability to formulate hypotheses on the basis of both visual and mechanical data, that is, an abstract versus a concrete manipulation of data.

4. Indicate any relationships which may exist between the ability to formulate hypotheses and: (a) grade, (b) age, (c) sex, (d) general intelligence, (e) perceptual speed ability, (f) verbal

meaning ability, (g) spatial-relations ability, (h) number facility, and (i) reasoning ability.

The decision to focus attention of each of these variables in this study, rested upon the following considerations:

Although specified by several bodies g. AAAS, Alberta Department of Education) as a process to be included in the elementary science program, formal data supportive of this decision has been lacking up to the present, little research having been carried out with respect to hypothesis formulation at the elementary school level. With little known of the nature of this process, as well as of the ability to hypothesize, an awareness of the variables, which might serve as predictors of the ability to formulate hypotheses, should be of assistance to the teacher intent upon evaluation and development of the hypothesizing abilities of students.

Torrance (1962) has shown that with increase in elementary grade level there is generally an associated increase in creative ability (as defined and measured by Torrance). However in grade four a marked exception to this trend occurs, a 'slump' in creative ability being manifested at this level. Extending this general finding to include the suggestion of Martin (1971) that creative ability and hypothesizing ability are interrelated, hypothesizing ability being at least in part a creative act, the grade level of a student should then be a predictor of hypothesizing ability, should both Torrance and Martin be correct in their assumptions and conclusions.

The variable 'sex' has been included since the mechanical components of the Hypothesis Machine may generally be found to be of wider appeal to boys rather than to girls, greater curiosity and interest in the machine, perhaps giving boys an advantage over girls in scoring levels obtained while using the machine.

According to Torrance (1962) and Kneller (1965) significant relationships exist between general intelligence and creative ability. Again accepting Martin's position that hypothesizing ability may be dependent in part upon creative ability; then relationships may exist between ability to hypothesize and general intelligence and/or components of general intelligence.

Records of most, if not all of these variables are kept by the classroom teacher. In cases where they are not immediately available they may be readily assessed.

In this and other studies in the series each of these variables have been afforded attention. Their inclusion in this study also, will enable ready comparison of findings to be made between studies.

DEFINITIONS

1. The AAAS-SAPA definition of Hypothesis states that:

> An hypothesis is a generalization that includes all objects, or events of the same class. Hypotheses can be formulated on the basis of observations or of inferences (AAAS Commission on Science Education, 1965, p. 31).

This definition will not be used for the purposes of this investigation since an hypothesis does not necessarily have to constitute a generalization. It may in fact consist of an attempt to account for a very specific situation in very specific terms.

The Alberta Curriculum Guide definition of 'formulating hypotheses' states that:

> The desired pupil behaviour involves developing increased competency in stating an hypothesis regarding causes of a phenomenon or the relationship between two variables. An hypothesis tells how to observe an expected outcome of an experiment (Alberta Curriculum Guide, 1969, p. 8).

This definition is also regarded as ~~being~~ unacceptable as the phrase 'the relationship between two variables' imposes too restrictive a condition. The formulation of hypotheses often involves the explanation of a phenomenon or phenomena in which more than two variables come into play.

For the purposes of this study hypotheses will be defined as 'alternative tentative explanations of observed phenomena, which lead to the formulation of testable predictions. The testable predictions, in turn, lead to the substantiation and acceptance of the original explanations, or to their rejection or modification.'

2. High Quality Hypothesis. Involves an explanation which is functional within the defined limits of the experimental situation.

3. Formulation of Hypotheses Score. Refers to scores based upon the number of functional hypotheses formulated by the test subject. These scores may be characterized according to specific task situations and student groupings as follows:

   a. Formulation of Hypotheses Score (individual visual-mechanical)

   b. Formulation of Hypotheses Score (individual visual)

   c. Formulation of Hypotheses Score (group visual).

4. <u>Formulation of Hypotheses Speed Score</u>. Refers to a score based upon the number of functional hypotheses formulated by the test subject, divided by the time required for their formulation.

5. <u>Intelligence</u>. For the purposes of this study intelligence has been designated as low, average or high on the basis of the score obtained on the S.R.A. <u>Primary Mental Abilities</u> 2-4 (Grades 1, 2, 3) or 4-6 (grades 4, 5, 6). On the basis of percentile norms provided with the S.R.A. test, students from the first to thirty-third percentile in each grade will be designated as the low I.Q. group for that grade. Students from the thirty-fourth to sixty-seventh percentile in each grade will be designated as the average I.Q. group for that grade, and students from the sixty-eighth to ninety-ninth percentile in each grade will be designated as the high I.Q. group for that grade.

6. <u>Verbal Ability</u>. Refers to the score obtained by the subjects on the 'Verbal Meaning Ability' subtest of the S.R.A. Primary Mental Abilities Test.

7. <u>Spatial Relations Ability</u>. Refers to the score obtained by subjects on the 'Spatial Relations' subtest of the S.R.A. Primary Mental Abilities Test.

8. <u>Numerical Ability</u>. Refers to the score obtained by subjects on the 'Number Facility' subtest of the S.R.A. Primary Mental Abilities Test.

9. <u>Reasoning Ability</u>. Refers to the score obtained by subjects on the 'Reasoning' subtest of the S.R.A. Primary Mental Abilities Test.

10. Perceptual Speed Ability. Refers to the score obtained by the subjects on the 'Perceptual Speed' subtest of the S.R.A. Primary Mental Abilities Test.

HYPOTHESES

1. No significant relationship exists between the Formulation of Hypotheses Score (individual visual-mechanical) and the Formulation of Hypotheses Score (individual visual).

2. No significant relationship exists between the Formulation of Hypotheses Speed Score (individual visual-mechanical) and the Formulation of Hypotheses Speed Score (individual visual).

3. There are no significant relationships between the Formulation of Hypotheses Scores (both individual visual-mechanical and individual visual), the Formulation of Hypotheses Speed Scores (both individual visual-mechanical and individual visual) and: (a) sex, (b) age, (c) grade, (d) general intelligence, (e) verbal meaning ability, (f) number facility, (g) spatial relations ability, (h) perceptual speed ability, and (i) reasoning ability.

4. There is no significant relationship between the Formulation of Hypotheses Score (group visual), the Formulation of Hypotheses Speed Score (group visual) and: (a) sex, (b) age, and (c) grade.

5. There is no significant interaction between grade level and sex with respect to:

(a) formulation of hypotheses score (individual visual-mechanical),

(b) formulation of hypotheses speed score (individual visual-mechanical),

(c) formulation of hypotheses score (individual visual),

(d) formulation of hypotheses speed score (individual visual).

6. There is no significant difference between boys and girls in:

(a) formulation of hypotheses score (individual visual-mechanical),

(b) formulation of hypotheses speed score (individual visual-mechanical),

(c) formulation of hypotheses score (individual visual),

(d) formulation of hypotheses speed score (individual visual) in each of the grades one through six.

7. There is no significant difference between grade levels in:

(a) formulation of hypotheses score (individual visual-mechanical),

(b) formulation of hypotheses speed score (individual visual-mechanical),

(c) formulation of hypotheses score (individual visual),

(d) formulation of hypotheses speed score (individual visual) from grades one through six.

8. There is no significant interaction between grade level and I.Q. with respect to:

(a) formulation of hypotheses score (individual visual-mechanical),

(b) formulation of hypotheses speed score (individual visual-mechanical),

(c) formulation of hypotheses score (individual visual),

(d) formulation of hypotheses speed score (individual visual).

9. There is no significant difference between low, average and high I.Q. students in

(a) formulation of hypotheses score (individual visual-mechanical),

(b) formulation of hypotheses speed score (individual visual-mechanical),

(c) formulation of hypotheses score (individual visual),

(d) formulation of hypotheses speed score (individual visual), in each of the grades one through six.

10. There is no significant interaction between I.Q. and sex with respect to:

(a) formulation of hypotheses score (individual visual-mechanical),

(b) formulation of hypotheses speed score (individual visual-mechanical),

(c) formulation of hypotheses score (individual visual),

(d) formulation of hypotheses speed score (individual visual).

LIMITATIONS

1. Prior experience of the students in the formulation of

hypotheses both in science and in other areas, was not taken into account in this study.

2. Although every effort was made to standardize procedures in administering and evaluating each task involving the formulation of hypotheses, experimenter bias may have influenced the administration and evaluation of the tasks.

3. The schools selected for this study were not selected at random, but were chosen by their respective administrations. This could mean that a truly representative sample was not obtained and this fact should be carefully considered if attempts are made to generalize any of the results with respect to other populations.

4. The validity and reliability of the tests employed was not established. The tests however, would appear to have 'face validity' if it is accepted that the tasks set involve the 'formulation of hypotheses' for their completion.

OVERVIEW OF THE STUDY

The nature of the problem under investigation having been presented, a review of the literature related to the study will be presented in Chapter 2. Chapter 3 contains a detailed description of each aspect of the experimental design, the methods and materials used in the study, and the statistical analysis used to test the hypotheses. The results of the analysis of data are reported in Chapter 4, together with a descriptive analysis of student performance with respect to the instruments used. Finally, Chapter 5 provides a summary of the results of the study, including conclusions, implications and suggestions for further research.

Chapter 2

REVIEW OF RELATED LITERATURE

Research literature pertaining to this study will be discussed under two main headings: research related to the development and evaluation of process skills, and research related to the process of formulating hypotheses.

PROCESS SKILLS

Prior to the nineteen-fifties, two distinct approaches towards science education were commonly adopted. The 'content' approach was most frequently followed and, to a lesser extent, the 'Scientific Method' approach was used.

The content approach emphasized the learning of a body of knowledge, of descriptive relationships, and of generalizations that provided the most widely applicable explanations of phenomena.

The scientific method approach encouraged students to solve problems, usually in accordance with the rigidly defined steps of certain formal models. The steps were considered representative of the essential steps encompassed by scientific reasoning. Kneller (1966) maintained that formal models, as commonly utilized, were of limited benefit to young students, on account of their highly abstract nature, and were also of limited benefit to older students who would likely have advanced to a stage where more specific skills were needed.

Gagne considered the scientific method approach to be limited in potential because it fails to establish a broad basis of knowledge which could be generalized to all situations which are likely to be encountered by the student (AAAS Commission on Science Education, 1965, p. 11).

The launching of Sputnik by the Russians in 1957 had a profound effect on science and science education in the United States. Fearing that American science standards in general were lagging behind those of the Russians, a large-scale reappraisal of science education was initiated in an attempt to upgrade, as quickly as possible, the quality and prestige of science and science education. This reappraisal was illuminated by a strong desire for involving students more directly with the 'modus operandi' of the scientist.

As new programs rapidly developed in response to the new demands of science education, the emergence of two distinct approaches became evident—namely the 'Creative' approach and the 'Process' approach.

The creative approach, as the term implies, was based upon a consideration of the scientist as being a highly creative individual. Accordingly attempts were made to develop the general creativity of the student. Situations designed to attain this objective were specifically devised to encourage, to a maximum, the generation of novel ideas.

While Gagne accepts the generation of novel ideas as a worthy objective, he nevertheless considers a program whose raison d'être is solely the achievement of that one objective as being too limited in perspective:

> It is not enough to be creative 'in general'—one must learn to carry out critical and disciplined thinking in connection with each of the processes of science (in AAAS Commission on Science Education, 1965, p. 4).

The present approach to science teaching regards the scientist's behaviour as complex sets of intellectual abilities or processes which are capable of being analysed into simpler components. Advocates of this view tend to consider that the processes can in fact be learned, and that a sequence of instructions may be devised to facilitate their acquisition. For the purpose of a program of this type, the acquisition of process skills is based on initial familiarity with the simple processes, students being introduced to the more complex, integrated processes subsequently. This subsequent incorporation of the more complex processes takes place in an accretionary fashion. The advocates of this approach believe that by following such a program the students become increasingly adept at solving problems, in making decisions, and, more generally in thinking critically.

Keislar (1969) makes a useful distinction between the creative and the process approaches towards problem-solving. He sees the creative approach as one which, typically expresses an 'open-ended' viewpoint, in the sense that few controls or restrictions are imposed upon the problem-solver. Systematic training does not occur, and objectives are not specified. In contrast, Keislar sees the process approach as one which typically expresses a 'goal-directed' orientation, in the sense that objectives are succinctly specified in behavioural terms.

Generally speaking, these opposing viewpoints have given rise to, and are reflected in, the current controversy raging between advocates of the behavioural objective viewpoint on the one hand, and their opponents and critics on the other hand.

In support of the behaviourists, Walbasser (1966), the director of SAPA evaluation, condemns those science programs which tend to make frequent usage of such vaguely defined objectives as 'increased understanding' or 'developing appreciation' for example, believing that these objectives cannot be objectively evaluated. Consequently Walbasser advocates the stating of specific objectives, which, within the SAPA program, are considered met with the acquisition of specific behaviours, the presence of which can supposedly be determined through measurement. In contrast to the views of Walbasser, Atkin (1968) maintains a very cautious attitude towards the wholesale adoption of behavioural objectives as the basis of curriculum design. He believes that:

1. Behaviourists assume they know, or can identify, all the major educational objectives for which an individual strives.

2. Among behaviourists there exists a tendency to believe that objectives most easily measured are the most important.

3. With the specifying of behavioural objectives, a tendency exists to teach explicitly for easily identifiable learning outcomes.

These key points indicate that Atkin considers that the behavioural approach is simplistic for the sake of convenience in its emphasis upon the identification of certain observable behaviours for the facilitation of measurement. Essentially Atkin feels that the behavioural approach involves the downplaying of non-observable objectives.

With reference to science education however, Walbasser (1966) stresses:

> the inescapable obligation of science programs to supply objective evidence of accomplishment (p. 34).

He further demands that all evidence be capable of satisfying the essential criterion that it was obtained by defensible research procedures which themselves are capable of replication by independent investigators. Evidence of this type, he believes, can only be obtained if objectives are spelled out in observable, and hence measurable terms.

Evaluation

Science programs which have chosen to adopt the content approach have tended to evaluate student performance almost entirely in terms of ability to recall facts. Teachers are commonly required to devise evaluation techniques in the form of examinations which require written or verbal student response for their successful completion. Until relatively recently, formal courses designed to improve test construction techniques were less frequently available to classroom teachers than is now the case. In consequence evaluation techniques commonly devised and implemented were often inadequate and subjective in nature.

With increasing acceptance of science as a mode of inquiry, rather than as a fixed body of knowledge, one is forced to give critical consideration to the adequacy and efficacy of current evaluation procedures and of their evolutionary potential with respect to the changes which must inevitably occur within the context of science and science education. Apparently student evaluation still rests heavily upon ability to recall (Munson, 1967). The lag existing between newly adopted instructional procedures and associated evaluation procedures has arisen largely as a result of the inconsistencies existing between stated and measured objectives. Teachers not expert in devising and effectively applying new evaluation procedures are experiencing difficulties in assessing the extent to which the stated objectives are attained by the students (Smith, 1969). Difficulties associated with the teaching of science processes will continue until a time is reached when:

> the objectives are written in terms of observable and hence measurable aspects of human behaviour (Hedges, 1966)

and when:

> evaluation techniques are constructed in the light of carefully formulated operational definitions of the instructional objectives (Engelhart and Beck, 1963).

It is apparent that these requirements can only rarely be satisfied by the individual teacher. Responsibility must therefore rest upon the combined efforts of experts to devise test and validation techniques within several related fields, and to provide informational and administrative services to those responsible for their application.

While no program may ever completely satisfy these requirements, the SAPA program comes close to attaining them. SAPA, in stressing behavioural objectives has led to the development of process 'competency measures' in an effort to determine the proportion of desired student performance characteristics. The process measures exist in the form of teacher check-lists by the use of which the teacher assesses the individual's ability in a certain process. Subjectivity is minimized as questioning procedures, recording of responses, subsequent final assessment and evaluation of responses are specifically and succinctly prescribed, forming an integral part of the procedures and documents to be used. The teacher, relieved of responsibility in devising the tests, acts solely in the capacity of administrator.

An everpresent difficulty associated with this type of evaluation rests in the time required for the administration of the test and for the assessment of the performance of the student on an individual basis (Anderson, 1967). However this problem seems to be an inevitable associate of all effective tests of this type. Readily available group tests would greatly reduce the problem associated with this time factor, and would increase administration efficiency. With less teacher/student interaction, subjectivity might also be minimized. At the present time, the SAPA program includes tests which evaluate only certain basic processes on a group basis.

Atkin (1963) has criticized the SAPA competency measures strategy in general on account of the check-lists evaluation procedures which, he feels, focus specifically on short-term behavioural changes, and he further maintains that long-term behavioural changes become obscured. Recently a "Science Process Instrument' (1970) has been constructed which purports to measure progress in students' mastery of behaviours associated with the processes. As such, the instrument supposedly provides a basis for long-term assessment of progress. At the time of writing, this instrument is available for the evaluation of basic processes only, and no data exist pertaining to its validity.

In addition to the evaluation attempts made by AAAS—SAPA, individual and group tests have been devised for objective evaluation of certain processes by certain other researchers, as is discussed below. The scarcity of available tests may be explained partially as a result of the difficulties associated with defining objectives in terms of student behaviour (Tannenbaum, 1964), and perhaps partially because:

> processes have only recently been objects of more intense research (Burns and Brooks, 1966, p. 28).

Further tests which are of relevance to the present discussion include those of:

(a) Butts and Jones (1966) who developed the TAB Test for assessing the performance of children from grades seven to twelve with respect to certain science processes.

(b) Tannenbaum (1969) who developed a Test of Science Processes for children from grades seven to nine. The processes consisted of observation, comparison, classification, quantification measurement, experimentation, inference and prediction, the test questions being posed in both written and in pictorial form. This test has yet to be validated.

(c) Dietz and George (1970) who developed a reliable and valid group test capable of evaluating certain problem-solving skills in children within grades one, two and three. The skills consisted of the ability to recall, the ability to collect data through visual observation and the ability to arrive at solutions to problems by reasoning, using 'if-then' statements. Test questions were orally posed in order to minimize variance due to reading directives.

and (d) Beard (1970) who developed a Basic Science Process Test capable of evaluating the processes of measurement and classification on a group basis.

FORMULATING HYPOTHESES

Definitions of Hypothesis

Definitions of the term hypothesis are many and varied. An analysis of definitions proposed by certain psychologists, philosophers and science educators illustrates the existence of wide differences in interpretation of the meaning of the term. To Guilford (1939) an hypothesis is simply an inference. He claims that whatever applies to an hypothesis may also apply to inferences in general.

To Gagne (1965) an hypothesis is a generalized inference. This definition has been accepted by the developers of the SAPA program and exercises designed for developing the student's ability to formulate hypotheses have been based upon this definition.

Postman considers an hypothesis to be a selecting device. He maintains that an hypothesis is an explanation or a predisposition of the organism which serves to select, organize and transfer to the stimulus information that comes from the environment (in Rahrer and Sherif, 1951, pp. 249-258).

Bruner (1956) and Inhelder and Piaget (1958) also consider an hypothesis to be a selecting device.

Many philosophers and science educators, including Atkin (1956), Woodburn and Obourn (1965), Coleman (1966), Hempel (1966), Moore (1967), Renner and Ragan (1968), Ruby (1968) and Quinn (1971) consider the element 'explanation' as an essential and crucial constituent of the definition of hypothesis. For the purposes of this study, as already stated, hypotheses will be defined as 'alternative tentative explanations of observed phenomena, which lead to the formulation of testable predictions. The testable predictions, in turn, lead to the substantiation and acceptance of the original explanations or to their rejection or modification.'

The High Quality Hypothesis

A review of the writings of Beardsley (1950), Beveridge (1957), Hullfish and Smith (1961), Woodburn and Obourn (1965), Moore (1967), Ruby (1968) and Quinn (1971) indicates common acceptance of the following qualities as essential constituents of a 'good' or high quality hypothesis:

1. The hypothesis accounts for all the presently known relevant facts.

2. The hypothesis is fruitful in directing further action enabling the prediction of specified future observation.

3. The hypothesis can be tested or verified either immediately or eventually.

4. The hypothesis is precisely stated.

5. The hypothesis is stated in the simplest form adequate

for the expression of all facets of the problem.

Hypotheses, Theories, Laws and Principles

Opinions concerning the relationships existing between hypotheses and theories vary considerably.

Rogers (1960) considers hypotheses to be building blocks necessary for theory construction. On the other hand, Suchman (1968) regards the terms 'hypothesis' and 'theory' as being synonymous. He considers it unnecessary, when teaching elementary school science, to distinguish between hypotheses, theories, laws and principles, provided students are capable of distinguishing between abstract theories and empirical events.

In contrast to Suchman, philosophers of science do attempt to make a distinction between these terms. Robinson (1965) for example, considers hypotheses to be deduced from laws, laws from principles, and principles from theories. However, as Quinn (1971) points out:

> Philosophers do not agree amongst themselves on exactly when an hypothesis becomes a law, nor on how principles differ from laws, nor on what constitutes theory. While there is general agreement that the hypotheses, theories, laws and principles should explain physical phenomena, there is considerable difference of opinions as to the function and essential characteristics of scientific explanation (p. 12).

The Hypothesis and Problem-Solving

Problem-solving occupies an essential position within the context of inquiry. Among others, Hutchinson (1949), Ghiselin (1952), Dewey (1953), Patrick (1955) and Osborn (1957) have constructed lists which feature the steps or stages which might be considered as essential in problem-solving. Construction of such lists has commonly resulted from the author's involvement in one or more of the following activities:

1. Introspective analysis of mental processes and methods of working, e.g. Poincare (1952),

2. Analysis of accounts provided by others, e.g. Ghiselin (1952),

3. Empirical investigations of scientists engaged in problem-solving, e.g. Patrick (1955).

Awareness of the fact that individuals solve problems in different manners, leads most investigators to point out that all identifiable processes involved in problem-solving may not be used in a specific situation by all individuals, nor may they be used in the same sequence by difference individuals in the course of the solution of a particular problem. Osborn (1957) admits that certain stages within his configuration may even at times be completely bypassed.

The problem-solving sequence of Dewey (1953) consists of: (a) definition of the problem, (b) location and evaluation of the data, (c) formulation of hypotheses, (d) evaluation of the hypotheses and (e) application of the solution, while that of Osborn (1957) comprises: (a) orientation, (b) preparation, (c) analysis, (d) hypothesis, (e) incubation, (f) synthesis and (g) verification.

Lists compiled by Patrick (1955) and Hutchinson (1949) include: (a) preparation, (b) incubation, (c) illumination and (d) verification, while an analysis by Williams (1960) of lists ompiled by twenty authors revealed that the formulation of hypotheses featured consistently as a significant process within the context of problem-solving.

The Formulation of Hypotheses

Martin (1972) distinguishes three procedures involved in the formulation of hypotheses:

1. Those procedures which may be deliberately adopted (i.e. those which are largely under conscious control),

2. Those procedures which cannot be deliberately adopted (i.e. those which are largely under non-conscious control),

3. Those procedures which can be partially adopted (i.e. those which are partially under conscious control).

Examples of the first type include operational techniques such as brainstorming and the synetics approach, Kneller (1965) citing several examples of bizarre devices used by eminent scholars as aids to hypothesis formulation.

Examples of the second type occur, according to Freudian theory, largely within the period of incubation. This incubation period represents a time during which the conscious part of the personality relaxes permitting the unconscious part to formulate in some unknown way, an hypothesis or hypotheses.

Examples of the third type include the utilization of the stages of preparation, incubation and illumination as suggested by Hutchinson (1949), Patrick (1955), and other authors. It is apparent that while the preparation stage can be deliberately adopted, the other two stages, presumed under largely non-conscious control, cannot be deliberately adopted.

Several writers, including Popper (1959) and Hempel (1966), argue that the formulation of an hypothesis as distinct from the testing of an hypothesis is a non-rational act. Martin (1972) identifies several possible interpretations of the term 'non-rational act' and suggests that the term may indicate that:

1. No procedure is known which leads in predetermined and followable steps to an actual hypothesis formulation.

2. Hypothesis formulation, being an uncontrollable process is best left to happenstance rather than to purposeful activity.

3. Procedures that can be adopted partially only, are more successful than procedures which may be deliberately adopted in toto only.

Martin considers this latter interpretation to be the most likely depiction of what generally is believed by those who consider hypothesis formulation to be non-rational. In suggesting that partial procedures are likely, at the present time, to be the most 'successful' method in formulating hypotheses (i.e. producing with a higher relative frequency, hypotheses with more desirable properties than those produced by other procedures), Martin (1972) nevertheless foresees, with an anticipated development in psychology and physiology, a time when the non-conscious elements associated with partial processes become, to a large extent, controlled.

Evaluation of Hypothesis Formation

If Craig (1966) is correct in asserting that young children can formulate hypotheses as tentative explanations, it becomes apparent that the valuation of ability to formulate hypotheses must account for much more than the mere determination of an individual's capability with respect to hypothesis formulation. Essentially, three factors must be accounted for in any effective and objective evaluation of the ability to formulate hypotheses—namely those factors involving the quality and quantity of the hypotheses formulated and the duration of time required for their formulation. In general terms then, an individual judged to have a high ability in formulating hypotheses is capable of formulating large quantities of high quality hypotheses in minimal time.

The criteria employed in the identification of high quality hypotheses have earlier been noted (pp. 22-23). It is therefore sufficient to say that objective evaluation of the quality of hypotheses formulated necessitates the existence of some reliable scale or index of quality which incorporates those attributes previously mentioned (pp. 22-23).

The importance of formulating hypotheses in quantity has been emphasized by several investigators—the principle of multiple working hypotheses generally finding favour. Chamberlain (1890) warned against the adoption of one hypothesis alone, the hypothesizer then being likely to develop a fondness for his one hypothesis, tends to seek only supportive evidence. As a precaution against the occurrence of such an event Chamberlain accordingly encourages the practice of the formulation of many hypotheses. Renner and Ragan (1968), Moore (1967) and Coleman (1966) consider the greater the number of alternative hypotheses formulated, the greater is the chance of the solution to the problem being found. Osborn (1957 believes that "early ideas are not usually true ideas" (p. 114).

He thus stresses the importance of formulating many alternative hypotheses in order to improve the quality of hypotheses formulated, his motto being, in general terms 'quantity yields quality.'

Accepting quantity as a significant factor in hypothesis formulation, the objective evaluation of the ability to formulate hypotheses must, then, take the factor of quantity into account.

Attempts to Determine Ability in the Formulation of Hypotheses

Hurlbut (1956) presented specific science problems to university students. The results obtained from the investigation indicated that:

1. Students of greater word and reading ability selected hypotheses of higher quality than did students possessing less ability in these areas.

2. A background in science appears to be advantageous to students in the selection of science hypotheses.

Atkin (1956) analysed the verbal responses of children from grades one three and six who were involved in specific science lesson situations. The results obtained indicated that:

1. Students from these grades hypothesize freely.

2. Students use a variety of sources when formulating hypotheses, including authority, experimentation, observation and

original thinking.

3. Grade six students tend to fall back upon authority when formulating hypotheses significantly more frequently than students from grades one and three.

4. Younger children use observation as a basis for formulating hypotheses significantly more frequently than do older students.

5. At the three grade levels studied, students hypothesize with about the same frequency of accuracy.

Attempts at Teaching the Formulation of Hypotheses

Coleman (1966) has described a technique in which alternative hypotheses formulated to explain locations of certain specified shapes on a blackboard, supposedly promote scientific thinking amongst non-scientists.

Micciche and Keany (1969) describe the application of an 'Hypothesis Machine' for use in improving a student's ability to formulate hypotheses, and Kilburn (1963) has described an experiment, involving the action of acids and alkalies on cabbage water, as a basis for providing students with experience in the formulation of hypotheses.

Quinn (1971) demonstrated that hypothesis formulation can be taught. The ability of sixth grade children to formulate hypotheses improved following sessions in which the Suchman Inquiry Development Program film-loops were shown and specific instructional procedures were adopted. Emphasis in this program was placed upon the formulation of quality hypotheses which were evaluated according to a 'Quality Scale' devised for the purpose by the author. No attempt was made to take into account the quantity of hypotheses formulated.

In summary then, the only measures which appear to have been devised for the evaluation of ability in the formulation of hypotheses, are those of the Competency measures utilized within the SAPA program, and that of the Quality Scale devised by Quinn.

Chapter 3

DESIGN OF THE STUDY

THE SAMPLE

The population from which the samples were selected consisted of students drawn from six elementary schools, three from the Edmonton Public school system, one from the Edmonton Separate school system and two from the County of Strathcona, Number Twenty school system. These schools, selected by their respective administrations, provided samples of students from a range of socio-economic and cultural backgrounds. One hundred and twenty-five students selected at random from the schools participated both in the individual visual-mechanical task and in the individual visual task. Approximately twenty students were selected from each school, four students normally being selected from each of the grades one through six. A further two hundred students participated in the group visual task. The two hundred students involved, comprised the members of nine classes, utilized in toto, at least one of the grades one through six being represented by one of the classes. Table I summarizes the composition of the individual and group samples with respect to sex and grade.

INSTRUMENTATION

Formulating Hypotheses Task

In order to achieve the objectives of this study, three

TABLE I

DISTRIBUTION OF STUDENTS IN SAMPLES

System			Edmonton Public			Edmonton Separate	County of Strathcona		Individual Tasks			Group Task		
School			1	2	3	4	5	6	Boys	Girls	Grade	Boys	Girls	Grade
									N	N	N	N	N	N
Grade	Ind.	M[a]	2	3	3	3	2		13		23			
		F[b]	2	2	2	2	2			10				
One	Group	M					7					7		19
		F					12						12	
Grade	Ind.	M	2	2	2	2	3		11		22			
		F	1	2	3	3	2			11				
Two	Group	M					12					12		21
		F					9						9	
Grade	Ind.	M	2		2	2	1		7		19			
		F	3	2	2	2	3			12				
Three	Group	M	8					17				25		45
		F	9					11					20	
Grade	Ind.	M	2	3	1	1	2		9		21			
		F	3	2	3	1	3			12				
Four	Group	M		11				20				31		51
		F		9				11					20	
Grade	Ind.	M	3	2	2	3	2		12		20			
		F	1	2	2		3			8				
Five	Group	M						13				13		24
		F						11					11	
Grade	Ind.	M	2	2	2	3			9		20			
		F	3	3	3	2				11				
Six	Group	M			13		13					26		40
		F			4		10						14	
School	Ind.		26	25	27	24	23							
N	Group		17	20	17		63	83						
System	Ind.			78		24	23							
N	Group			54			146							
Total	Ind.				125									
N	Group				200									

activities involving the formulation of hypotheses, comprising two individual tasks and one group task, were designed.

The major activity, upon which the other activities were based, required students, in an individual setting, to formulate hypotheses through manipulation of an 'Hypothesis Machine' specifically designed and created for this purpose. This machine was a modification of the 'Hypothesis Formulation Machine' created by Micciche and Keany (1969).

The other individual and group activities each employed a paper-and-pencil test in order to assess the ability of the students to formulate hypotheses under constraints which require a more abstract operative mode.

All of the test activities presented were designed to meet specific criteria with respect to the formulation of hypotheses as designated within the broad definition of an hypothesis given in Chapter 1. In addition, the test activities were designed in a fashion which permitted the objective evaluation of students' abilities in the formulation of hypotheses. As noted in Chapter 2, several investigators have stressed the need for improvement of the quality of hypotheses formulated and of increasing the quantity of hypotheses formulated. Therefore this objective evaluation was based upon the criteria of quality, quantity and the time required for the formulation of the hypotheses.

Materials

1. Visual-Mechanical Task. The stimulus device used for the individual visual-mechanical task consisted of an Hypothesis

Machine constructed from balsa wood and consisting of six channels, the sides of which were fixed to a rectangular base measuring 22" x 6" and set at an angle of 5° to the horizontal in order to facilitate motion of a marble located within the machine (see Plate I, p. 35). Each channel was divided vertically into five identical sections, separated by four gaps. Left-sloping (black) triangles and right-sloping (green) triangles could be inserted into these four gaps. The marble, introduced into the top section of a channel and released, would roll down the channel until it reached the bottom section. A triangle positioned within one of the gaps associated with this channel served to deflect the marble into the channel immediately to the left or right, depending upon the nature of the slope of the triangle. A cover positioned on top of the machine served to prevent observation of the nature and distribution of the triangles, and of the route taken by the marble between start and finish.

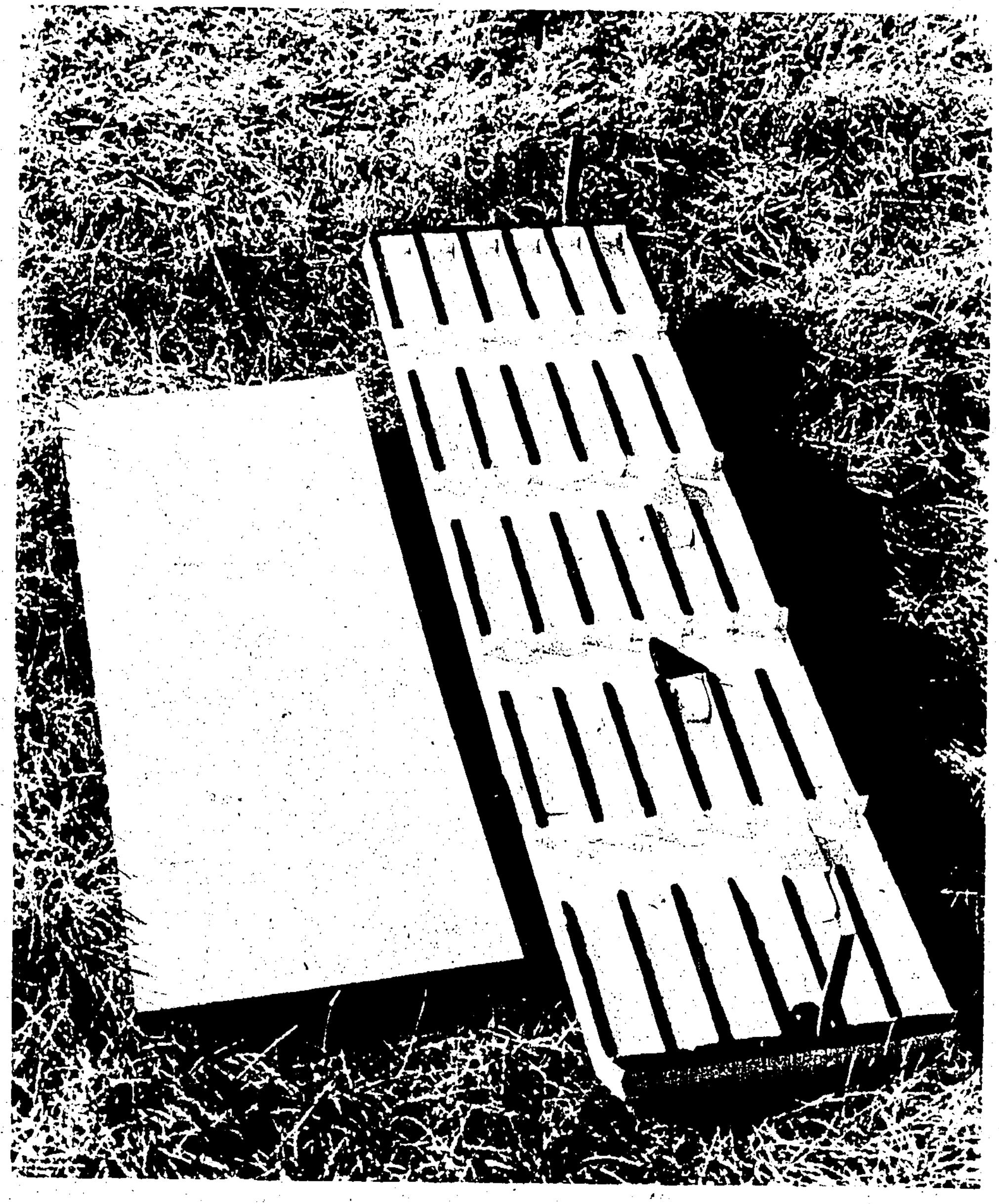
2. Visual Task. The visual task consisted of a paper-and-pencil test in which thirty printed representations of the Hypothesis Machine were provided. Each illustration showed a marble positioned in the same top section of a particular channel and a marble positioned in the same bottom section of a particular channel (see copy of this test in Appendix F).

Procedures

1. Visual-Mechanical Task. Students were tested individually and in random order in each school by the investigator using a standard procedure. The visual-mechanical task involved manipulation, by the students, of the Hypothesis Machine. The machine was displayed to the

PLATE I

HYPOTHESIS FORMULATION MACHINE



students and its principal features were described in order to familiarize them with its operation. The students were asked to insert the marble in the top section of certain channels, and to observe the outcomes of release of the marble. The right-sloping and left-sloping triangles were then presented, and following identification their mode of operation was demonstrated. Students were invited to position one of the triangles within the machine, and were further invited to insert the marble in top of the channel considered to be instrumental in effecting eventual contact between the marble and the triangle. Having witnessed the deflection of the marble by the triangle, students were asked to describe the effect. After participating in several manipulations involving different numbers and types of triangles, students were given two minutes in which to experiment with different combinations and positions of triangles within the machine. The function of the cover was then demonstrated. The students were informed that a certain number and combination of triangles, known only to the investigator would be positioned under the cover within the machine. This having then been done, a particular channel was identified by a 'flag.' The students were then invited to insert the marble in the indicated channel and to note the channel in which the marble eventually came to rest. This latter channel was also marked with a flag. The students were informed that the particular combination of triangles, under the cover, was responsible for the marble having travelled by some particular route from the top flag position to the bottom flag position. The cover and triangles were then removed, the flags alone remaining in their original position. Students were then invited to insert triangles in any position they wished within the machine in attempts to direct the movement of the marble from the indicated top position to the indicated bottom position. Hints were given that several alternative possibilities for achieving this existed. For a complete description of the instructional phase of this task see Appendix B.

The following observable responses were recorded by the investigator during the course of student performance of the task:

1. The number of hypotheses formulated within the defined limits of the experimental situation.

2. The number of hypotheses formulated which offered explanations not functionally possible within the defined limits of the experimental situation.

3. The number of functional hypotheses formulated on a repeated basis.

4. The order in which each functional hypothesis was formulated.

5. The time required for the formulation of each functional hypothesis.

6. The time required by the students to complete the task to the extent that they were able. However, for purposes of economy of time in administration of the task, fifteen minutes were set as a maximum time limit allowable for its completion.

2. <u>Individual Visual Task</u>. Immediately following completion of the machine task, a paper-and-pencil test was administered to the

students. They were informed that the diagrams presented were printed representations of the machine, and that the functional capabilities of channels, gaps, triangles and marble within the Hypothesis Machine were to apply, in a like manner, to the printed representations of the machine. Students were then invited to draw in, on the copies provided, the alternative routes that the marble could take in travelling from the top indicated position to the bottom indicated position, such positions being indicated by appropriately placed black dots on the printed representations (see p. 145). As an additional and optional feature, students were invited to indicate the possible combinations of triangles which would bring about such alternative routes. For a complete description of the instructional phase of this task see Appendix E.

3. Group Visual Task. The students engaged in the group visual task had not had an opportunity to manipulate the Hypothesis Machine, and so had no knowledge of its mode of operation. To facilitate an understanding of its operation, a large scale reproduction of the machine, measuring 66" x 18" was positioned at the front of the classroom in full view of the students. By way of illustration, the investigator demonstrated several possible operations and functions of the machine and its contents. Following completion of the demonstration, a paper-and-pencil test, identical in form to that used by individual students was administered to the students in the group setting. Information given to the group was also identical in substance to that given to the students engaged in performance of the individual task.

Scoring

1. Visual-Mechanical Task. The two questions associated with the visual-mechanical task were scored on the basis of certain observable responses made by the students, and recorded by the investigator on specially prepared data sheets. One point was given for each different combination of triangles formulated by the student which offered an explanation which was functionally possible within the defined limits of the experimental situation. The ten functionally possible explanations for the event depicted in the first question associated with the individual visual-mechanical task defined a maximum total Formulation of Hypotheses Score (individual visual-mechanical) of ten. The sixteen functionally possible explanations in the second question provided a maximum total Formulation of Hypotheses score (individual visual-mechanical) of sixteen.

For purposes of analysis, the Formulation of Hypotheses Score (individual visual-mechanical) consisted of the total Formulation of Hypotheses Scores obtained from the first and second individual visual-mechanical task.

In an effort to add more discriminative power to the task, a time factor was introduced, the time required for the completion of each question being recorded, fifteen minutes representing the maximum duration permitted for each question. The Formulation of Hypotheses Speed Score (individual visual-mechanical) was determined by dividing the Formulation of Hypotheses Score (individual visual-mechanical) by the ~~time~~ required for formulation.

2. Visual Task. The individual and group visual tasks

were scored in identical fashion. Two questions were associated with each task. The investigator allowed one point for each hypothesis formulated which offered a possible functional explanation of the manner in which the marble travelled from the indicated top position to the indicated bottom position. The sixteen functionally possible routes associated with the first question defined a maximum Formulation of Hypotheses Score (visual) of sixteen for both the group and the individual task. The nine functionally possible routes for question two indicated a maximum Formulation of Hypotheses Score (visual) of nine for both the individual and the group visual tasks.

For purposes of analysis, the individual visual and group visual Formulation of Hypotheses Scores consisted of the totals of the Formulation of Hypotheses Scores obtained from the first and second questions for the individual visual and group visual tasks respectively.

The time required for the completion of each question was noted, fifteen minutes being the maximum time permitted. The Formulation of Hypotheses Speed Score (visual) for both the individual and group settings was determined by dividing the Formulation of Hypotheses Score (visual) by the time required for completion of the task.

<u>I.Q. scores</u>. I.Q. scores were obtained for all of the students involved in the individualized tasks by administering the S.R.A. Primary Mental Abilities Test. I.Q. testing was considered necessary in view of the fact that each school system used a variety of intelligence tests, often administered at different times of the school

year, comparison of data from these different sources being difficult and having little meaning. The S.R.A. Primary Mental Abilities Test was chosen for administration because none of the schools had previously utilized the test, and because this measure had also been utilized as the common basis for the estimation of an intelligence score by previous investigators in this series of process studies. Within the S.R.A. Primary Mental Abilities Test, the general quotient is based upon five factors of intelligence comprising: verbal ability, number facility, reasoning ability, spatial relations ability and perceptual speed ability. Scores associated with each factor may be used as an aid in the determination of which of these factors, if any, exhibit important relationships with respect to the ability to formulate hypotheses.

PILOT STUDY

A pilot study was conducted in March, 197[illegible], among eighteen students not subsequently involved in the main study. The pilot study was undertaken to determine:

1. The approximate time required for students to complete the two individualized formulating hypotheses tasks.

2. The type and amount of instruction required in order have the individualized tasks understood by students from each of grades involved.

3. The feasibility of presenting the individualized tasks to a broad range of grades.

4. The feasibility of applying the Hypothesis Machine on a

group basis.

5. The optimal final format of the individualized tasks.

6. Administration problems occurring during task procedures.

On the basis of the results obtained from the pilot study, it was decided that:

1. The approximate time required for completion of each question associated with the individual visual-mechanical task was seven minutes for each grade one student and ten minutes for each grade three and six student. Each of the questions associated with the individual visual task required approximately three minutes for completion by students from each of the grades one, three and six.

2. The originally formulated verbal instructions, pertaining to the individual visual-mechanical task, were found to be inadequate and unsuitable for use with some grade one students. In particular, it was found that it was necessary for the investigator to visually demonstrate certain aspects of the instructional procedure in order to facilitate full understanding on the part of young students. It was also necessary to allow students to familiarize themselves with the machine by manipulating the machine and its contents prior to final administration of the task. Verbal instructions, pertaining to the individual visual task were found to be adequate.

3. Students from each of the grades tested were found to experience little difficulty in attempting each task. The number of printed representations of the machine provided for the paper-and-pencil test were found to be inadequate, most students requiring quantities in excess of those initially provided.

4. An increase in the number of hypotheses formulated for each question associated with each task, occurred with rise in grade level. These results are summarized in Table II and Table III.

TABLE II

MEAN FORMULATION OF HYPOTHESES SCORES ON THE INDIVIDUAL VISUAL-MECHANICAL TASK (PILOT STUDY)

Grade	One	Three	Six
Score	3.2	6.5	7.2

TABLE III

MEAN FORMULATION OF HYPOTHESES SCORES ON THE INDIVIDUAL VISUAL TASK (PILOT STUDY)

Grade	One	Three	Six
Score	2.7	7.5	7.7

5. The Hypothesis Machine, because of its present size, and the necessity for its actual manipulation, was not suitable for assessing students' abilities in formulating hypotheses on a group basis.

6. Young students in particular, experienced difficulty in observing and manipulating the contents of the machine, when in a seated position. To facilitate machine operation, a low-lying table was used to support the machine, and students were allowed to stand for the duration of the machine task.

THE MAIN TESTING PROGRAM

The main testing program was conducted between May 8 and June 16, 1973. Administration of the tasks to students involved in each of the six schools, was conducted by the investigator.

TYPES OF DATA ANALYSIS USED

Hypotheses #1, #2, #3 and #4 were subjected to Pearson Product Moment correlations in order to determine the relationships, if any, existing between the variables encompassed by each of these hypotheses.

Hypotheses #6, #7 and #9 were subjected to a one-way analysis of variance.

Hypotheses #5, #8 and #10 were subjected to a two-way analysis of variance in order to determine the significance of the interaction, if any, existing between the variables within each of these hypotheses.

Chapter 4

RESULTS OF THE INVESTIGATION

The results of the statistical analysis associated with each of the hypotheses and a description of student performance relative to the several tasks will be presented in this chapter.

STATISTICAL ANALYSIS OF THE HYPOTHESES

Hypothesis #1

No significant relationship exists between the Formulation of Hypotheses Score (individual visual-mechanical) and the Formulation of Hypotheses Score (individual visual).

The correlations existing between the two scores are shown in Table IV, p. 46. A significant level of 0.05 was adopted for rejection or non-rejection of the hypothesis.

Significant correlations were found to exist between the scores. Therefore Hypothesis #1 was rejected for this relationship.

Hypothesis #2

No significant relationship exists between the Formulation of Hypotheses Speed Score (individual visual-mechanical) and the Formulation of Hypotheses Speed Score (individual visual).

The correlations existing between the two Formulation of Hypotheses Speed Scores are shown in Table IV, p. 46. A level of significance of 0.05 was adopted as the basis for rejection or non-rejection of the hypothesis.

TABLE IV

CORRELATIONS BETWEEN FORMULATION OF HYPOTHESES SCORES AND SPEED SCORES (INDIVIDUAL VISUAL-MECHANICAL, INDIVIDUAL VISUAL) AND SPECIFIED VARIABLES

Variable		Individual Visual-Mechanical				Individual Visual			
		N	Score	N	Speed Score	N	Score	N	Speed Score
Individual	Score	125	1.000	125	0.337^b	125	0.631^b	125	0.319^b
Visual-Mechanical	Speed Score	125	0.337^b	125	1.000	125	0.374^b	125	0.477^b
Individual Visual	Score	125	0.631^b	125	0.374^b	125	1.000	125	0.630^b
	Speed Score	125	0.319^b	125	0.477^b	125	0.630^b	125	1.000
Sex		125	0.324^b	125	0.273^b	125	0.305^b	125	0.215^b
Age		125	0.344^b	125	0.410^b	125	0.447^b	125	0.299^b
Grade		125	0.360^b	125	0.413^b	125	0.459^b	125	0.296^b
I.Q.		123	0.407^b	123	0.338^b	123	0.438^b	123	0.307^b
Verbal Ability		125	0.269^b	125	0.317^b	125	0.283^b	125	0.178^b
Number Facility		123	0.416^b	123	0.129	123	0.341^b	123	0.155
Spatial Relations Ability		125	0.231^b	125	0.233^b	125	0.307^b	125	0.301^b
Perceptual Speed Ability		123	0.116	123	0.077	123	0.187^b	123	0.178^b
Reasoning Ability		61^a	0.114	61	0.184	61	0.205	61	0.267^b

[a] reasoning ability only measured for grades 4 - 6 by test used

[b] significant at 0.05 level

A significant correlation was shown to exist between the two Speed Scores. Therefore Hypothesis #2 was rejected for this relationship. The low correlation of .484 obtained between the two Speed Scores illuminates the danger of predicting a Speed Score on the one task merely from a knowledge of the Speed Score on the other task.

Hypothesis #3

There are no significant relationships between the Formulation of Hypotheses Scores (individual visual-mechanical and individual visual) and the Formulation of Hypotheses Speed Scores (individual visual-mechanical and individual visual) and: (a) sex, (b) age, (c) grade, (d) I.Q., (e) verbal meaning ability, (f) number facility, (g) spatial relations ability, (h) perceptual speed ability and (i) reasoning ability.

The purpose of this hypothesis was to determine the relationship, if any, existing between the Formulation of Hypotheses Scores and Speed Scores and each of the variables mentioned.

The correlations between the Formulation of Hypotheses Scores and Speed Scores and the specified variables are presented in Table IV. Again a significance level of 0.05 was adopted as the basis for rejection or non-rejection of the hypothesis. Significant relationships were found to exist between all Scores and Speed Scores. Significant relationships were also found to exist between the Scores and Speed Scores and the variables sex, age, grade, I.Q., verbal ability and spatial relations ability. In addition analysis revealed the existence of a significant relationship between the variable 'number ability' and the Scores and Speed Scores and between the variable 'reasoning ability' and individual visual Speed Score. Therefore Hypothesis #3 was rejected for each of these relationships. It should be noted however that the correlations between Scores and Speed Scores and the variables specified were in all cases within the range .200-.450. It should be noted that in view of the low level of the correlations obtained, that caution should be exercised in using this data for prediction purposes. Since analysis of the data relating to the 'verbal meaning ability' and 'spatial relations ability' scores yielded correlations of .269 and .231 with the individual visual-mechanical Scores, and correlations of .283 and .307 with the individual visual Scores, it would seem that factors associated with verbal meaning ability and spatial relations ability have little relationship to the factors associated with hypothesizing ability. Therefore it would appear that tests yielding data relating to verbal meaning ability and spatial relations ability are of little value as predictors of hypothesizing ability, and further it would seem that exercises involving verbal meaning ability and spatial relations ability are likely to be of little value in enhancing the hypothesizing abilities of students. The variable 'number facility' was not found to correlate significantly with the Formulation of Hypotheses Speed Scores (individual visual-mechanical and individual visual). No significant relationships were found to exist between the variable 'perceptual speed ability' and either the Formulation of Hypotheses Score (individual visual-mechanical and individual visual) or with the Formulation of Hypotheses Speed Score (individual visual-mechanical). In addition, analysis revealed that there were no significant relationships between the variable 'reasoning ability' and either the Formulation of Hypotheses Score (individual visual-mechanical and individual visual) or the Formulation of Hypotheses Speed Score (individual visual-mechanical). Therefore no evidence appeared to exist for rejection of Hypothesis #3 for each of these relationships.

Hypothesis #4

There is no significant relationship between the Formulation of Hypotheses Score (group visual), the Formulation of Hypotheses Speed Score (group visual) and: (a) sex, (b) age and (c) grade.

The correlations between the Scores and Speed Scores and the specified variables are shown in Table V. A significance level of 0.05 was again adopted as the basis for rejection or non-rejection of the hypothesis.

TABLE V

CORRELATIONS BETWEEN FORMULATION OF HYPOTHESES SCORES AND SPEED SCORES (GROUP VISUAL) AND SPECIFIED VARIABLES

Variable	N	Score	N	Speed Score
Sex	200	0.233[b]	200	0.135
Age*	145	0.649[b]	145	0.367[b]
Grade	200	0.650[b]	200	0.379[b]

[b] significant at 0.05 level

*age data not available from cumulative cards for all subjects at time that data gathered.

Significant relationships occurred between the variables age and grade and the group visual Formulation of Hypotheses Scores and Speed Scores. The variable 'sex' was also found to correlate significantly with the group visual Formulation of Hypotheses Score. Therefore Hypothesis #4 was rejected for each of these relationships. The moderate degree of correlation of .649 and .650 between age and grade and the group visual Score indicates that generally the older students in higher grades perform at levels superior to those of the younger children in lower grades. However it is to be noted that the lower correlation of .367 between the variable age and the group visual Speed Score indicates that the performance of students of different ages with respect to Speed Scores is less predictable. The variable sex was not found to be significantly related to the group visual Speed Score, therefore no evidence appeared to exist for rejection of Hypothesis #4 for the sex variable.

Hypothesis #5

There is no significant interaction between grade level and sex with respect to:

(a) Formulation of Hypotheses Score (individual visual-mechanical)

(b) Formulation of Hypotheses Speed Score (individual visual-mechanical)

(c) Formulation of Hypotheses Score (individual visual)

(d) Formulation of Hypotheses Speed Score (individual visual).

The purpose of this hypothesis was to determine whether or not the sex of the student had a differential effect upon each of the Scores and Speed Scores in each of the grades. Figures 1, 2, 3 and 4 illustrate the relationships existing between Formulation of Hypotheses Scores (individual visual-mechanical and individual visual) and the sex variable in each of the grades one through six. The mean Scores and Speed Scores for boys and girls are presented in Table VI; interaction between grade level and sex being shown in Table XII.

1. <u>Formulation of Hypotheses Score (individual visual-mechanical)</u>

The 'Test for Additivity' on this variable yielded an F value of .227 and the corresponding level of significance was .925. Therefore Hypothesis #5 was not rejected for this variable as the probability criterion for interaction was set at the .05 level of significance.

2. <u>Formulation of Hypotheses Speed Score (individual visual-mechanical)</u>

The Test for Additivity on this variable yielded an F value of .981 and associated probability of .432. Since this probability was not significant at the .05 level Hypothesis #5 was not rejected for this variable.

3. <u>Formulation of Hypotheses Score (individual visual)</u>

The Test for Additivity on this variable resulted in an F value of .621 yielding a probability of .684. Since this probability was not significant at the level defined, Hypothesis #5 was not rejected.

4. <u>Formulation of Hypotheses Speed Score (individual visual)</u>

The Test for Additivity resulted in an F value of .129

TABLE VI

MEAN FORMULATION OF HYPOTHESES SCORES AND SPEED SCORES FOR BOYS AND GIRLS BY GRADE

Variable		Sex	N	Scores by Grade One	N	Two	N	Three	N	Four	N	Five	N	Six
Individual Visual-Mechanical	Score	M	13	10.00		13.00	7	17.29	10	16.10	13	12.85	9	17.78
		F	10	6.[illegible]	11	8.91	12	10.75	11	11.54	7	9.29	11	13.91
	Speed Score	M		0.01	11	0.01	7	0.01	10	0.01	13	0.02	9	0.02
		F	10	0.01	11	0.01	12	0.01	11	0.01	7	0.02	11	0.02
Individual Visual	Score	M	13	10.15	11	11.18	7	15.71	10	15.70	13	15.38	9	17.44
		F	10	8.30	11	9.37	12	10.17	11	11.45	7	13.71	11	14.36
	Speed Score	M	13	0.02	11	0.03	7	0.03	10	0.03	13	0.03	9	0.03
		F	10	0.02	11	0.02	12	0.02	11	0.03	7	0.03	11	0.03
Group Visual	Score	M	7	5.29	12	8.92	25	9.60	31	14.16	13	17.70	26	17.85
		F	12	6.67	9	5.67	20	8.45	20	12.85	12	13.17	13	15.31
	Speed Score	M	7	0.01	12	0.02	25	0.02	31	0.02	13	0.02	26	0.03
		F	12	0.02	9	0.01	20	0.01	20	0.02	12	0.02	13	0.02

TABLE VII

COMPARISON OF BOYS AND GIRLS FORMULATION OF HYPOTHESES SCORES AND SPEED SCORES WITHIN EACH GRADE

Variable			S.Dev. Boys	S.Dev. Girls	Degrees of Freedom	T	Prob.
Individual Visual-Mechanical	Score		4.00	2.55	21	2.479	.022[a]
		Two	4.80	4.91	20	1.977	.062
		Three	5.09	5.48	17	2.571	.020[a]
		Four	4.61	3.45	19	2.582	.018[a]
		Five	4.86	3.64	18	1.691	.108
		Six	4.35	5.66	18	1.680	.110
	Speed Score	One	0.00	0.00	21	3.530	.002[a]
		Two	0.00	0.01	20	1.159	.260
		Three	0.00	0.01	17	0.579	.570
		Four	0.00	0.01	19	0.874	.393
		Five	0.01	0.01	18	1.124	.276
		Six	0.00	0.01	18	-0.662	.516
Individual Visual	Score	One	3.95	4.52	21	1.047	.307
		Two	5.13	2.50	20	1.056	.304
		Three	5.44	5.11	17	2.230	.040[a]
		Four	3.83	3.83	19	2.536	.020[a]
		Five	4.19	4.31	18	0.842	.411
		Six	3.13	5.82	18	1.424	.171
	Speed Score	One	0.01	0.01	21	1.306	.206
		Two	0.01	0.01	20	0.995	.331
		Three	0.01	0.02	17	1.035	.315
		Four	0.01	0.01	19	0.726	.477
		Five	0.01	0.01	18	1.150	.265
		Six	0,01	0.01	18	1.379	.185

[a] significant at .05 level

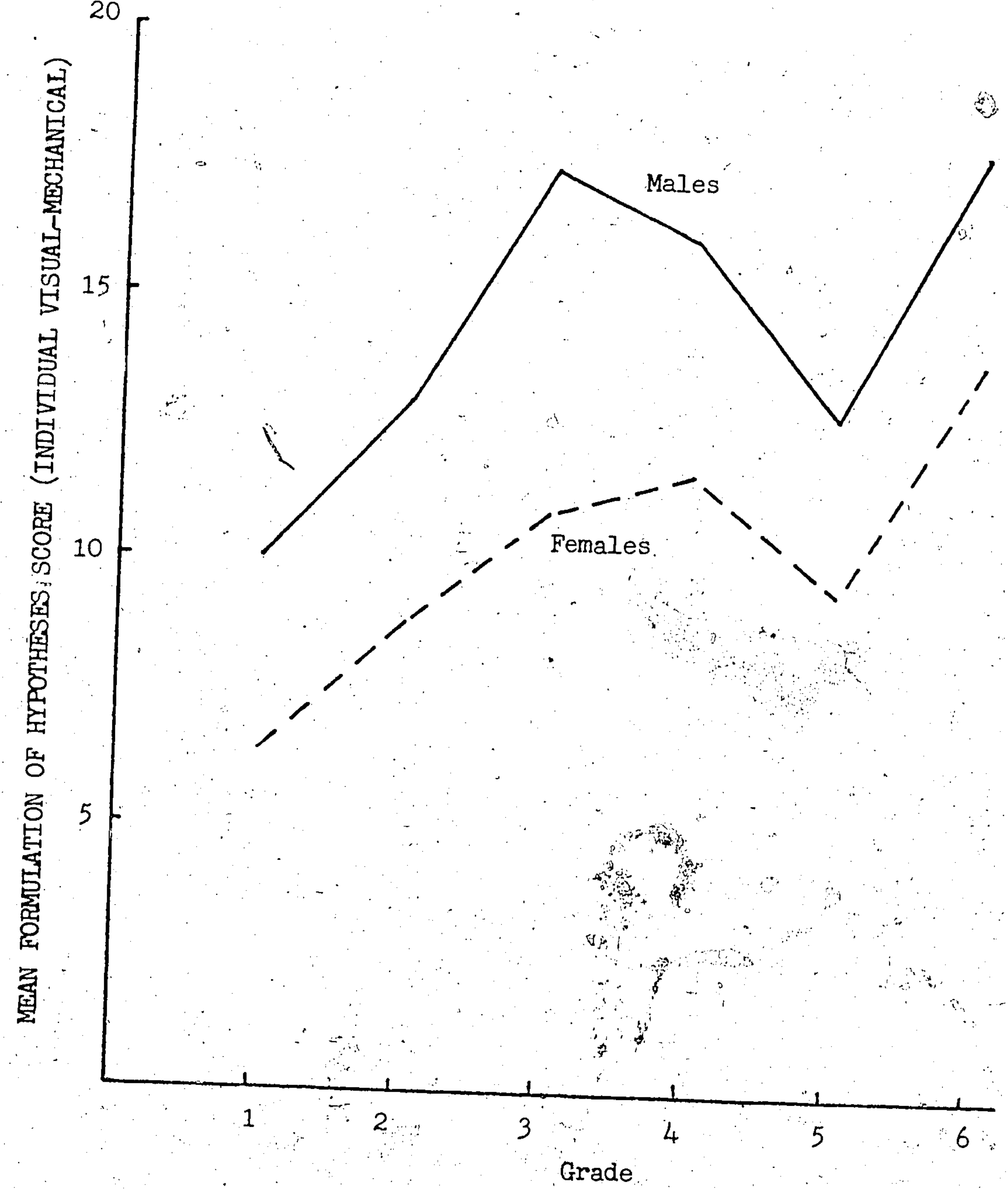


FIGURE 1

INTERACTION BETWEEN GRADE AND SEX ON FORMULATION OF HYPOTHESES SCORE (INDIVIDUAL VISUAL-MECHANICAL) CRITERION

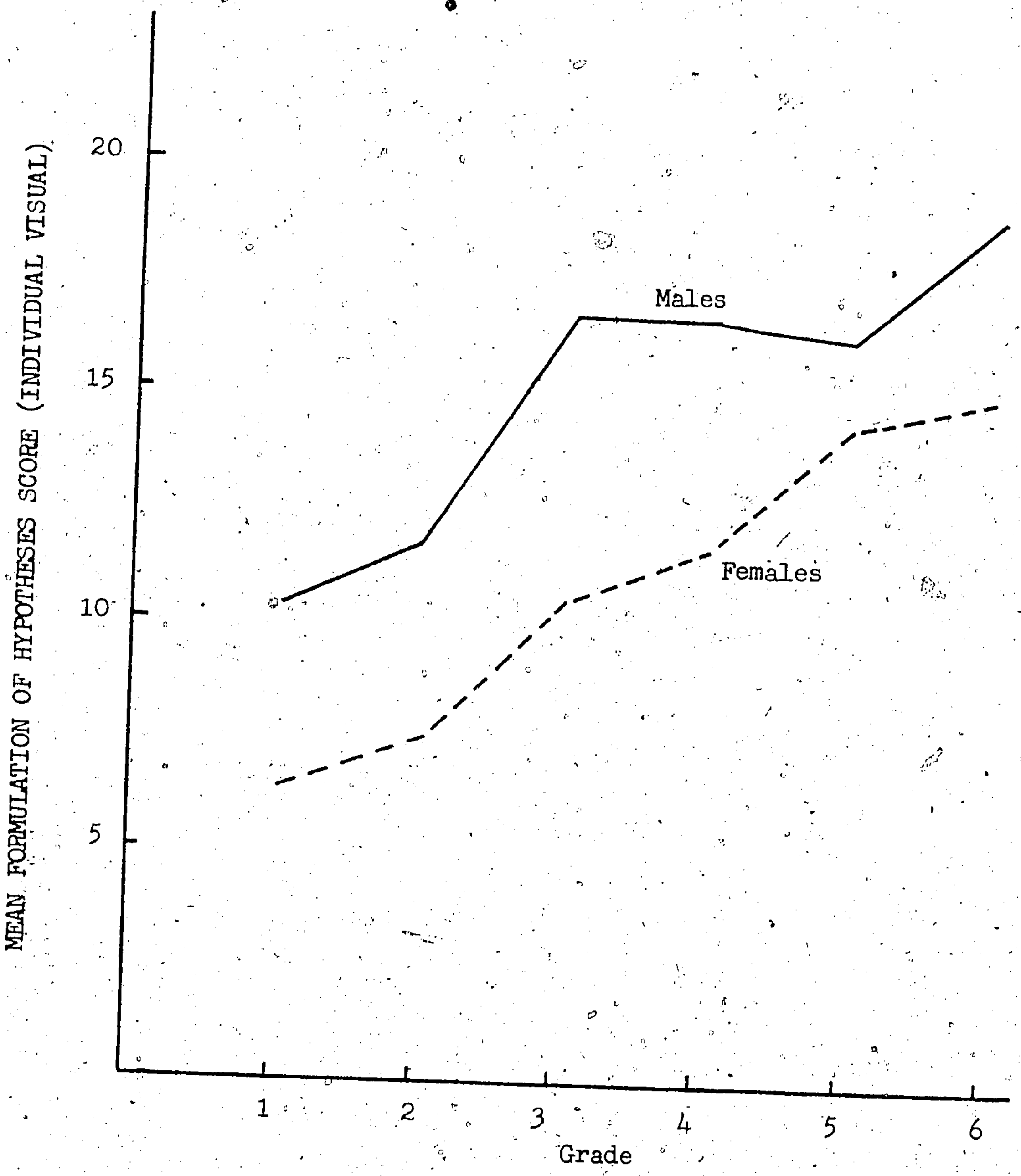


FIGURE 2

INTERACTION BETWEEN GRADE AND SEX ON FORMULATION OF HYPOTHESES SCORE (INDIVIDUAL VISUAL) CRITERION

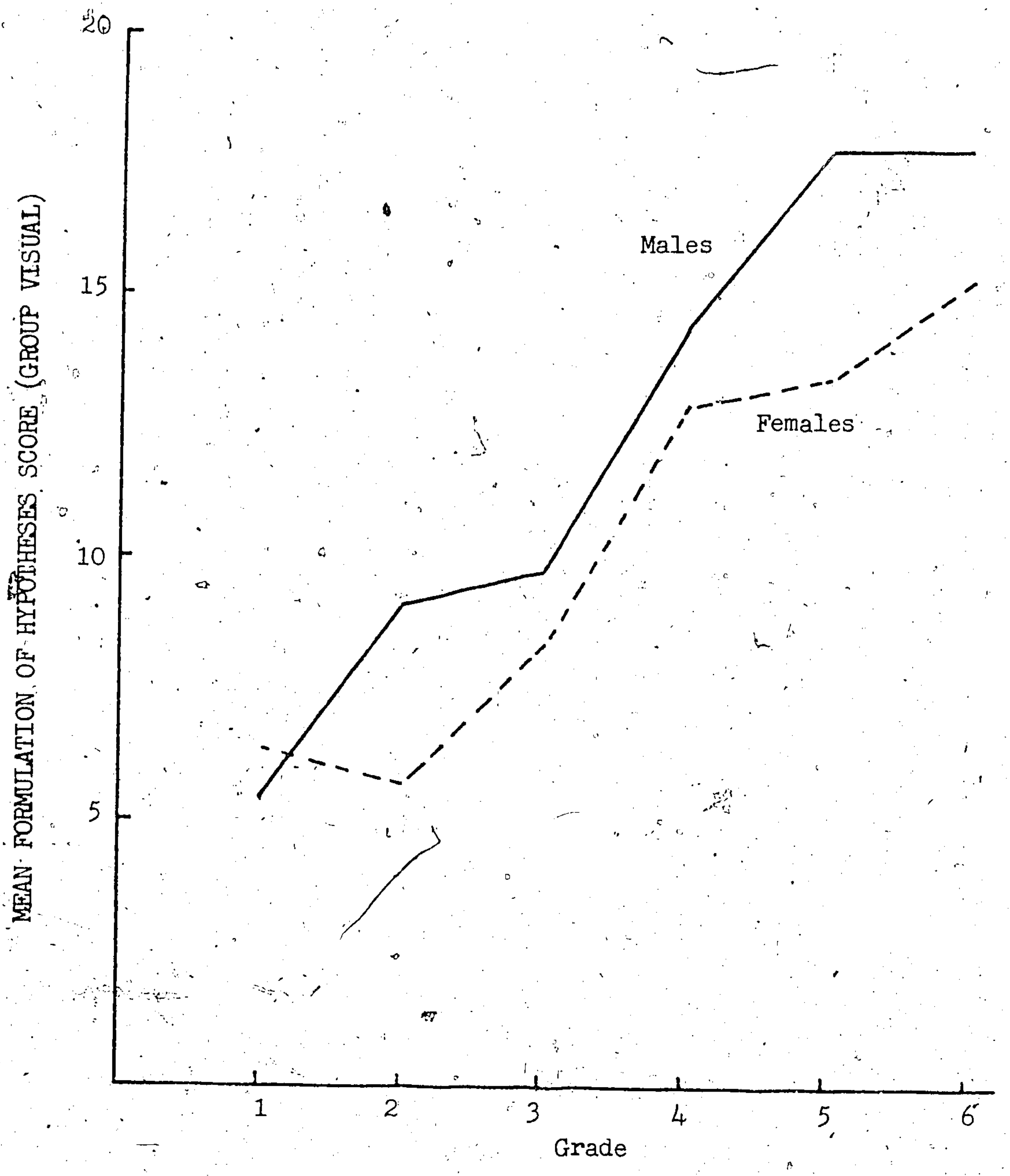


FIGURE 3

INTERACTION BETWEEN GRADE AND SEX ON FORMULATION OF HYPOTHESES SCORE (GROUP VISUAL) CRITERION

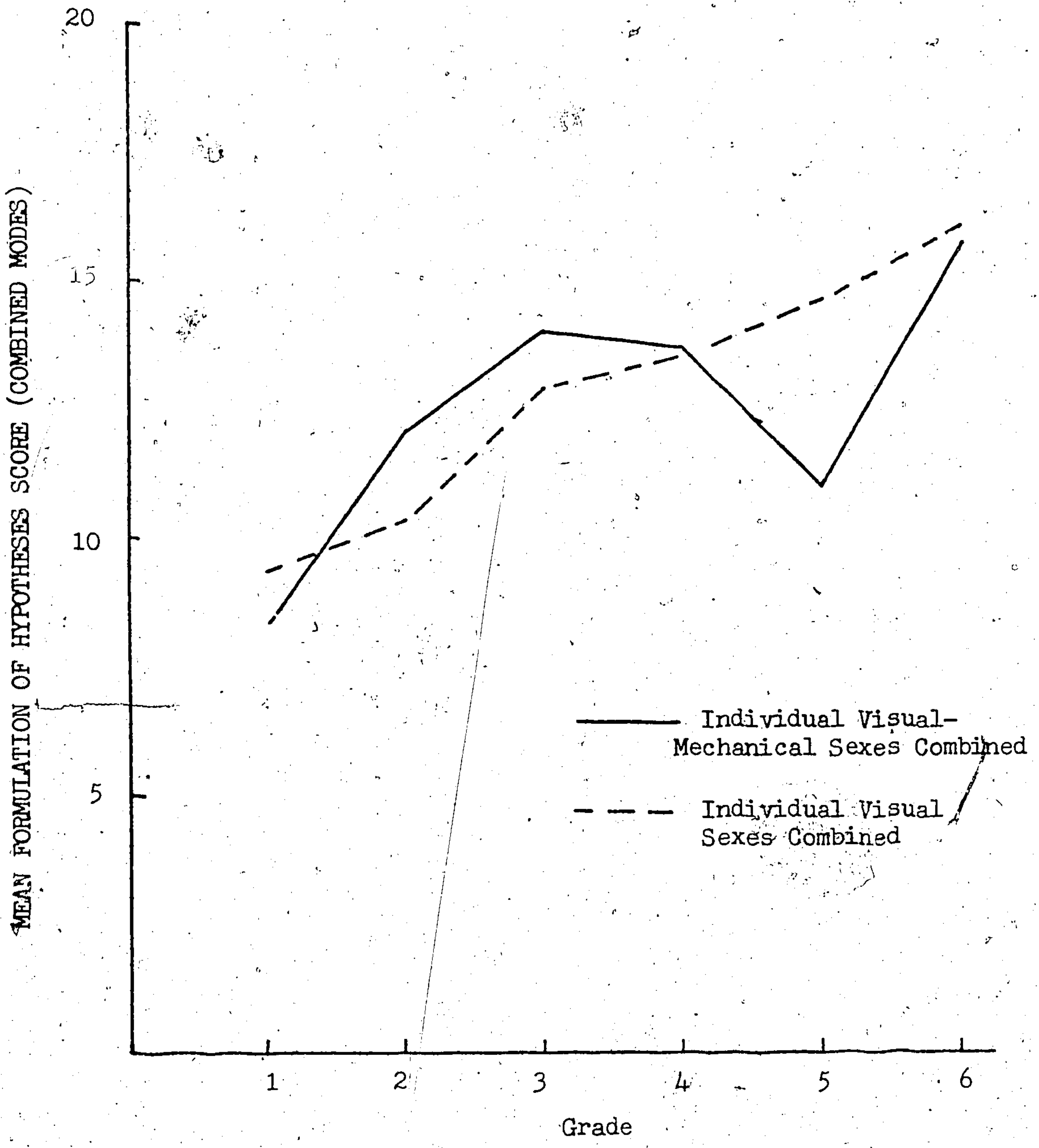


FIGURE 4

INTERACTION BETWEEN GRADE (SEXES COMBINED) AND FORMULATION OF HYPOTHESES SCORES (INDIVIDUAL VISUAL-MECHANICAL AND INDIVIDUAL VISUAL) yielding a probability of .986. Since this probability was not significant, Hypothesis #5 was not rejected with respect to this variable.

These findings indicate that there is no significant difference in the effect of the sex variable upon each of the grades one through six. Thus, while the boys in each of the grades achieved higher mean scores than did the girls, their superiority in performance did not differ significantly across the grades.

Hypothesis #6

There is no significant difference between the mean scores obtained by boys and girls in:

(a) Formulation of Hypotheses Score (individual visual-mechanical)

(b) Formulation of Hypotheses Speed Score (individual visual-mechanical).

(c) Formulation of Hypotheses Score (individual visual)

(d) Formulation of Hypotheses Speed Score (individual visual)

in each of the grades one through six.

The purpose of this hypothesis was to determine whether boys or girls achieve higher Formulation of Hypotheses Scores and Speed Scores with respect to individual visual-mechanical and individual visual modes of operation. Mean Scores and Speed Scores for boys and girls by grade are presented in Table VI. A significance level of .05 was adopted as the basis for rejection or non-rejection of this hypothesis.

1. Formulation of Hypotheses Score (individual visual-mechanical)

Significant differences between boys' and girls' Scores were found to exist in grades one, three and four. Therefore Hypothesis #6 was rejected for grades one, three and four for the individual visual-mechanical Score, but was not rejected for grades two, five and six.

2. Formulation of Hypotheses Speed Score (individual visual-mechanical)

Significant differences between boys' and girls' Speed Scores existed in grade one only. Therefore Hypothesis #6 was rejected for grade one with respect to this variable, but was not rejected for grades two, three, four, five and six.

3. Formulation of Hypotheses Score (individual visual)

Significant differences between boys' and girls' Scores existed in grades three and four. Therefore Hypothesis #6 was rejected for grades three and four for this particular variable and was not rejected for grades one, two, five and six.

4. Formulation of Hypotheses Speed Score (individual visual)

No significant differences between boys' and girls' Speed Scores were found at any grade level. Therefore no evidence appeared to exist for rejection of Hypothesis #6 with respect to this variable.

Data associated with this hypothesis indicate that in general boys in each of the grades achieved higher Scores on both the individual visual-mechanical and individual visual tasks. The finding that significant differences were not obtained between boys' and girls' Speed Scores on either task at the grade two, three, four, five and six levels indicates that, in general, boys in these grades required less time than did the girls in order to achieve their superior Scores."

Hypothesis #7

There is no significant difference between grade levels in:

(a) Formulation of Hypotheses Score (individual visual-mechanical)

(b) Formulation of Hypotheses Speed Score (individual visual-mechanical)

(c) Formulation of Hypotheses Score (individual visual)

(d) Formulation of Hypotheses Speed Score (individual visual)

in grades one through six.

The purpose of this hypothesis was to determine whether the ability to formulate hypotheses increased with grade level increase or not. Scores and Speed Scores were tested using the Scheffe Multiple Comparison of Means. A significance level of .10 was adopted as the basis for rejection or non-rejection of the hypothesis. This significance level was adopted because of the rigorous nature of the Scheffe procedure, the .10 level having been suggested by Scheffe (Ferguson, 1971, p. 271).

Scheffe Probability Matrices for the multiple comparison of the Scores and Speed Scores are presented in Tables VIII and IX.

1. Formulation of Hypotheses Score (individual visual-mechanical)

The mean score in grade one was significantly lower than the mean scores in grades three, four and six, the mean score in grade two also being significantly lower than the mean score in grade six while the mean score for grade five was significantly lower than

TABLE VIII

SCHEFFE PROBABILITY MATRICES FOR THE FORMULATION OF HYPOTHESES SCORES AND SPEED SCORES (INDIVIDUAL VISUAL-MECHANICAL) BY GRADE

Variable	Grade	One	Two	Three	Four	Five	Six
Score	One	1.000	.501	.010[a]	.006[a]	.532	.000[a]
	Two	.501	1.000	.572	.502	1.000	.034[a]
	Three	.010[a]	.572	1.000	.999	.606	.819
	Four	.006[a]	.502	.999	1.000	.534	.830
	Five	.532	1.000	.606	.534	1.000	.044[a]
	Six	.000[a]	.034[a]	.819	.830	.044[a]	1.000
Speed Score	One	1.000	.999	.991	.903	.000[a]	.047[a]
	Two	.999	1.000	.998	.956	.001[a]	.082[a]
	Three	.991	.998	1.000	.999	.011[a]	.267
	Four	.903	.956	.999	1.000	.030[a]	.479
	Five	.000[a]	.001[a]	.011[a]	.030[a]	1.000	.831
	Six	.047[a]	.082[a]	.267	.479	.831	1.000

[a] significant at 0.10 level

TABLE IX

SCHEFFE PROBABILITY MATRICES FOR THE FORMULATION OF HYPOTHESES SCORES AND SPEED SCORES (INDIVIDUAL VISUAL) BY GRADE

Variable	Grade	One	Two	Three	Four	Five	Six
Score	One	1.000	.980	.275	.056[a]	.013[a]	.000[a]
	Two	.980	1.000	.716	.307	.113	.006[a]
	Three	.275	.716	1.000	.993	.908	.357
	Four	.056[a]	.307	.993	1.000	.997	.703
	Five	.013[a]	.113	.908	.997	1.000	.940
	Six	.000[a]	.006[a]	.357	.703	.940	1.000
Speed Score	One	1.000	.834	.196	.309	.057[a]	.118
	Two	.834	1.000	.875	.959	.612	.777
	Three	.196	.875	1.000	.999	.998	.999
	Four	.309	.959	.999	1.000	.978	.997
	Five	.057[a]	.612	.998	.978	1.000	.999
	Six	.118	.777	.999	.997	.999	1.000

[a] significant at 0.10 level

that for grade six. Therefore Hypothesis #7 was rejected for the grade pairs one and three, one and four, one and six, two and six, and five and six, but was not rejected for all other pairs of grades.

2. Formulation of Hypotheses Speed Score (individual visual-mechanical)

The mean Speed Score in grade one was significantly lower than the mean Speed Scores in grades five and six. For grade two it was significantly lower than grades five and six, ~~and~~ for grade four it was significantly lower than for grade five. Therefore Hypothesis #7 was rejected for comparisons between grades one and five, one and six, two and five, two and six, four and five, but was not rejected for all other pairs.

3. Formulation of Hypotheses Score (individual visual)

The mean score in grade one was significantly lower than the mean score in grades four, five and six, while the mean score in grade two was also significantly lower than the mean score in grade six. Therefore Hypothesis #7 was rejected for all comparisons between grades one and four, one and five, one and six and two and six, but was not rejected for all other pairs.

4. Formulation of Hypotheses Speed Score (individual visual)

The mean Speed Score in grade one was significantly lower than the mean Speed Score in grade five. Therefore Hypothesis #7 was rejected with respect to this pair but was not rejected for all other comparisons.

The finding that the grade three, four and six levels achieved significantly higher individual visual-mechanical Scores than did grade one, whereas grade five did not achieve such significant Scores highlights the substantial 'slump' in Score manifested at the grade five level. Boys' and girls' Scores at this particular level are lower than those at the grade three and four levels. Results from the individual visual task indicated that no slump in Score was manifested at this grade level, or at any other level.

Hypothesis #8

There is no significant interaction between grade level and I.Q. with respect to:

(a) Formulation of Hypotheses Score (individual visual-mechanical

(b) Formulation of Hypotheses Speed Score (individual visual-mechanical)

(c) Formulation of Hypotheses Score (individual visual)

(d) Formulation of Hypotheses Speed Score (individual visual)

The purpose of this hypothesis was to determine whether or not I.Q. had a differential effect upon each of the grades one through six. Figures 5 and 6 illustrate the relationships existing between Scores and I.Q. groupings in each of the grades. The mean Scores and Speed Scores for each of the three I.Q. groupings in each grade are presented in Table X, interaction between grade level and I.Q. being shown in Table XIII.

1. Formulation of Hypothesis Score (individual visual-mechanical)

The Test for Additivity on this variable resulted in an F value of 2.187, which yielded a probability of .024 significant at the .05 level. Therefore Hypothesis #8 was rejected with respect to

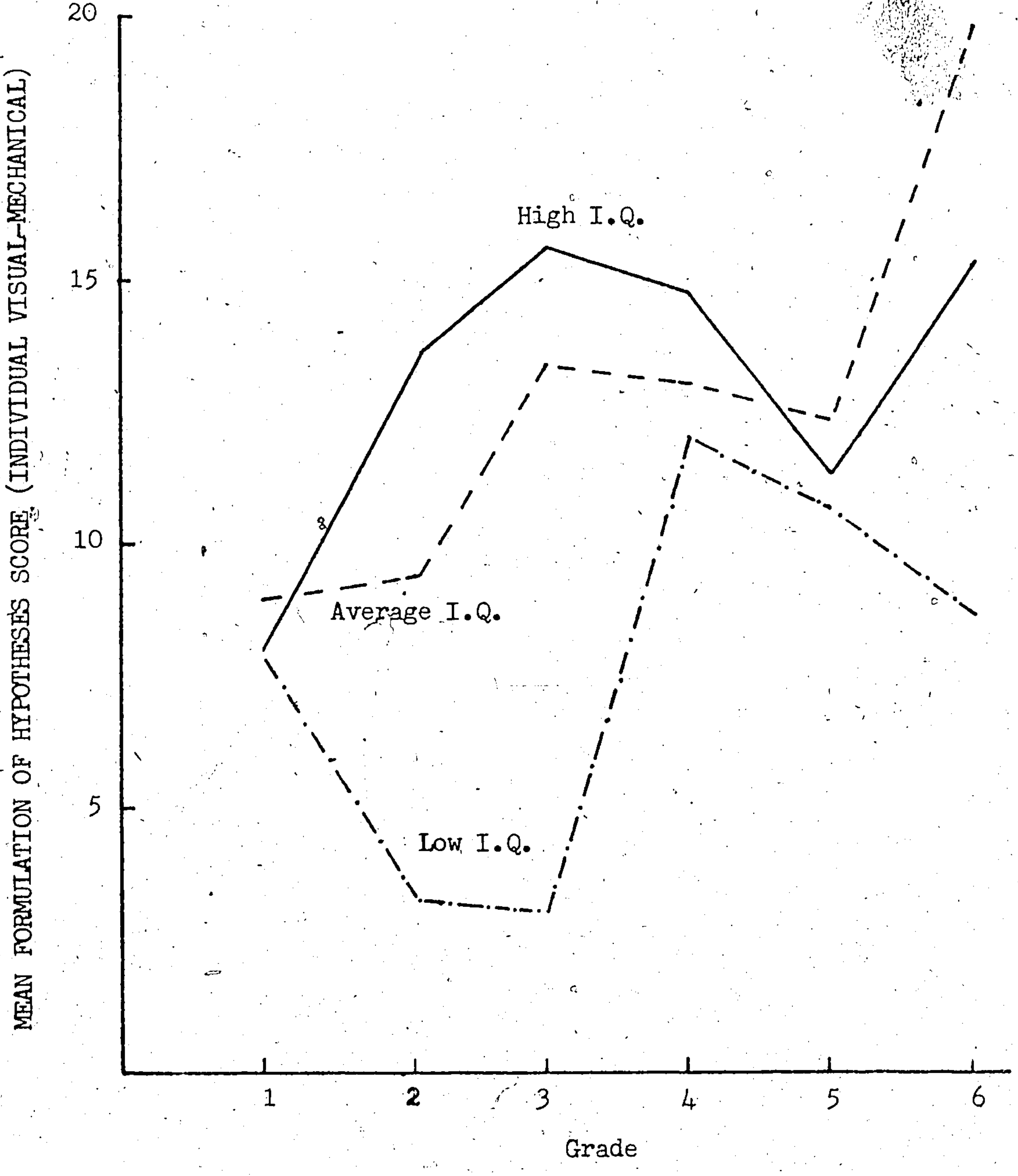


FIGURE 5

INTERACTION BETWEEN GRADE AND I.Q. ON FORMULATION OF HYPOTHESES SCORE (INDIVIDUAL VISUAL-MECHANICAL) CRITERION

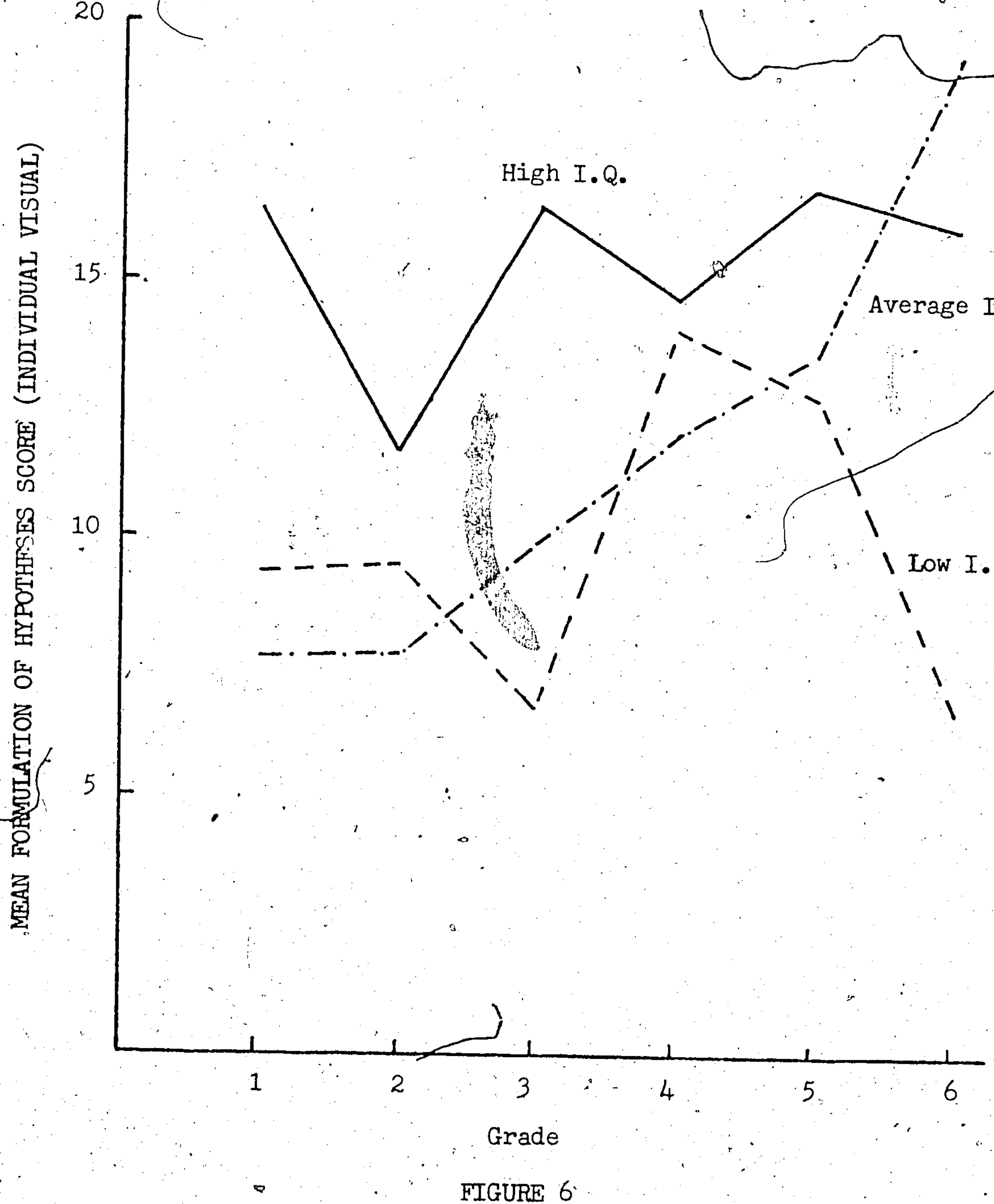


FIGURE 6

INTERACTION BETWEEN GRADE AND I.Q. ON FORMULATION OF HYPOTHESES SCORE (INDIVIDUAL VISUAL) CRITERION

TABLE X

MEAN FORMULATION OF HYPOTHESES SCORES AND SPEED SCORES FOR EACH I.Q. GROUP BY GRADE

Variable		I.Q. Group	N	One	N	Two	N	Three	N	Four	N	Five	N	Six
Individual Visual-Mechanical	Score	High	3	8.000	13	13.462	8	15.375	10	14.700	9	11.222	13	15.154
		Average	12	8.750	6	9.333	9	13.444	8	13.125	8	12.375	5	19.800
		Low	8	8.125	3	3.333	2	3.000	3	12.000	3	10.667	2	8.500
	Speed Score	High	3	.014	13	.012	8	.014	10	.012	9	.020	13	.018
		Average	12	.010	6	.012	9	.011	8	.014	8	.020	5	.014
		Low	8	.011	3	.004	2	.003	3	.011	3	.014	2	.012
Individual Visual	Score	High	3	16.333	13	11.615	8	16.375	10	14.500	9	16.667	13	15.846
		Average	12	7.667	6	7.833	9	9.778	8	12.000	8	13.500	5	19.200
		Low	8	9.25	3	9.333	2	6.500	3	14.000	3	12.667	2	6.500
	Speed Score	High	3	.030	13	.025	8	.036	10	.025	9	.036	13	.028
		Average	12	.015	6	.019	9	.021	8	.026	8	.027	5	.033
		Low	8	.021	3	.027	2	.020	3	.034	3	.022	2	.016

this variable.

2. Formulation of Hypotheses Speed Score (individual visual-mechanical)

The Test for Additivity resulted in an F value of 1.161 yielding a probability of .325 which was not significant at the .05 level. Therefore Hypothesis #8 was not rejected with respect to this variable.

3. Formulation of Hypotheses Score (individual visual)

The Test for Additivity resulted in an F value of 2.809 yielding a probability of .004 significant at the .05 level. Therefore Hypothesis #8 was rejected with respect to this variable.

4. Formulation of Hypotheses Speed Score (individual visual)

The Test for Additivity resulted in an F value of 2.070, yielding a probability of 0.033, significant at the .05 level. Therefore Hypothesis #8 was rejected with respect to this variable.

These findings indicate that there is a significant difference in the effect of the I.Q. variable upon individual visual Scores and Speed Scores and upon individual visual-mechanical Scores across the grades one through six.

Hypothesis #9

There is no significant difference between Low, Average and High I.Q. groups in:

(a) Formulation of Hypotheses Score (individual visual-mechanical)

(b) Formulation of Hypotheses Speed Score (individual visual-mechanical)

(c) Formulation of Hypotheses Score (individual visual)

(d) Formulation of Hypotheses Speed Score (individual visual)

for each of the grades one through six.

The purpose of this hypothesis was to determine whether or not significant differences in the ability to formulate hypotheses exist between I.Q. groups within each grade. Relevant data were tested using the Scheffe Multiple Comparison of Means procedure. The .10 level of significance was used as the basis for rejection or non-rejection of the hypothesis. Table X provides the mean Scores and Speed Scores for each of the three I.Q. groupings in each [illegible] Table XI provides the probability levels derived from the Scheffe procedure.

1. Formulation of Hypotheses Score (individual visual-mechanical)

No significant differences were found between any pair of I.Q. grouping at the grades one, four and five levels. A significant difference was found to exist between scores obtained by the High group (13.462) and the Low group (3.333) at the grade two level, between the scores obtained by the High group (15.375) and the Low group (3.00), and between the Average group (13.444) and the Low group (3.00) at the grade three level. A significant difference between the Average group (19.800) and Low group (8.500) at the grade six level also emerged. Therefore Hypothesis #9 was not rejected on the basis of the Scores obtained by the High and Average I.Q. groups within each of the six grade levels. Similarly the hypothesis was not rejected for High and Low I.Q. groups on the basis of Scores obtained by these groups in grades one, four, five

TABLE XI

SCHEFFE MULTIPLE COMPARISON OF MEANS OF I.Q. GROUP BY GRADE

Variable		I.Q. Group Compared	Probability Level by Grade One	Two	Three	Four	Five	Six
Individual Visual-Mechanical	Score	High-Average	.959	.129	.749	.781	.891	.185
		High-Low	.999	.003^{a}	.027^{a}	.688	.986	.190
		Average-Low	.943	.123	.062^{a}	.940	.878	.030^{a}
	Speed Score	High-Average	.222	.999	.380	.819	.999	.446
		High-Low	.565	.041^{a}	.018^{a}	.945	.507	.425
		Average-Low	.647	.073^{a}	.090^{a}	.745	.527	.924
Individual	Score	High-Average	.002^{a}	.166	.032^{a}	.498	.297	.255
		High-Low	.015^{a}	.659	.050^{a}	.985	.354	.014^{a}
		Average-Low	.574	.861	.671	.798	.955	.003^{a}
Visual	Speed Score	High-Average	.005^{a}	.447	.146	.996	.191	.635
		High-Low	.111	.969	.413	.386	.092^{a}	.271
		Average-Low	.148	.538	.996	.440	.651	.133

[a] significant at 0.10 level

and six, but was rejected on the basis of Scores obtained at the grades two and three levels. The hypothesis was not rejected for the Average and Low I.Q. groupings on the basis of Scores obtained at the grades three and six levels.

2. Formulation of Hypotheses Speed Score (individual visual-mechanical)

No significant differences were found between the Speed Scores obtained by any pair of I.Q. groupings at the grade one, four, five and six levels. Significant differences were found between Speed Scores obtained by the High I.Q. group (.012) and the Low group (.004), and by the Average I.Q. group (.012) and the Low group (.004) at the grade two level, as well as by the High I.Q. group (.014) and the Low I.Q. group (.003), and by the Average I.Q. group (.011) and the Low at the grade three level. Therefore hypothesis #9 was not rejected for High and Average I.Q. groupings for Speed Scores obtained at all six levels. The hypothesis was also not rejected for High and Low I.Q. groupings for Speed Scores obtained at the one, four, five and six levels, but was rejected for these groupings for Speed Scores obtained at the grade two and three levels.

3. Formulation of Hypotheses Score (individual visual)

No significant differences were found between Scores obtained by any pair of I.Q. grouping at the grades two, four and five levels. Significant differences were found to exist between Scores obtained by the High I.Q. groupings (16.33) and the Average group (7.667) at the grade one level, and by the High group (16.375) and the Average group (9.778) at the grade three level. Significant differences were found between Scores obtained by the High I.Q. group (16.333) and the Low group (9.250) at the grade one level, between the Scores of the High I.Q. group (16.375) and the Low I.Q. group (6.500) at the grade three level and between the Scores obtained by the High I.Q. group (15.846) and the Low I.Q. group (6.500) at the grade six level. A further significant difference was found to exist between Scores obtained by the Average I.Q. group (19.200) and the Low I.Q. group (6.500) at the grade six level. Therefore Hypothesis #9 was not rejected for High-Average I.Q. groups for Scores obtained at the grade two, four, five and six levels, but was rejected for these groupings for Scores obtained at the grade one and three levels. The hypothesis was not rejected for High-Low I.Q. groupings for Scores obtained at the grade two, four and five levels, but was rejected for these groupings at the grade one, three and six levels. The hypothesis was not rejected for Average-Low I.Q. groupings for Scores obtained at the grades one, two, three, four and five levels, but was rejected for these groupings at the grade six level.

4. Formulation of Hypotheses Speed Score (individual visual)

No significant differences were found to exist between Speed Scores obtained by any pair of I.Q. groupings at the grades two, three, four and five levels. A significant difference was found to exist between Speed Scores obtained by the High I.Q. group (.030) and the Average I.Q. group (.015) at the grade one level, while a significant difference was found between the Speed Scores obtained by the High I.Q. group (.036) and the Low I.Q. group (.022) at the grade five level. Therefore Hypothesis #9 was not rejected for High-Average I.Q. groupings for Speed Scores obtained at the grades two, three, four, five and six levels, but was rejected for these groupings at the grade one level. It was not rejected for the High-Low I.Q. groupings for Speed Scores obtained at the grade one, two, three, four and six levels, but was rejected at the grade five level. It was not rejected for Average-Low I.Q. groupings for Speed Scores obtained at any of the six grade levels.

In the majority of cases, scores obtained by High I.Q. groups on both the individual visual-mechanical and individual visual tasks were superior at each grade level to those obtained by the Average and Low groups. Scores of the Average I.Q. groups in turn, were generally superior to those of Low I.Q. groups.

Hypothesis #10

There is no significant interaction between I.Q. and sex with respect to:

(a) Formulation of Hypotheses Score (individual visual-mechanical).

(b) Formulation of Hypotheses Speed Score (individual visual)

(c) Formulation of Hypotheses Score (individual visual)

(d) Formulation of Hypotheses Speed Score (individual visual).

The purpose of this hypothesis was to determine whether or not I.Q. had a differential effect upon each of the Scores and Speed Scores according to sex difference. Figures 7 and 8 illustrate the relationships existing between scores, I.Q. and sex. Scores and

TABLE XII

INTERACTION BETWEEN GRADE LEVEL AND SEX WITH RESPECT TO FORMULATION OF HYPOTHESES SCORES AND SPEED SCORES

Variable		Source of Variance	Sum of Squares	D.F.	Mean Squares	F	Prob.
Individual Visual-Mechancial	Score	Interaction	28.8281	5	5.76562	.277	0.925
		Error	2352.22	113	20.8161		
	Speed Score	Interaction	137.303	5	2746.06	.981	0.432
		Error	31.6180	113	2798.05		
Individual Visual	Score	Interaction	59.9688	5	11.9937	.621	0.684
		Error	2181.18	113	19.3025		
	Speed Score	Interaction	7134.68	5	1426.94	.129	0.986
		Error	1.2546	113	111.027		

TABLE XIII

INTERACTION BETWEEN GRADE LEVEL AND I.Q. WITH RESPECT TO FORMULATION OF HYPOTHESES SCORES AND SPEED SCORES

Variable		Source of Variance	Sum of Squares	D.F.	Mean Squares	F	Prob.
Individual Visual-Mechanical	Score	Interaction	450.609	10	45.0609	2.187	0.024
		Error	2204.53	17	20.6031		
	Speed Score	Interaction	309.449	10	3094.49	1.161	0.325
		Error	28.5092	17	2664.41		
Individual Visual	Score	Interaction	443.984	10	44.3984	2.809	0.004
		Error	1691.51	17	15.8085		
	Speed Score	Interaction	20.1535	10	201.535	2.070	0.033
		Error	1.0417	17	9735.55		

TABLE XIV

MEAN FORMULATION OF HYPOTHESES SCORES AND SPEED SCORES FOR EACH I.Q. GROUP BY SEX

Variable		Sex	N	I.Q. High	N	I.Q. Average	N	I.Q. Low
Individual Visual-Mechanical	Score	Boys	27	14.56	25	14.72	13	9.46
		Girls	29	12.90	24	9.46	7	4.71
	Speed Score	Boys	27	0.02	25	.02	13	0.01
		Girls	29	0.01	24	.01	7	0.01
Individual Visual	Score	Boys	27	15.74	25	13.44	13	10.61
		Girls	29	14.03	24	8.63	7	7.71
	Speed Score	Boys	27	.031	25	.026	13	.23
		Girls	29	.027	24	.20	7	.22

TABLE XV

INTERACTION BETWEEN I.Q. AND SEX WITH RESPECT TO FORMULATION OF HYPOTHESES SCORES AND SPEED SCORES

Variable		Source of Variance	Sum of Squares	D.F.	Mean Squares	F	Prob.
Individual Visual-Mechanical	Score	Interaction	92.3847	2	46.1934	2.094	.128
		Error	2625.02	119	22.0590		
	Speed Score	Interaction	112.396	2	5619.79	1.801	.170
		Error	37.1247	119	3119.70		
Individual Visual	Score	Interaction	63.3359	2	31.6680	1.679	.191
		Error	2244.45	119	18.8609		
	Speed Score	Interaction	7408.86	2	3704.43	.341	.712
		Error	1.29328	119	108.679		

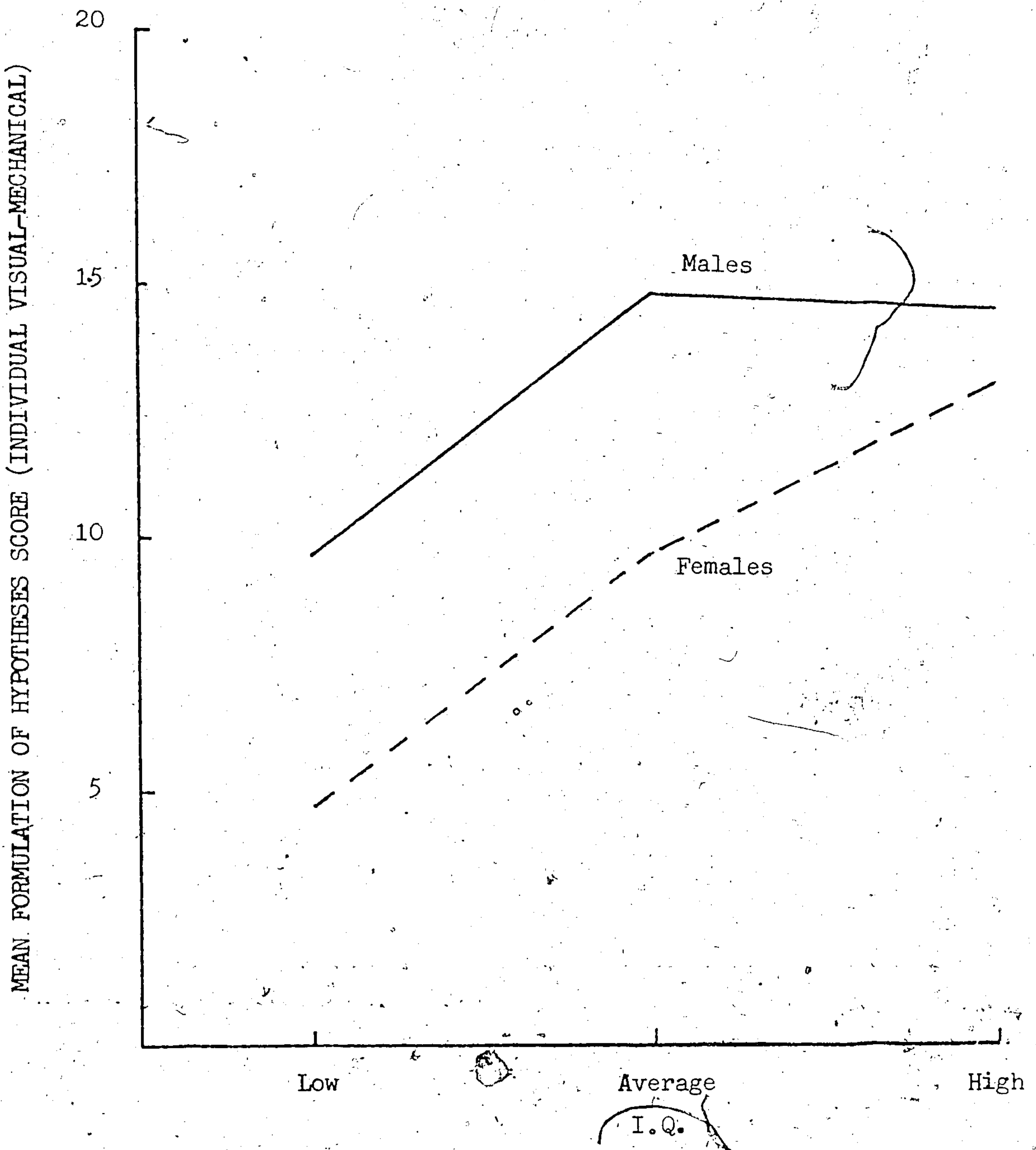


FIGURE 7

INTERACTION BETWEEN I.Q. AND SEX ON FORMULATION OF HYPOTHESES SCORE (INDIVIDUAL VISUAL-MECHANICAL) CRITERION

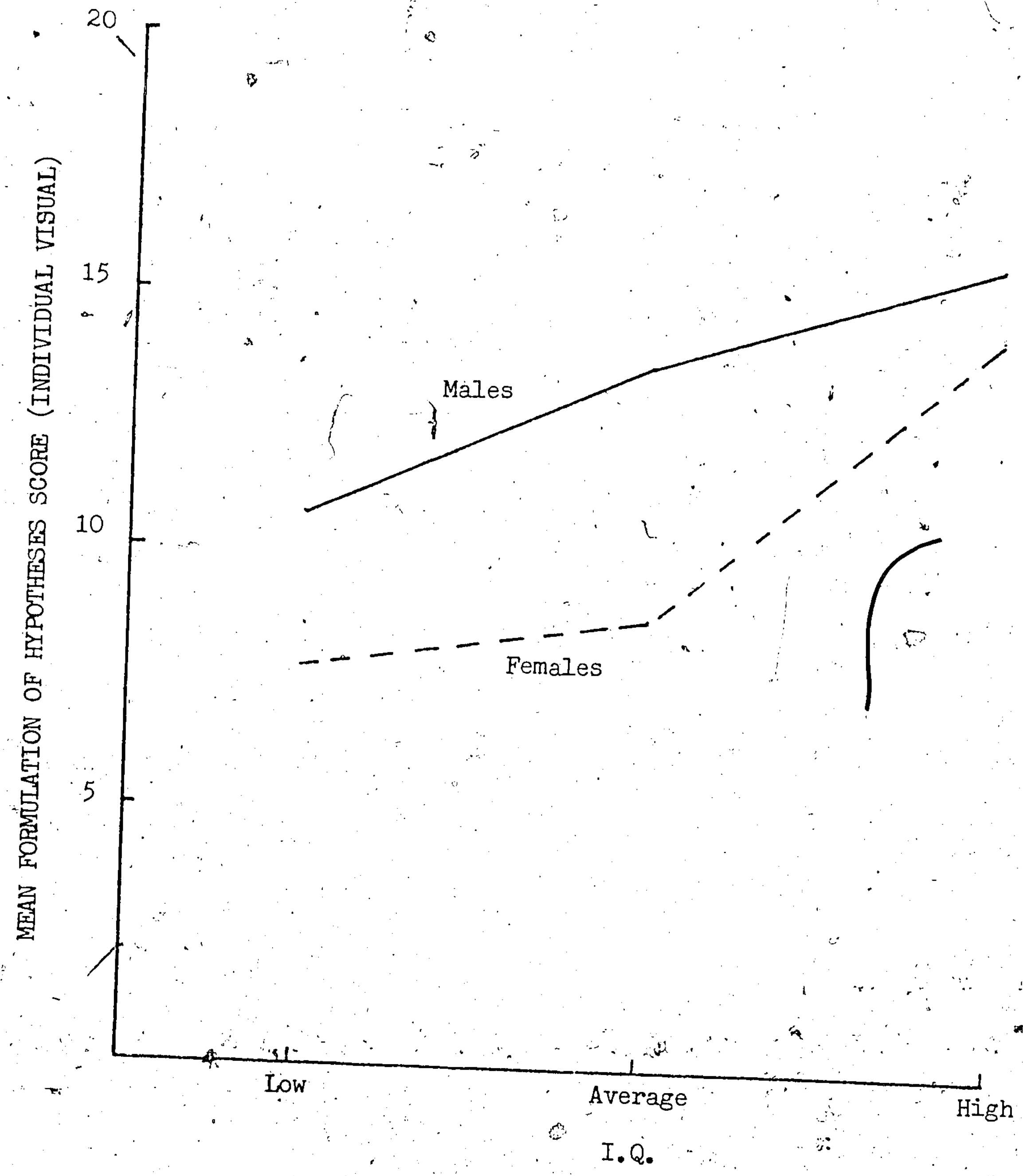


FIGURE 8

INTERACTION BETWEEN I.Q. AND SEX ON FORMULATION OF HYPOTHESES SCORE (INDIVIDUAL VISUAL) CRITERION

Speed Scores are shown in Table XIV; interaction between I.Q. and sex in Table XV.

1. <u>Formulation of Hypotheses Score (individual visual-mechanical)</u>

The Test for Additivity resulted in an F value of 2.094 which yielded a probability of .128 which was not significant at the .05 level. Therefore Hypotheses #10 was not rejected with respect to this variable.

2. <u>Formulation of Hypotheses Speed Score (individual visual-mechanical)</u>

The Test for Additivity resulted in an F value of 1.1801 yielding a probability of .170 which was not significant at the .05 level. Therefore the hypothesis was not rejected with respect to this variable.

3. <u>Formulation of Hypotheses Score (individual visual)</u>

The Test for Additivity resulted in an F value of 1.679 yielding a probability of .191, again not significant at the .05 level. Therefore the hypothesis was not rejected for this variable.

4. <u>Formulation of Hypotheses Speed Score (individual visual)</u>

The Test for Additivity resulted in an F value of .341 yielding a probability of .712, not significant at the .05 level. Therefore Hypothesis #10 was not rejected with respect to this variable.

These findings indicate that there is no significant difference in the effect of the sex variable upon each of the Scores and Speed Scores for each of the three I.Q. groupings. Thus, while the boys in each I.Q. group in general achieved higher Scores than the girls, their superiority in performance did not alter significantly with respect to I.Q. group.

DESCRIPTION OF PERFORMANCE

The Individual Visual-Mechanical Task

In the following discussion relating to each of the two questions associated with this particular task, attention will focus on the following points:

1. The nature of the triangle combinations
2. The frequency of utilization of the various triangle combinations for all grade levels combined
3. The overall triangle combination preference at each of the grade levels
4. The average number of triangle combinations hypothesized per student at each grade level
5. The first, second and third triangle combination preferences at each grade level.

The First Question

1. Triangle Combination Composition. Ten functionally operative triangle combinations were possible for the valid completion of this question. These are identified and illustrated in Figure 9, p. 84.

2. Frequency of Utilization of the Triangle Combination. Question one permitted the utilization of two-triangle and four-triangle combinations.

Both types of triangle combination were widely utilized

TABLE XVI

OVERALL TRIANGLE COMBINATION PREFERENCE IN THE FIRST INDIVIDUAL VISUAL-MECHANICAL TASK

		Percentage of Students Making Choice										Total Number of Combinations Hypothesized
Grade	No. Students	A	B	C	D	E	F	G	H	I	J	
One	23	13.0	65.2	22.2	55.7	26.1	39.1	26.1	34.8	13.0	34.8	76
Two	22	31.8	81.8	27.3	63.6	63.6	40.9	13.6	40.9	22.7	59.1	98
Three	19	36.8	79.0	31.6	52.6	57.9	57.9	42.1	52.6	52.6	57.9	99
Four	21	33.3	90.5	57.1	52.4	47.6	76.2	28.6	33.3	19.0	95.2	112
Five	20	50.0	80.0	50.0	65.0	35.0	65.0	30.0	30.0	20.0	65.0	98
Six	20	80.0	90.0	70.0	55.0	55.0	70.0	35.0	35.0	25.0	90.0	121
Combined	125	40.0	80.8	42.4	57.6	47.2	57.6	28.8	37.6	24.8	70.4	604

TABLE XVI

FREQUENCY OF UTILIZATION OF THE TRIANGLE COMBINATIONS IN THE FIRST INDIVIDUAL VISUAL-MECHANICAL TASK

Grade	Fr[illegible]ncy of Utilization Position									
	1st	2n[illegible]	[illegible]	[illegible]	5th	6th	7th	8th	9th	10th
One	B^2	D[illegible]	[illegible]	[illegible]	[illegible]	E^2 G^2		C^4	A^4	I^2
Two	B^2	D^2 E^2	[illegible]	[illegible]	[illegible]		A^4	C^4	I^2	G^2
Three	B^2	E^2 F^4 J^4	[illegible]	[illegible]	[illegible]^2 H^2 I^2			G^2	A^4	C^4
Four	J^4	B^2	F^4	C^4	D^2	E^2	A^4 H^2		G^2	I^2
Five	B^2	D^2 F^4 J^4			A^4 C^4		E^2	G^2 H^2		I^2
Six	B^2 J^4		A^4	C^4 F^4		D^2 E^2		G^2 H^2		I^2
Combined	B^2	J^4	D^2 F^4		E^2	C^4	A^4	H^2	G^2	I^2

2 Two-Triangle Combination

4 Four-Triangle Combination

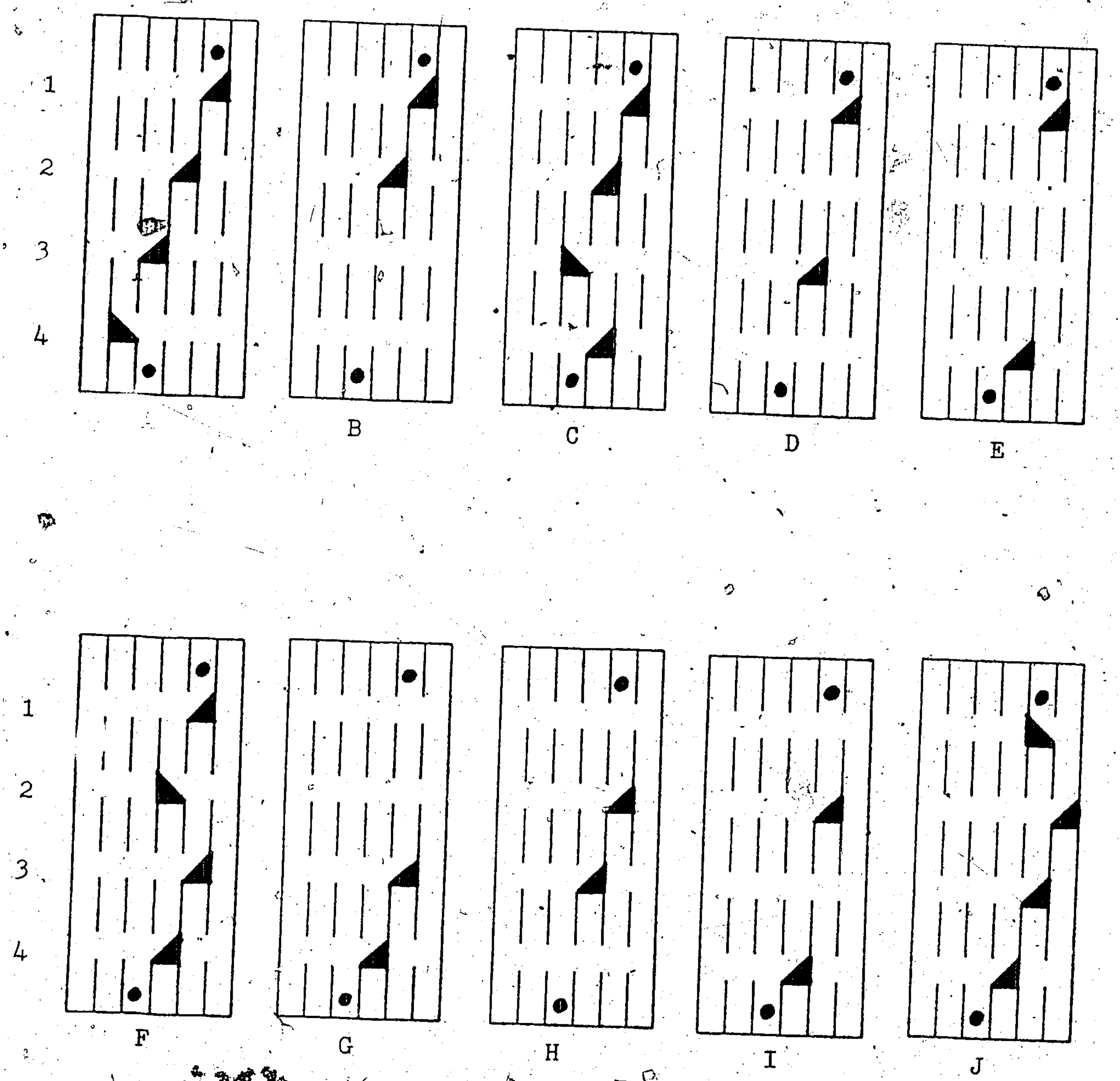


FIGURE 9

POSSIBLE TRIANGLE COMBINATIONS FIRST INDIVIDUAL VISUAL-MECHANICAL TASK

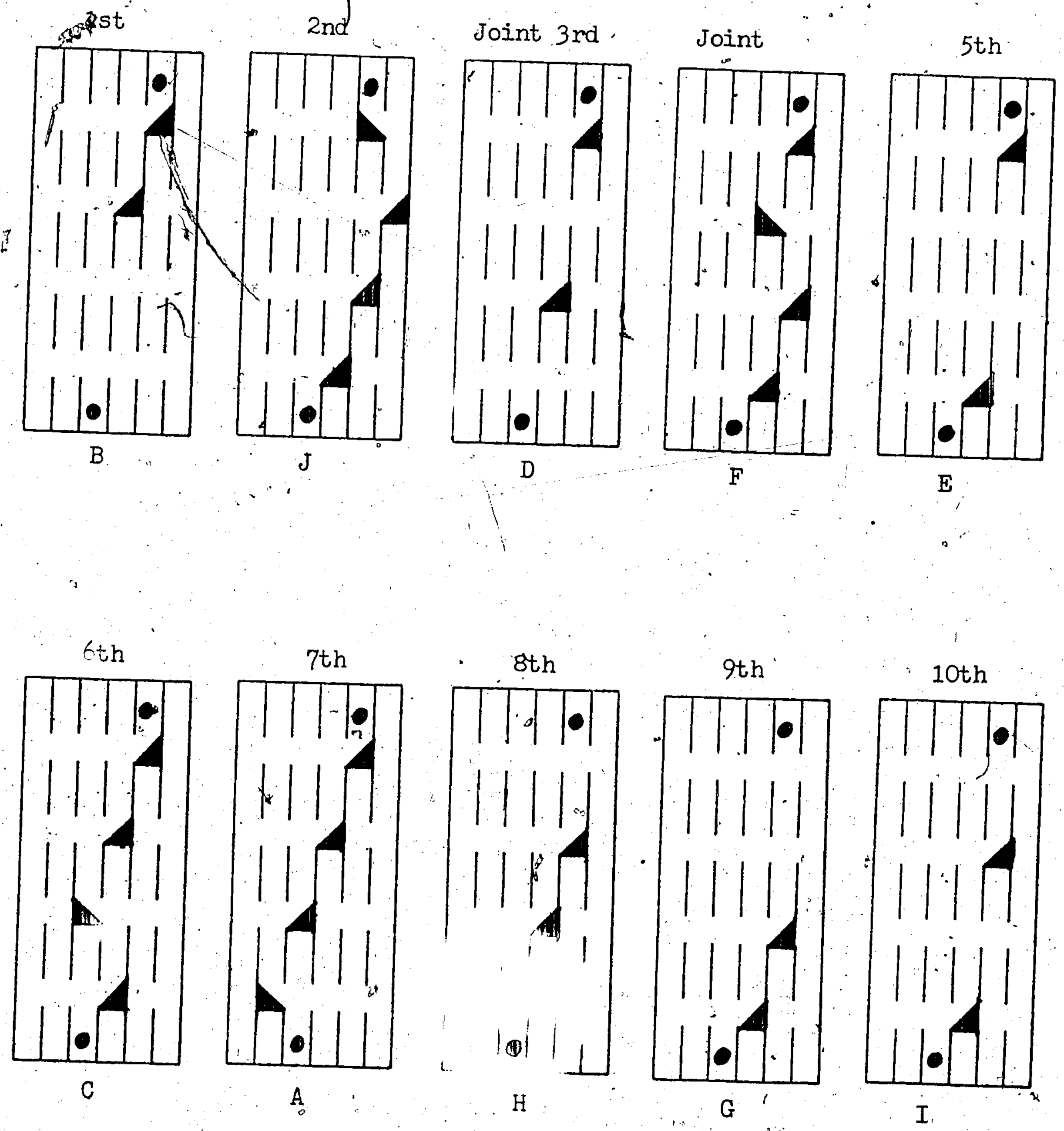


Figure 10

SEQUENCE OF TRIANGLE COMBINATIONS PREFERENTIALLY CHOSEN
FIRST INDIVIDUAL VISUAL-MECHANICAL TASK

by the students. Specifically, two-triangle combinations occupied first, third, fifth, eighth, ninth and tenth positions in frequency of choice (see Table XVII, p. 83). Figure 10, p. 85, presents the sequence of two-triangle combinations preferentially chosen by the students. This Figure illustrates that combinations G, H, and I, with no triangle in gap one, are the lowest three in frequency of choice utilization.

The remaining triangle combinations (A, C, F and J) of the ten, in which all four possible gaps are filled, constitute the second, third, sixth and seventh frequencies of choice respectively. Figure 10, p. 85, also presents the sequence of these four-triangle combinations preferentially chosen.

3. Overall Triangle Combination Preference. A remarkable similarity with respect to which of the triangle combinations were most frequently hypothesized as being operative was evident across all of the grades. Triangle combination B, for example, was the most frequently hypothesized as being operative by five of the six grades (grades one, two, three, five and six) and was also the second most frequently hypothesized combination for grade four.

Similarity in preference for certain triangle combinations across grades was also evident with respect to triangle combinations least frequently utilized. Combination I, for example, was the least frequently utilized by four of the six grades (grades one, four, five and six). A summary of results which show all triangle combination preferences for each grade is given in Table XVII, p. 83, and in Figure 11, p. 87.

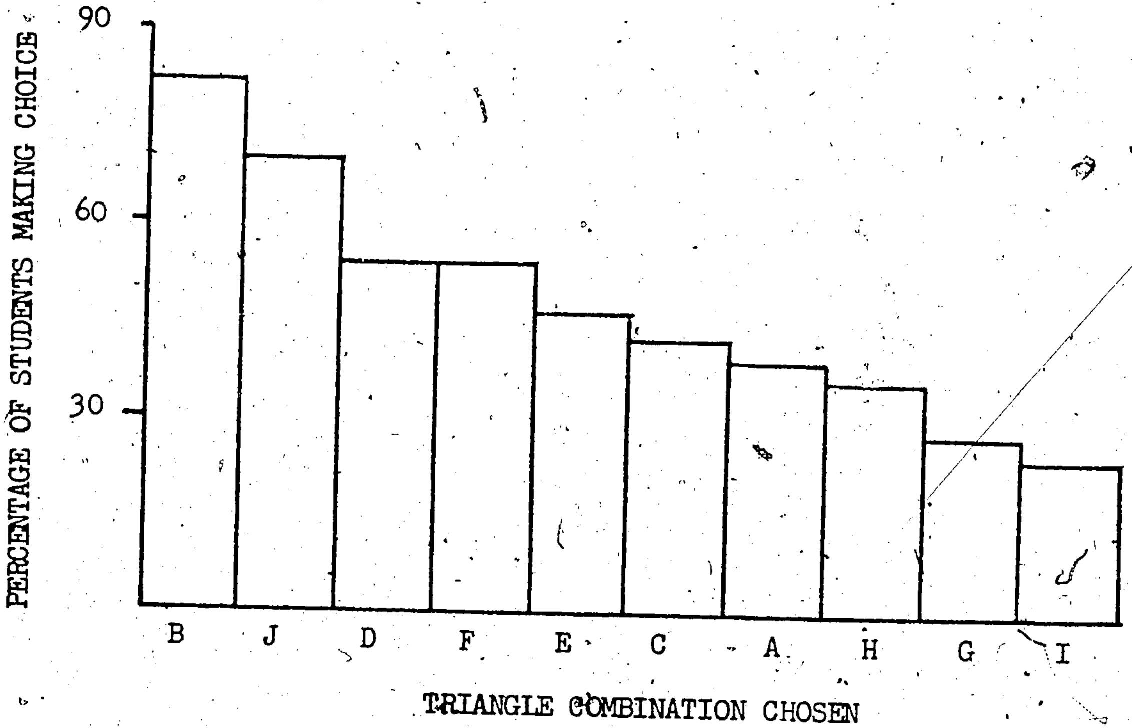


FIGURE 11

OVERALL TRIANGLE COMBINATION PREFERENCE DURING FIRST INDIVIDUAL VISUAL-MECHANICAL TASK (ALL GRADES COMBINED)

4. *Number of Triangle Combinations Hypothesized*. Table XVI, p. 82 shows the average performance of students in each of the grades with respect to their ability to hypothesize the utilization of each triangle combination. The table shows that, in general, as the grade level increases, the average number of triangle combinations hypothesized per student also increases. A notable exception to this trend however, is manifested by grade five students, a general decline in average being evident at this level. Specifically, combinations B, C, E, F, H, and J tend to be hypothesized with less frequency by grade five students than by grade four students, while combinations A, D, G and I are hypothesized more frequently.

With respect to the triangle combination first used as a basis for an hypothesis by each of the grades one through six, two-triangle combination B was the most frequently chosen (see Table XVIII, p. 89, and Figure 12, p. 94).

With respect to the second triangle combination used as a basis for the formulation of an hypothesis, the four-triangle J was the most frequently utilized by four of the grades—namely grades one, two, four and five (see Table XIX, p. 90 and Figure 14, p. 96).

The Second Question

1. *Triangle Combination Composition*. Sixteen functionally operative triangle combinations were possible for the valid completion of this question. These are identified and illustrated in Figure 15, p. 97.

TABLE XVIII

TRIANGLE COMBINATION FIRST CHOSEN AS A BASIS FOR AN HYPOTHESIS IN THE FIRST INDIVIDUAL VISUAL-MECHANICAL TASK

	Percentage of Students Making Choice											Triangle Combination		
Grade	A	B	C	D	E	F	G	H	I	J	Grade	Most Frequently Chosen	Second Most Frequently Chosen	Third Most Frequently Chosen
One	0.0	52.2	0.0	21.7	0.0	13.0	4.3	4.3	0.0	4.3	One	B	D	F
Two	0.0	63.7	9.1	13.6	9.1	0.0	4.6	9.1	4.6	0.0	Two	B	D	C E H
Three	0.0	42.1	10.5	5.2	5.2	0.0	0.0	15.8	10.5	10.5	Three	B	H	C I J
Four	0.0	54.8	4.8	9.6	0.0	14.3	4.8	4.8	0.0	4.8	Four	B	F	D
Five	0.0	50.0	0.0	20.0	5.0	5.0	0.0	15.0	0.0	5.0	Five	B	D	H
Six	0.0	65.0	0.0	15.0	5.0	10.0	0.0	5.0	0.0	0.0	Six	B	D	F
Combined	0.0	54.6	4.1	14.2	4.1	5.4	2.9	9.0	2.5	4.1	Combined	B[2]	D[2]	H[2]

---

[2] Two-Triangle Combination

TABLE XIX

SECOND TRIANGLE COMBINATION CHOSEN AS A BASIS FOR AN HYPOTHESIS IN THE FIRST INDIVIDUAL VISUAL-MECHANICAL TASK

	Percentage of Students Making Choice											Triangle Combination		
Grade	A	B	C	D	E	F	G	H	I	J	Grade	Most Frequently Chosen	Second Most Frequently Chosen	Third Most Frequently Chosen
One	4.3	8.6	8.6	17.4	0.0	4.3	0.0	13.0	0.0	21.7	One	J	D	H
Two	4.6	9.1	4.6	18.2	9.1	9.1	4.6	4.6	4.6	22	Two	J	D	B E F
Three	16.0	16.0	0.0	16.0	5.2	10.5	0.0	5.2	10.5	10.5	Three	A B D		
Four	4.8	4.8	9.6	4.8	9.6	9.6	4.8	9.6	4.8	37.7	Four	J	C E F H	
Five	5.0	10.0	15.0	15.0	0.0	10.0	10.0	5.0	0.0	30.0	Five	J	C D	
Six	20.0	5.0	10.0	10.0	5.0	20.0	5.0	5.0	5.0	15.0	Six	A F		J
Combined	9.1	8.9	8.0	13.6	4.8	10.6	4.1	7.1	4.2	22.7	Combined	J[4]	D[2]	F[4]

[2] Two-Triangle Combination

[4] Four-Triangle Combination

TABLE XX

THIRD TRIANGLE COMBINATION CHOSEN AS A BASIS FOR AN HYPOTHESIS IN THE FIRST INDIVIDUAL VISUAL-MECHANICAL TASK

Grade	Percentage of Students Making Choice									
	A	B	C	D	E	F	G	H	I	J
One	0.0	4.3	13.0	13.0	8.6	8.6	0.0	13.0	4.3	4.3
Two	9.1	4.6	0.0	13.6	13.6	18.2	0.0	13.6	4.6	13.6
Three	0.0	10.5	0.0	5.2	10.5	21.0	10.5	5.2	0.0	21.0
Four	0.0	4.8	0.0	9.6	14.3	28.6	9.6	4.8	0.0	28.6
Five	0.0	25.0	0.0	15.0	5.0	15.0	10.0	0.0	5.0	20.0
Six	15.0	0.0	10.0	10.0	0.0	15.0	0.0	10.0	0.0	35.0
Combined	4.1	6.5	3.8	11.1	8.7	17.7	5.1	7.8	2.3	20.4

Grade	Triangle Combination		
	Most Frequently Chosen	Second Most Frequently Chosen	Third Most Frequently Chosen
One	C D H		
Two	F	D E H J	
Three	F J		B E H
Four	F J		E
Five	J	B D F	
Six	J	A F	
Combined	J[4]	F[4]	D[2]

[2] Two-Triangle Combination

[4] Four-Triangle Combination

TABLE XXI

OVERALL TRIANGLE COMBINATION PREFERENCE IN THE SECOND INDIVIDUAL VISUAL-MECHANICAL TASK

Grade	No. Students	Percentage of Students Making Choice																Total Number of Combinations Hypothesized
		K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	
One	23	4.4	39.1	87.0	22.2	17.4	47.8	22.2	34.8	34.8	4.4	52.2	13.0	17.4	60.9	13.0	22.2	113
Two	22	18.2	59.1	68.2	29.1	18.2	72.7	40.9	45.5	31.8	9.1	40.9	22.7	13.6	50.0	18.2	50.0	125
Three	19	42.1	52.6	94.7	31.6	47.4	63.2	47.4	68.4	63.2	31.6	47.4	10.5	21.0	73.7	42.1	63.2	152
Four	21	42.9	66.7	100.0	29.5	38.1	90.5	57.1	76.2	57.1	14.3	61.9	38.1	42.9	85.8	52.4	52.4	186
Five	20	15.0	60.0	90.0	20.0	15.0	70.0	40.0	50.0	50.0	10.0	55.0	20.0	15.0	75.0	30.0	35.0	132
Six	20	40.0	100.0	85.0	30.0	45.0	100.0	75.0	55.0	60.0	35.0	65.0	35.0	55.0	100.0	45.0	55.0	196
Combined	125	26.4	62.4	87.2	20.0	29.6	73.6	46.4	54.4	50.4	16.8	53.6	25.2	27.2	73.6	32.8	45.6	904

TABLE XXII

FREQUENCY OF UTILIZATION OF THE TRIANGLE COMBINATIONS IN THE SECOND INDIVIDUAL VISUAL-MECHANICAL TASK

	Frequency of Utilization Position															
Grade	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th
One	M	X	U	P	L	R S		N Q Z			O W		V Y		K T	
Two	P	M	L	X Z		R	Q U		S	V	K O Y			W	N T	
Three	M	X	R	P S Z			L	O Q U			K Y		N T		W	V
Four	M	P	X	R	L	U	Q S		Y Z		K W		O V			N
Five	M	X	P	L S		U	R	Q	Z	Y	N V		K O W			T
Six	L P X			M	Q	U	S	R W Z			O W		K	T V		N
Combined	M^1	P^3 X^3		L^3	R^1	U^1	S^1	Q^3	Z^3	Y^3	O^3	W^3	K^3	V^3	N^3	T^3

[1] One-Triangle Combination

[2] Three-Triangle Combination

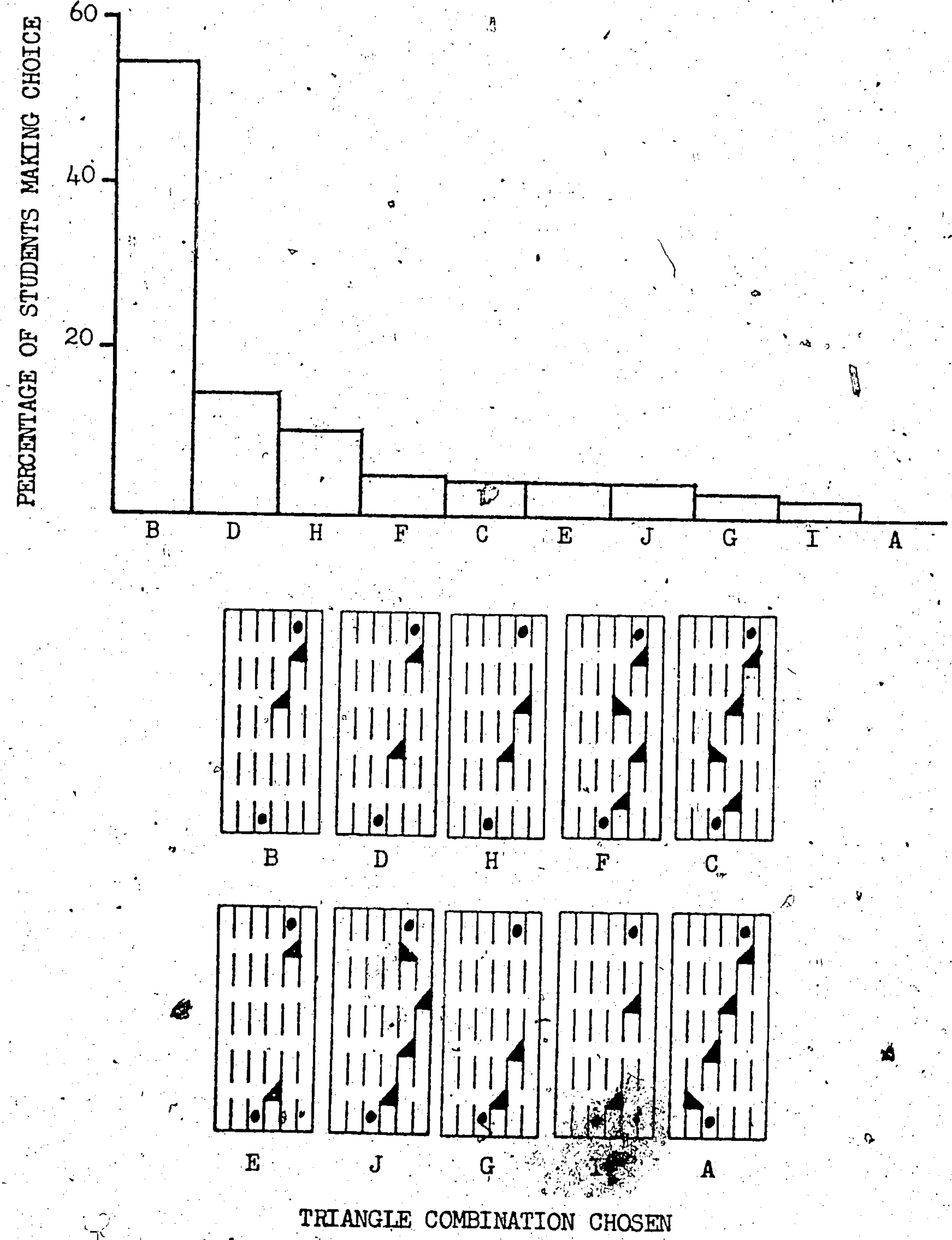


FIGURE 12

INITIAL TRIANGLE COMBINATION PREFERENCE AS INDICATED IN THE FIRST INDIVIDUAL VISUAL-MECHANICAL TASK (GRADES COMBINED)

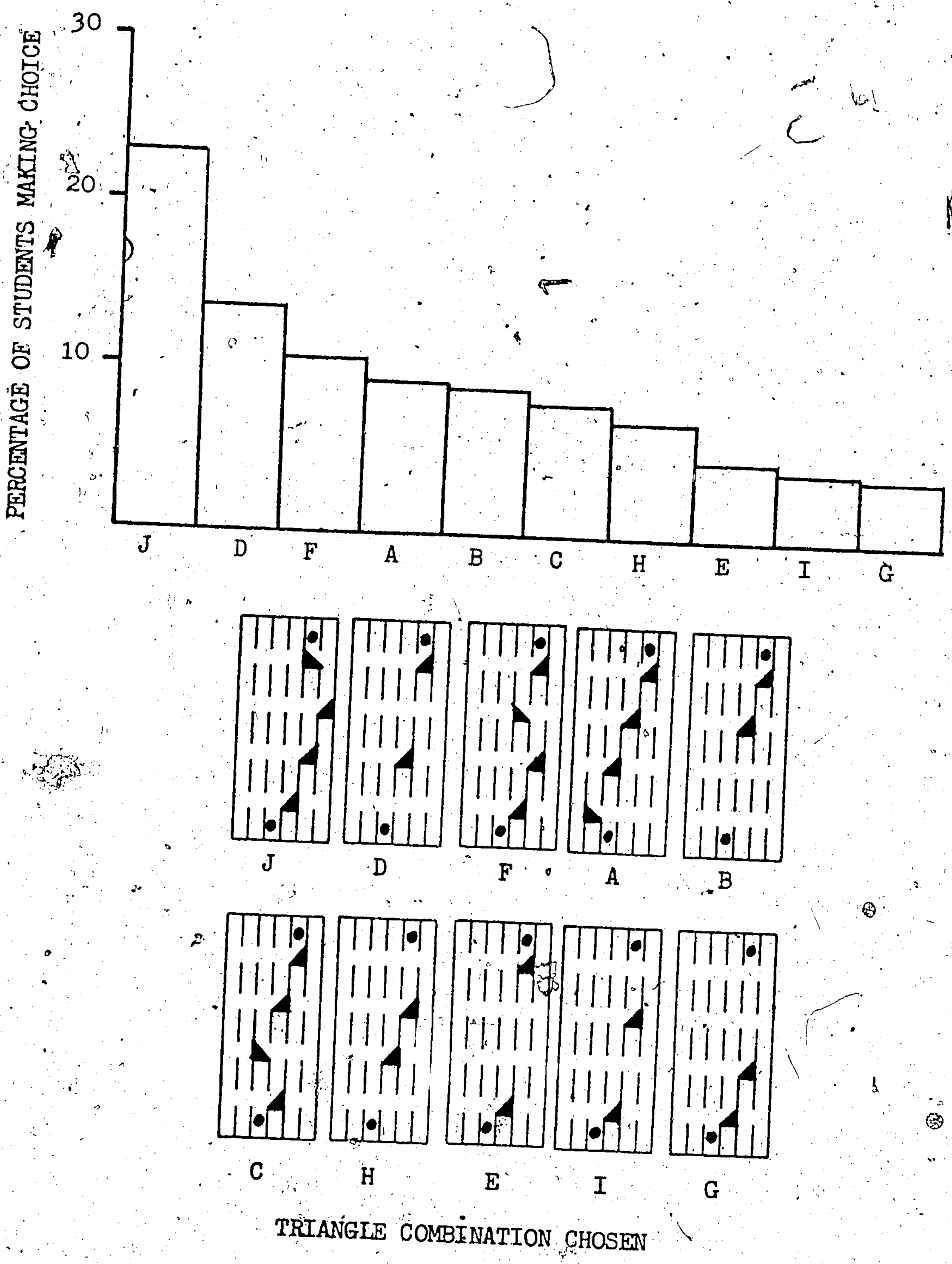


FIGURE 13

SECOND TRIANGLE COMBINATION PREFERENCE AS INDICATED IN THE FIRST INDIVIDUAL VISUAL-MECHANICAL TASK (GRADES COMBINED)

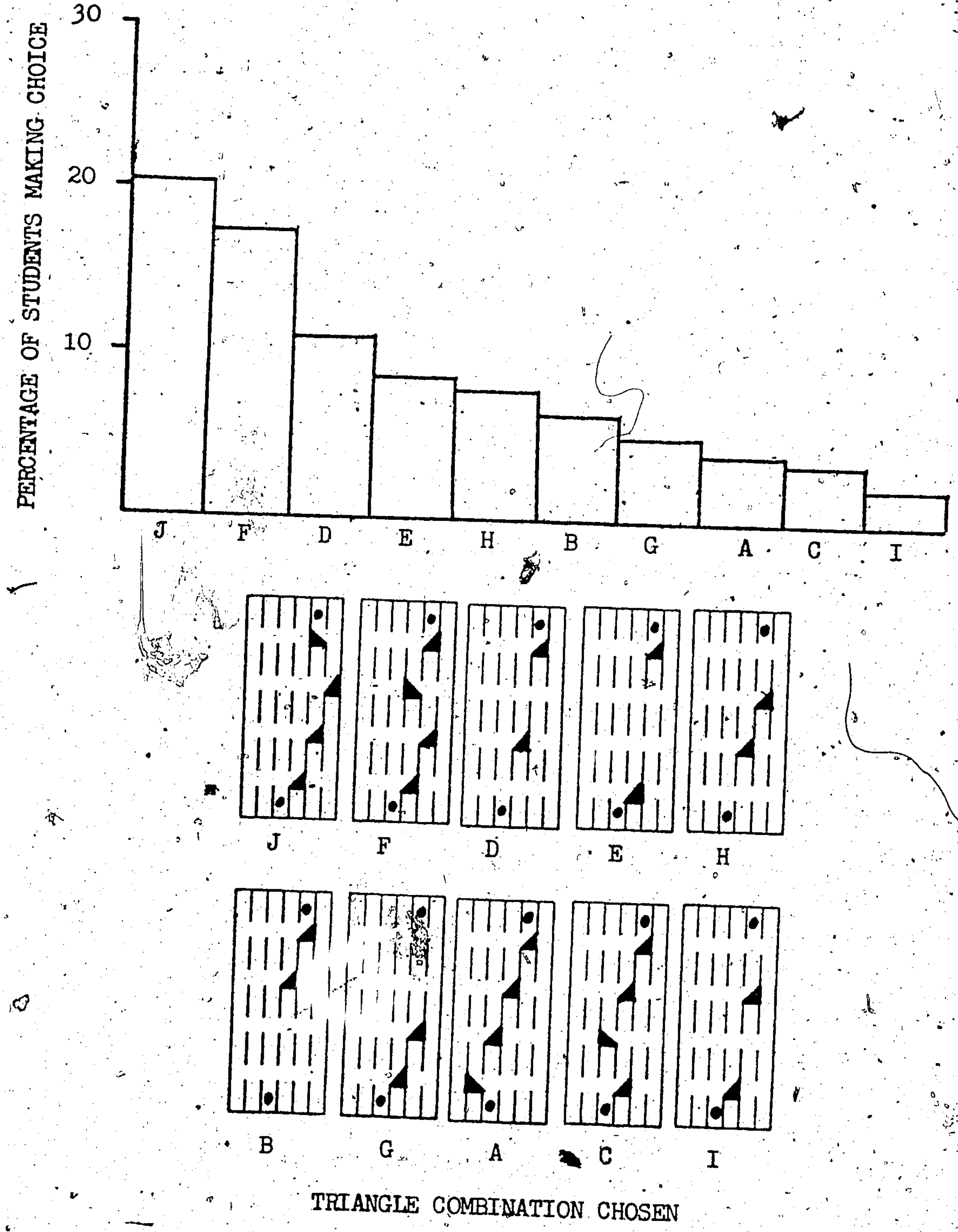


FIGURE 14

THIRD TRIANGLE COMBINATION PREFERENCE AS INDICATED IN THE FIRST INDIVIDUAL VISUAL-MECHANICAL TASK (GRADES COMBINED)

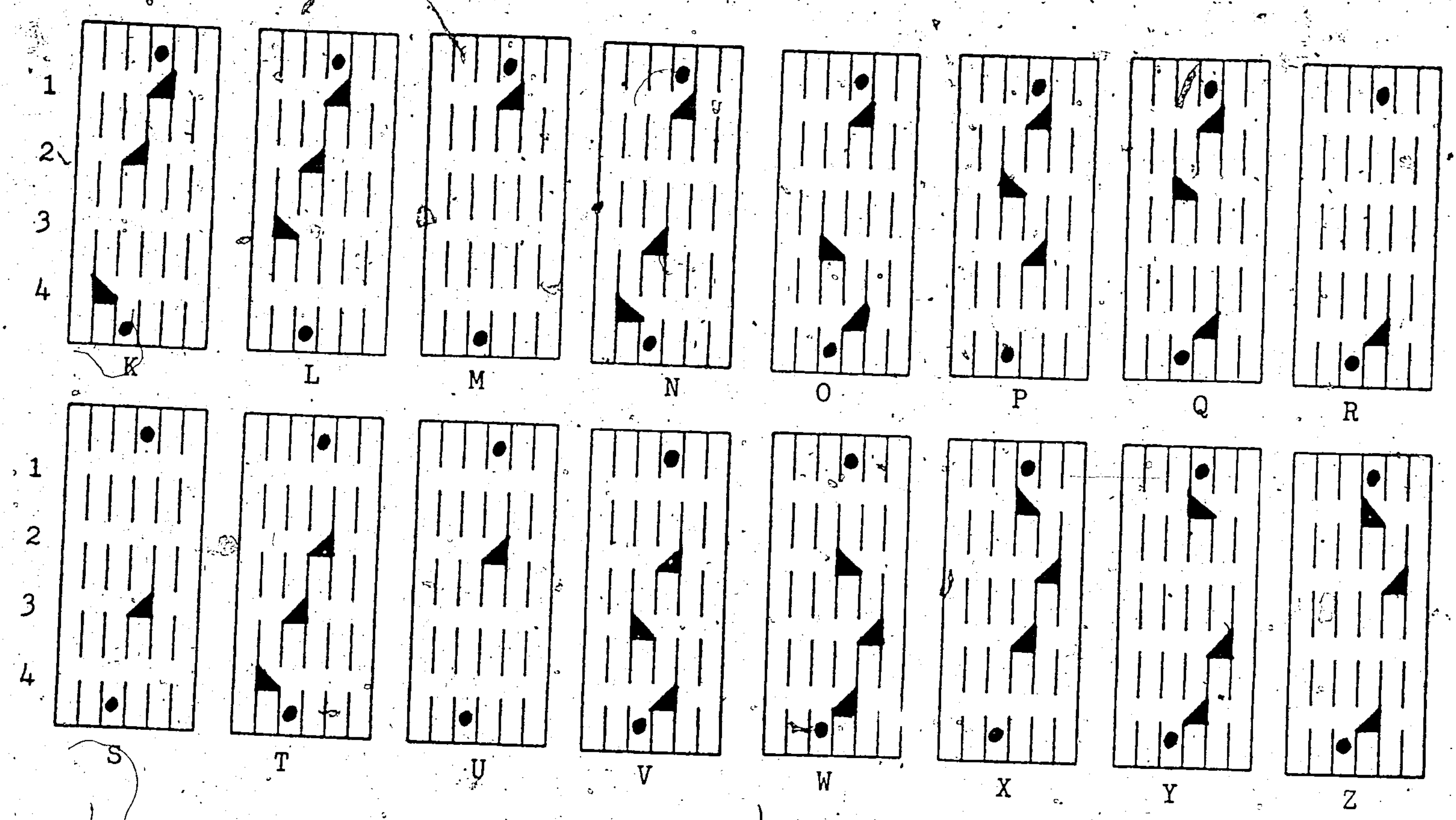


Figure 15

POSSIBLE TRIANGLE COMBINATIONS SECOND INDIVIDUAL
VISUAL-MECHANICAL TASK

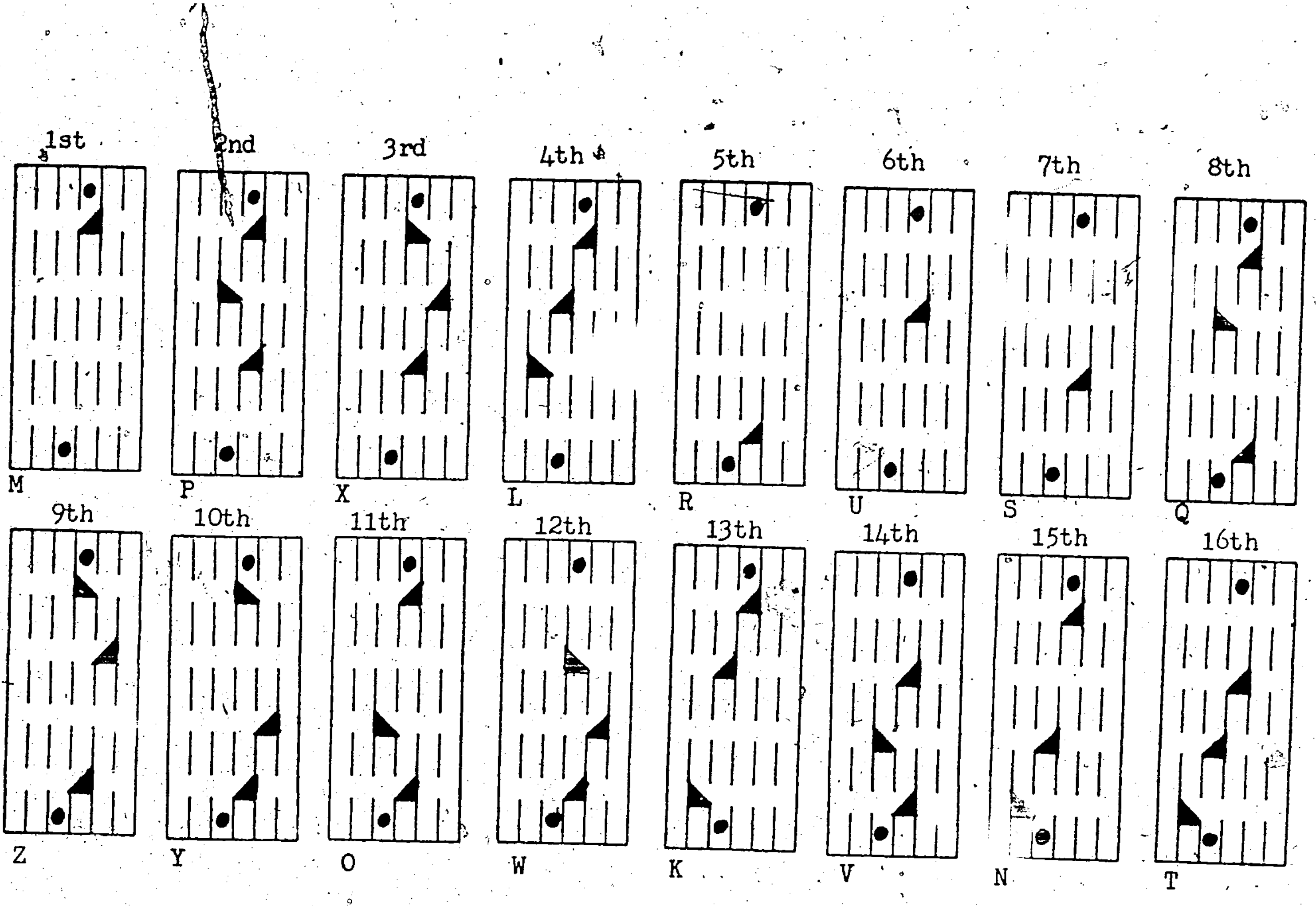


FIGURE 16

SEQUENCE OF TRIANGLE COMBINATIONS PREFERENTIALLY CHOSEN
SECOND INDIVIDUAL VISUAL-MECHANICAL TASK

2. *Frequency of Utilization of the Triangle Combination.* Question two permitted the utilization of one-triangle and three-triangle combinations.

The four situations involving only one left-sloping triangle occupied first, fifth, sixth and seventh frequency of choice positions (see Table XXII, p. 93 and Figure 16, p. 98). Of these situations M (first gap) was the most frequently chosen, while U (second gap) constituted the sixth choice frequency, S (third gap) was seventh, and R (fourth gap) the fifth.

The twelve remaining three-triangle combinations each consisting of two left-sloping triangles and one right-sloping triangle, occupied the remaining frequency of choice positions (see Figure 16, p. 98). Combinations P, X and L, (each located in the first, second and third gaps) occupied joint second and fourth positions respectively, while combinations Q, Z and K (each in the first, second and fourth gaps) occupied eighth, ninth and thirteenth frequency of choice positions respectively. Combinations Y, O and N (each consisting of triangles in the first, third and fourth gaps) occupied tenth, eleventh and fifteenth positions respectively while combinations W, V and T (each with triangles situated in the second, third and fourth gaps) occupied twelfth, fourteenth and sixteenth positions respectively. It can be seen that while combinations involving triangles placed in the first, second and third gaps are frequently utilized, triangle combinations involving the fourth gap are usually the less frequently chosen.

3. *Overall Triangle Combination Preference.* As was discovered

in the case of the first question, a definite pattern manifested itself for the second question with respect to which of the triangle combinations were more frequently chosen. M, for example, was the triangle combination most frequently chosen by four of the six grades (grades one, three, four and five), was the second most frequently preferred by grade two, and was the fourth most frequently chosen by grade six. Similarity across grades was also evident with respect to triangle combinations least frequently chosen, T and N, for example, being consistently among the combinations least frequently utilized by each of the grades. A summary of results of all triangle combination preferences for each grade is presented in Table XXII, p. 93 and in Figure 17, p. 104.

4. Number of Triangle Combinations Hypothesized. Table XXI, p. 92 shows the average frequency of choice of each triangle combination per student in each of the grades.

As in the case of the first question, a general increase in the average number of triangle combinations used in hypothesizing by each student occurs with increase in grade level the exception to this trend again occurring at the grade five level, where a general decline in the average number of combinations chosen manifests itself. Specifically, all of the sixteen triangle combinations, with the exception of N, tend to be chosen with less frequency by the grade five students than by the grade four students.

With respect to the first triangle combination to be chosen by each of the grades one through six, the one-triangle combination M was the most frequently chosen (see Table XXIII, p. 101 and Figure

TABLE XXIII

TRIANGLE COMBINATION FIRST CHOSEN AS A BASIS FOR AN HYPOTHESIS IN THE SECOND INDIVIDUAL VISUAL-MECHANICAL TASK

Grade	Percentage of Students Making Choice															
	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
One	4.3	4.3	60.9	0.0	0.0	0.0	0.0	4.3	4.3	0.0	17.4	0.0	0.0	4.3	0.0	4.3
Two	0.0	13.6	50.0	4.6	0.0	4.6	0.0	13.6	0.0	0.0	9.1	0.0	0.0	4.6	0.0	4.6
Three	0.0	0.0	36.9	0.0	0.0	10.5	0.0	31.6	5.2	0.0	5.2	0.0	0.0	5.2	0.0	5.2
Four	0.0	0.0	66.7	0.0	0.0	4.8	0.0	14.3	0.0	0.0	0.0	0.0	0.0	9.6	0.0	4.8
Five	0.0	15.0	55.0	0.0	0.0	10.0	0.0	0.0	10.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0
Six	0.0	0.0	70.0	0.0	0.0	5.0	0.0	0.0	5.0	0.0	10.0	0.0	0.0	5.0	0.0	5.0
Combined	0.7	5.5	56.6	0.8	0.0	5.9	0.0	10.6	4.1	0.0	8.6	0.0	0.0	4.8	0.0	4.0

Grade	Triangle Combination		
	Most Frequently Chosen	Second Most Frequently Chosen	Third Most Frequently Chosen
One	M	U	K S L X R Z
Two	M	L R	
Three	M	R	P
Four	M	R	X
Five	M	L	P S U
Six	M	U	O X S Z
Combined	M[1]	R[1]	U[1]

[1] One-Triangle Combination

TABLE XXIV

SECOND TRIANGLE COMBINATION CHOSEN AS A BASIS FOR AN HYPOTHESIS IN THE SECOND INDIVIDUAL VISUAL-MECHANICAL TASK

	Percentage of Students Making Choice														
Grade	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
One	0.0	8.6	13.0	0.0	4.3	21.7	4.3	0.0	13.0	0.0	21.7	0.0	0.0	8.6	4.3	0.0
Two	0.0	13.6	4.6	0.0	0.0	27.2	9.1	0.0	9.1	0.0	9.1	0.0	0.0	13.6	0.0	9.1
Three	0.0	0.0	15.8	0.0	0.0	5.2	5.2	0.0	10.5	5.2	15.8	0.0	5.2	15.8	0.0	10.5
Four	0.0	9.6	4.8	0.0	0.0	23.8	0.0	0.0	4.8	0.0	4.8	0.0	0.0	19.2	14.3	9.6
Five	0.0	25.0	10.0	0.0	0.0	25.0	5.0	10.0	0.0	10.0	10.0	0.0	0.0	20.0	0.0	5.0
Six	0.0	30.0	0.0	5.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	20.0	0.0	10.0
Combined	0.0	14.5	8.0	0.8	0.7	22.2	3.9	1.8	6.2	2.5	10.2	0.8	0.8	16.2	3.1	7.4

	Triangle Combination		
Grade	Most Frequently Chosen	Second Most Frequently Chosen	Third Most Frequently Chosen
One	P U		M S
Two	P	L X	
Three	M U X		
Four	P	X	Y
Five	P	X	M T R U
Six	P L		X
Combined	P[3]	X[3]	L[3]

[3] Three-Triangle Combination

TABLE XXV

THIRD TRIANGLE COMBINATION CHOSEN AS A BASIS FOR AN HYPOTHESIS IN THE SECOND INDIVIDUAL VISUAL-MECHANICAL TASK

Grade	Percentage of Students Making Choice															
	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
One	0.0	4.3	4.3	4.3	0.0	17.4	0.0	4.3	8.6	0.0	8.6	0.0	4.3	26.0	0.0	8.6
Two	4.6	13.6	4.6	18.2	0.0	13.6	0.0	0.0	13.6	4.6	4.6	4.6	4.6	18.2	4.6	0.0
Three	5.2	10.5	10.5	0.0	0.0	15.8	5.2	0.0	15.8	5.2	10.5	0.0	0.0	5.2	0.0	5.2
Four	4.8	9.6	9.6	0.0	0.0	19.2	9.6	9.6	9.6	0.0	9.6	0.0	4.8	9.6	0.0	0.0
Five	0.0	25.0	10.0	0.0	0.0	0.0	15.0	0.0	15.0	0.0	5.0	0.0	5.0	20.0	5.0	0.0
Six	5.0	20.0	0.0	0.0	0.0	5.0	5.0	5.0	10.0	0.0	15.0	0.0	5.0	20.0	5.0	5.0
Combined	3.3	13.8	6.5	3.8	0.0	12.0	5.8	3.2	12.0	1.6	8.9	0.7	3.9	16.4	2.4	3.1

Grade	Triangle Combination		
	Most Frequently Chosen	Second Most Frequently Chosen	Third Most Frequently Chosen
One	X	P	S U Z
Two	N X		L P S
Three	P S		L M U
Four	P	L Q S M R U X	
Five	L	X	Q S
Six	L X		U
Combined	X[3]	L[3]	P[3] S[1]

[1] One-Triangle Combination

[3] Three-Triangle Combination

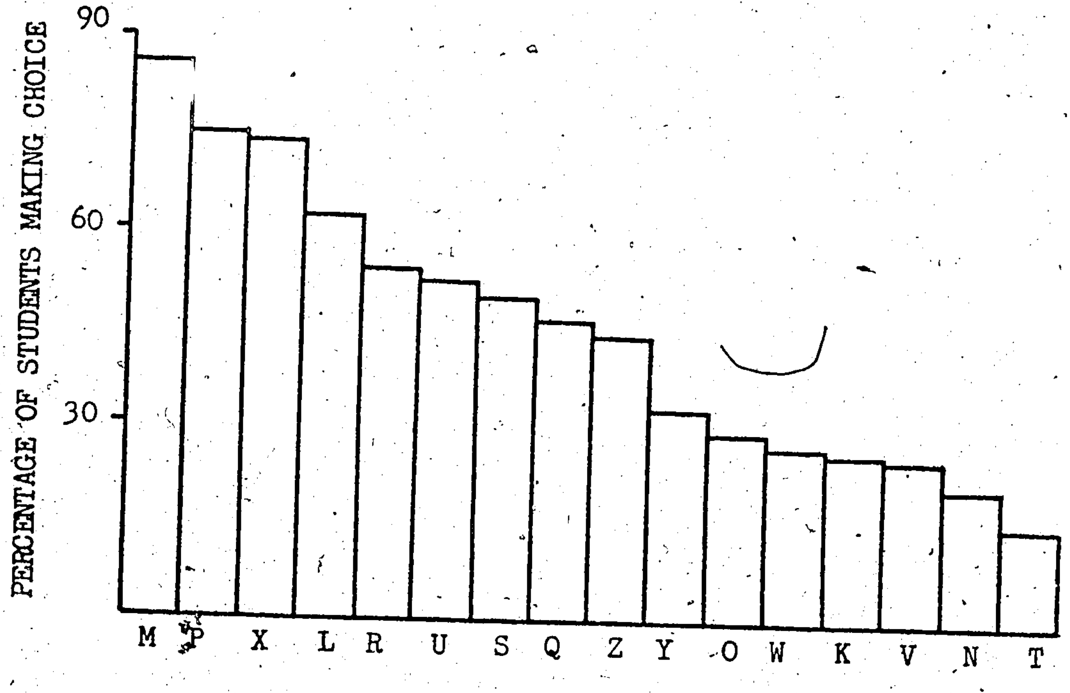


FIGURE 17

OVERALL TRIANGLE COMBINATION PREFERENCE DURING SECOND INDIVIDUAL VISUAL-MECHANICAL TASK (ALL GRADES COMBINED)

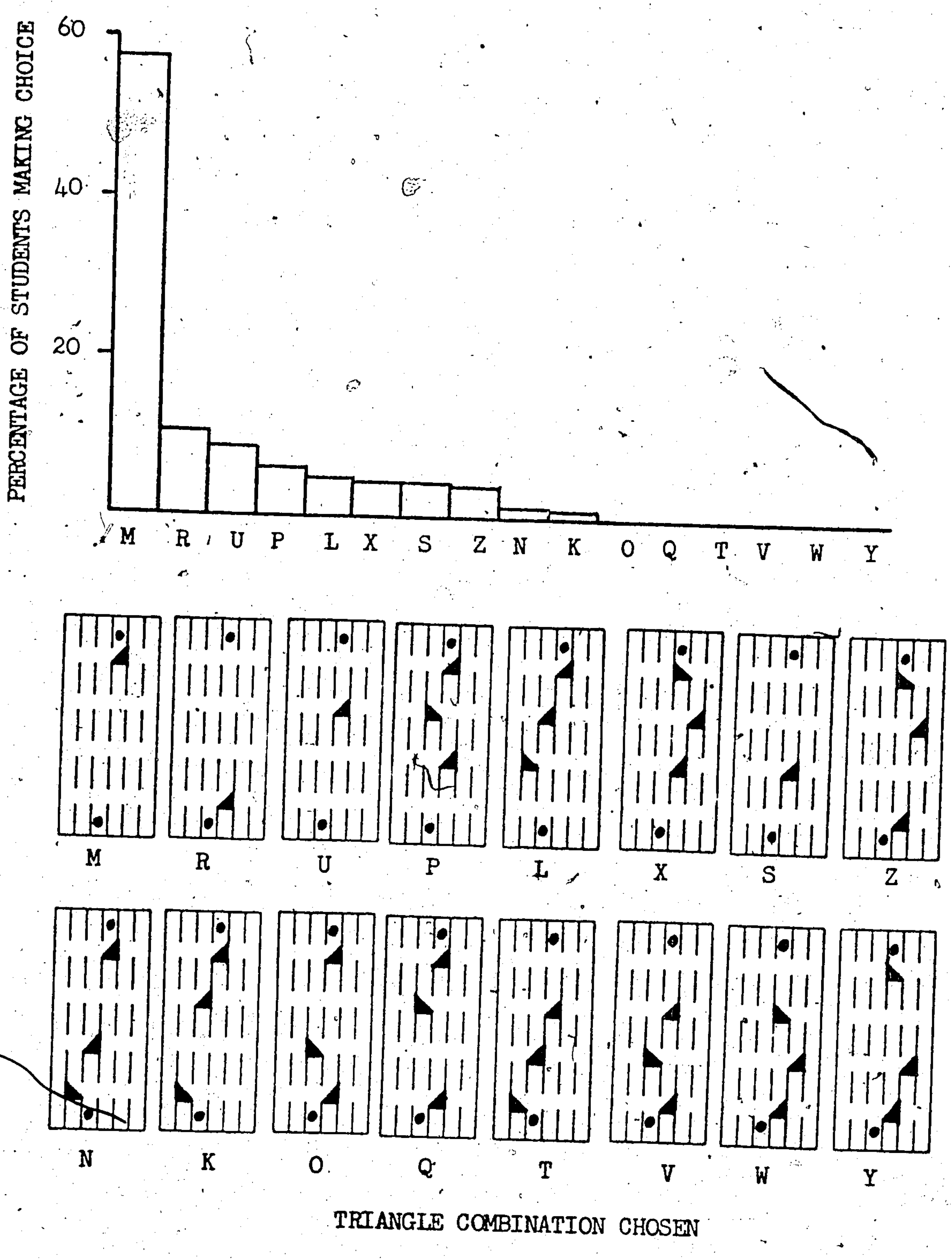


FIGURE 18

INITIAL TRIANGLE COMBINATION PREFERENCE AS INDICATED IN THE SECOND INDIVIDUAL VISUAL-MECHANICAL TASK (GRADES COMBINED)

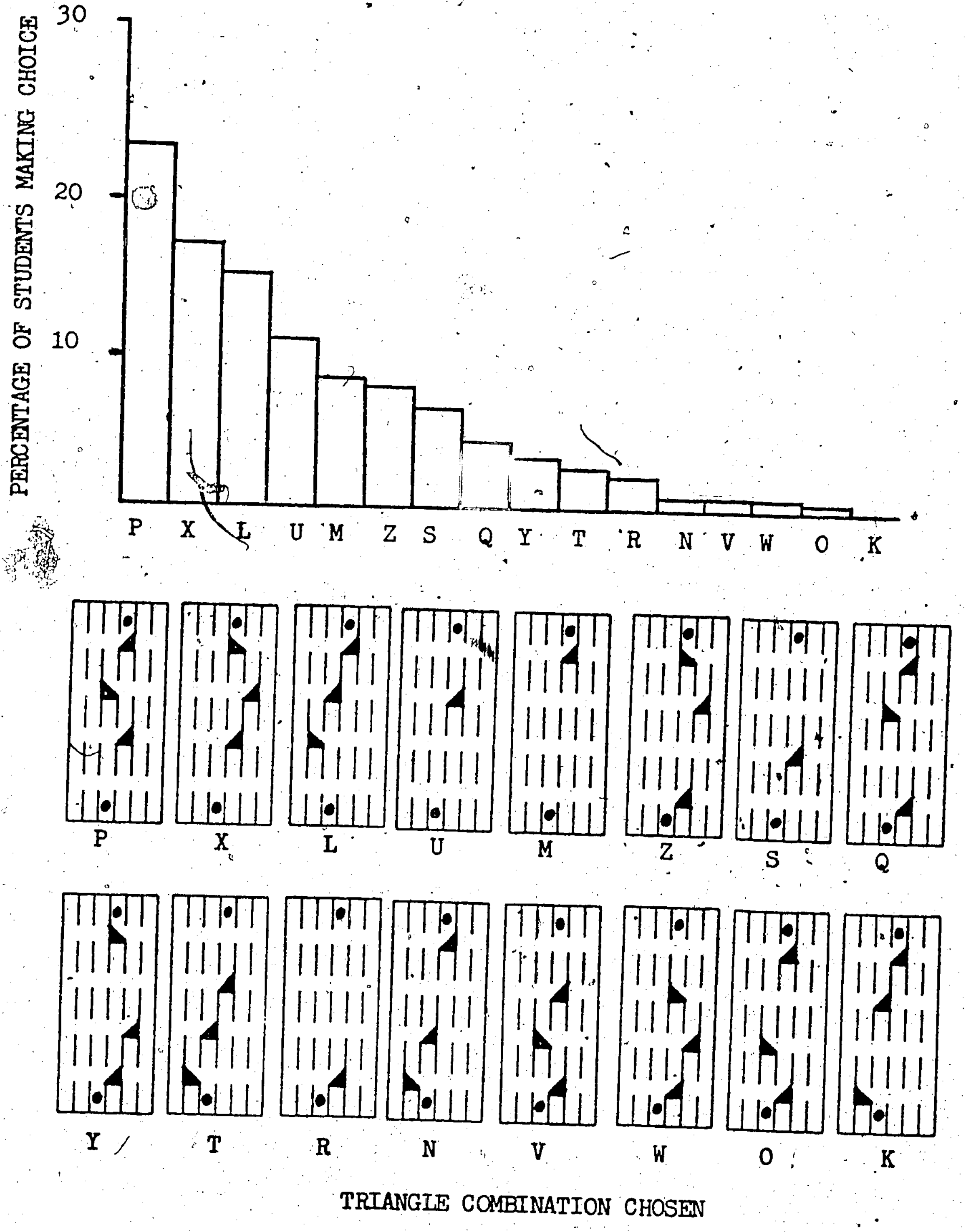
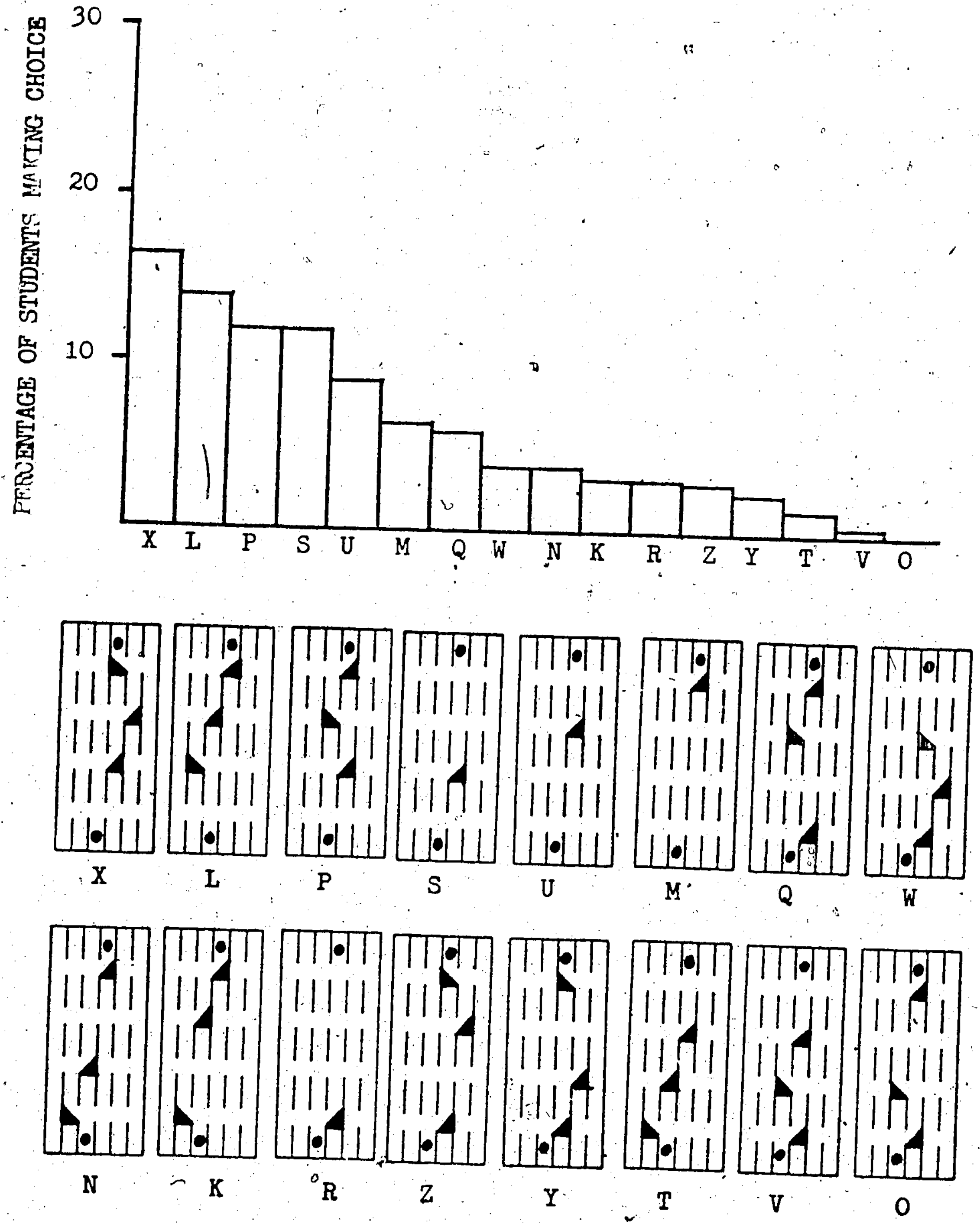


FIGURE 19

SECOND TRIANGLE COMBINATION PREFERENCE AS INDICATED IN THE SECOND INDIVIDUAL VISUAL-MECHANICAL TASK (GRADES COMBINED)



TRIANGLE COMBINATION CHOSEN

FIGURE 20

THIRD TRIANGLE COMBINATION PREFERENCE AS INDICATED IN THE SECOND INDIVIDUAL VISUAL-MECHANICAL TASK (GRADES COMBINED)

18, p. 105).

With respect to the third triangle to be utilized the three triangle combination X was the most frequently preferred by three of the six grades—namely grades one, two and six (see Table XXV, p. 103 and Figure 20, p. 107).

SUMMARY OF RESULTS

Hypothesis #1

This hypothesis examined the relationship existing between the Formulation of Hypotheses Score (individual visual-mechanical) and the Formulation of Hypotheses Score (individual visual). A significant correlation was found to exist between these Scores (see Table IV, p. 46).

Hypothesis #2

This hypothesis examined the relationship existing between the Formulation of Hypotheses Speed Score (individual visual-mechanical) and the Formulation of Hypotheses Speed Score (individual visual). A significant correlation was found to exist between these Speed Scores (see Table IV, p. 46).

Hypothesis #3

This hypothesis examined the relationships existing between the Formulation of Hypotheses Scores (individual visual-mechanical and individual visual), the Formulation of Hypotheses Speed Scores (individual visual-mechanical and individual visual) and: sex, age, grade, verbal meaning ability, number facility, spatial relations ability, perceptual speed ability and reasoning ability. Most of the variables correlated significantly with each of the Scores and Speed Scores. However the variable 'number facility' did not correlate significantly with the Speed Scores. Furthermore, the variable 'perceptual speed ability' did not correlate significantly either with the Score or Speed Score of the Individual visual-mechanical mode. The variable 'reasoning ability' correlated significantly only with the Individual visual-mechanical Speed Score (see Table IV, p. 46).

Hypothesis #4

This hypothesis examined the relationships existing between the Formulation of Hypotheses Score (group visual), the Formulation of Hypotheses Speed Score (group visual) and: sex, age and grade. Significant correlations were found to exist between the variables sex, age and grade and the group visual Scores and Speed Scores (see Table V, p. 49).

Hypothesis #5

This hypothesis examined the possibility of interaction between grade level and sex with respect to Formulation of Hypotheses Scores and Speed Scores (individual visual-mechanical and individual visual). No significant interaction was observed in any instance (see Table VI, p. 52 and Table XII, p. 74).

Hypothesis #6

This hypothesis compared boys' and girls' Formulation of Hypotheses Scores and Speed Scores (individual visual-mechanical and individual visual) in each of the grades one through six. Significant differences between boys' and girls' Scores (individual visual-mechanical) were found to exist in grades one, three and four, while significant differences between boys' and girls' Speed Scores (individual visual-mechanical) occurred in grade one. Significant differences between boys' and girls' Scores (individual visual) were found to exist at the grade three and four levels, but no significant differences were found to exist between boys' and girls' Speed Scores (individual visual) in any of the six grades investigated (see Table VI, p. 52).

Hypothesis #7

This hypothesis compared the Formulation of Hypotheses Scores and Speed Scores (individual visual-mechanical and individual visual) obtained by each grade, with the Scores and Speed Scores obtained by each of the other grades. Significant differences in Scores (individual visual-mechanical) were found to exist between grades one and three, one and four, one and six, two and six, five and six, while significant differences in Speed Scores (individual visual-mechanical) occurred between grades one and five, one and six, two and five, two and six, three and five, and four and five. Significant differences in Scores (individual visual) existed between grades one and four, one and five, one and six, and between two and six, and significant differences in Speed Scores (individual visual) occurred between grades one and five (see Table XIII, p. 75 and Table IX, p. 62).

Hypothesis #8

This hypothesis examined the possibility of interaction between I.Q. and grade level ~~with~~ respect to Formulation of Hypotheses Scores and Speed Scores (individual visual-mechanical and individual visual). Significant interaction was found to exist with respect to Scores (individual visual-mechanical and individual visual) and to Speed Scores (individual visual) (see Table XI, p. 70 and Table XIII, p. 75).

Hypothesis #9

This hypothesis compared Formulation of Hypotheses Scores and Speed Scores (individual visual-mechanical and individual visual) obtained by each of the I.Q. groups in each of the grades. Significant differences in Scores (individual visual-mechanical) were found to exist between the High-Low I.Q. group of the grade two and three levels, and between the Average-Low grouping of the grade three levels, while significant differences in Speed Scores (individual visual-mechanical) occurred between the High-Low I.Q. grouping and between the Average-Low grouping of the grade two and three levels. Significant differences in Scores (individual ~~visual)~~ were found to exist between the High-Average I.Q. group of the grade one and three levels, between the High-Low I.Q. group of the grade one, three and six levels, and between the Average-Low I.Q. group of the grade six level. Significant differences in Speed Scores (individual visual) were observed to exist between the High-Average I.Q. grouping of the grade one level, and between the High-Low I.Q. grouping of the grade five level (see Table X, p. 67).

Hypothesis #10

This hypothesis examined the possibility of interaction between I.Q. and sex with respect to Formulation of Hypotheses Scores and Speed Scores (individual visual-mechanical and individual visual). In no case was significant interaction observed (see Table XIV, p. 76 and Table XV, p. 77).

Chapter 5

CONCLUSIONS, IMPLICATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

The specific conclusions relating to each hypothesis have been presented in Chapter 4. On the basis of this information the following general conclusions were formulated:

1. According to Martin (see p. 25) hypothesis formulation may be considered a complex process which entails both logical and non-logical (creative) operations. While the AAAS-SAPA program also considers hypothesizing to be a complex 'integrated' process, hypothesis formulation contrastingly is viewed as a process entailing solely logical procedures that may consciously be learned and adopted by the student during inquiry. If one accepts that each of the variables 'reasoning ability,' 'verbal meaning ability,' 'spatial relations ability,' 'number facility' and 'general intelligence' (as measured by the S.R.A. Primary Mental Abilities Test) feature essentially logical rather than non-logical operations, then the findings of this study would seem to support Martin's position rather than that of the AAAS. Although each of these variables, with the exception of reasoning ability, correlate significantly with hypothesizing ability, correlations in all cases were low in magnitude. Thus, no obvious and simple relationship appeared to exist between hypothesis formulation and any of the 'logical' variables in this study.

2. Martin's position is further supported by data relating

to the order (i.e. the 'logical' order as indicated by the number of triangles utilized and the sequence of their placement) in which formulation of hypotheses took place with respect to the individual visual-mechanical task. In the first of the two questions associated with this task, the selection of an hypothesis (i.e. nature of triangle placement) was clearly not influenced by the number of triangles utilized in the construction of a preceeding hypothesis (see Figure 10, p. 85). Thus an hypothesis involving a two-triangle combination was sometimes formulated following an hypothesis involving another two-triangle combination and sometimes following one involving a four-triangle combination. With respect to the gap positions employed, hypotheses formulated at an early stage always utilized the uppermost gap. Hypotheses formulated at later stages, in most instances involved gaps located in lower positions. Results from the second question in contrast to those of the first, indicated that the number of triangles utilized, may, to a limited extent, have been a factor which was influential in determining the order of hypotheses formulated, one-triangle combinations being found to occupy first, fifth, sixth and seventh positions of choice respectively (see Figure 16, p. 98). Although the first hypotheses formulated utilized triangles positioned in the uppermost gap, not all hypotheses which included such placement were chosen at an early stage; in fact several hypotheses which were formulated in later stages of the task also utilized the uppermost gap.

Thus while the present study provides some evidence in support of the suggestion that logical operations are sometimes involved during hypothesis formulation, the sequence of choice of triangle combinations employed during the hypothesizing associated with the visual-mechanical task cannot always be explained in terms of any single logical argument. In other words hypothesizing possibly, even in fact probably, involves subtle and complex blends of several patterns of logical thought acting and interacting simultaneously.

3. The additional suggestion that hypothesis formulation may be dependent, at least in part, upon other less logical and more creative processes, is supported by the present study in that data derived from student performance on the individual visual-mechanical task indicate an increase from grades one through three in the ability to formulate hypotheses, performance leveling out between grades three and four, decreasing between grades four and five, and increasing again between grades five and six. Investigations conducted by Torrance (1962) found that, in general, creative abilities of students increased from grades one through six, an exception to this trend manifesting itself in a 'creative slump' at the grade four level. This decrease in creative ability was generally attributed to major 'gang pressures' which operated against any individualistic expression at that grade level. Similar pressures may have been influential in causing the decline in hypothesizing ability at the grade four and five levels which was encountered in this study.

4. An alternative or additional explanation for the grade four/five slump in hypothesizing ability with respect to the visual-mechanical task may be examined in the light of general developmental theory. It is generally accepted that young students are

predominantly limited to concrete thought operations while older children become increasingly adept at thinking in more abstract terms. The large slump in hypothesizing ability at the grade four and five levels, as reflected in performance of the visual-mechanical task, a task which essentially involves the manipulation of concrete objects, may reflect in part the tendency or desire of the children at this developmental level to think more in abstract rather than in concrete terms. This proposition is supported by the finding that hypothesizing scores associated with the more abstract individual visual and group visual tasks did not decrease at the grades four and five levels, a continual increase in ability to hypothesize across the six grade levels being manifested on these tasks. Of course this latter finding raises the alternative question as to why the performance of both the young 'concrete' group and the older 'abstract' group manifests itself in a continuous growth pattern as revealed by the data derived from this study. We do not at present have sufficient information to resolve this conflict and further investigation of this point is clearly needed as it is likely to throw light on the matter of the stages of development of thought processes in children.

5. This study reveals a significant though low correlation between an elementary school child's ability to formulate hypotheses utilizing an individual visual-mechanical (machine) mode of operation and his ability to formulate hypotheses utilizing an individual (pictorial) mode of operation. The absence of high correlations between hypothesizing scores employing different task modes indicates

that hypothesizing ability is to some extent task-specific and obviously this lack of high correlation points up the issues raised in the preceeding paragraphs. Since some students who obtain high scores in hypothesizing on one task may obtain inferior scores on the other, caution should be exercised in interpreting general hypothesizing ability on the basis of performance on only one of the two modes.

6. As noted above, this study revealed a significant though low positive correlation between verbal ability and hypothesizing ability. As several studies (noted by Smith and Dechant, 1961) show that girls at the elementary level generally have superior verbal abilities with respect to boys it might be anticipated that girls should obtain [illegible]er scores than boys in tasks involving hypothesizing. However, in this study, the hypothesizing scores of the boys in each of the grades were consistently higher than those obtained by the girls, significant differences between boys' and girls' scores occurring at the grade one, three and four levels with respect to the individual visual-mechanical task. Generally speaking greater interest was shown by boys both in the handling of the components of the machine and in the drawing of the diagrams necessary for the completion of the paper-and-pencil tests. This factor, operating in favor of the boys, may have been responsible at least in part for reducing any advantage that the girls' superior verbal ability might have contributed. It is possible however, that these findings are specific to the particular modes of operation used, and again caution should be exercised against interpreting these data as

indicative of the generally superior hypothesizing ability of boys.

7. With respect to general intelligence, students from the high I.Q. groups tended to obtain higher formulation of hypotheses scores than did members of the low I.Q. groups. As any particular I.Q. group within any grade was represented by a minimum of two students and a maximum of thirteen some caution should be exercised in the general interpretation and application of these results.

IMPLICATIONS FOR TEACHING AND EVALUATION

The following implications may be drawn from this study:

1. A student's ability to formulate hypotheses can be predicted in part on the basis of sex, verbal meaning ability, spatial relations ability and number facility as determined by means of the S.R.A. Primary Mental Abilities Test.

2. The mean Formulation of Hypotheses Scores associated with the individual visual-mechanical, and individual and group visual modes of operation, for each of the grades one through six, may serve as bases for comparisons and evaluation of other students outside the population studied, with respect to their ability in the formulation of hypotheses as manifested by scores obtained during the performance of the tasks indicated, the necessary precautions in interpretation and evaluation as noted being taken.

3. The mean Formulation of Hypotheses Scores by grade derived from performance of each task may also serve as bases for setting and assessing standards of performance of students with respect to those parts of the process-oriented elementary instructional sequence which

involve the formulation of hypotheses.

4. Periodic use of tasks similar to those used in this study could possibly serve as diagnostic tools for the assessment of growth in the hypothesizing abilities of students.

5. The study indicates that activities and experiences related to the formulation of hypotheses and designed to enhance the ability to hypothesize could constitute a beneficial component of the grade one through six science experience as no specific peak in ability with respect to this process was reached at, or before, the grade six level.

6. The study indicates that children in each of the grades one through six are capable of formulating hypotheses on the basis of individual visual-mechanical, and individual and group visual modes of operation. Therefore activities involving these modes might profitably be provided in each of these grades. As earlier noted, the Formulation of Hypotheses Scores at the grades four and five levels were generally low when the individual visual-mechanical mode of operation was utilized. Opportunity should therefore be provided at these grade levels for appropriate experiences related to the formulation of hypotheses involving activities, in particular, which involve and necessitate direct physical manipulation of concrete phenomena. This suggestion perhaps may be further justified on the basis of the argument that although a developmental transition from concrete to abstract thinking may be taking place this transition should not involve exclusive modes of thinking and behaviour. Thus the students should be able to combine both abstract and concrete

modes and, in fact, the blending of both in set tasks may help some children through what might otherwise be a difficult period of transition. Furthermore those children manifesting facility in abstract modes of operation should not move too far away from operations involving the use of apparatus, for facility in the latter is important, even essential, for their subsequent endeavours in scientific investigation.

SUGGESTIONS FOR FURTHER RESEARCH

This study showed that, for grade five students, Formulation of Hypotheses Scores obtained during the utilization of the individual visual-mechanical task were generally lower than the grade four scores obtained from using the same task. A more detailed study of this finding, repeating the administration of the individual visual-mechanical task with a different and possibly more extensive sample may yield information that would substantiate or reject the tentative suggestions made earlier (see p. 115). The underlying reasons for this drop in performance also warrant full investigation (see p. 116).

The nature of the Hypothesis Machine and of the paper-and-pencil test, coupled with the nature of the manner in which instructions associated with each of the tasks are given, may have a significant influence upon the nature of the results obtained from tasks identical with, or similar to, those employed in this study. The possible influences of all these factors calls for further investigation.

The ability to formulate hypotheses as determined by this study was largely dependent upon visual sensory input and, to a lesser degree, was also dependent upon haptic sensory input. Further research utilizing sound, taste and smell modalities in the formulation of hypotheses might profitably be undertaken in order to extend our understanding of the significance of such factors with respect to the ability to formulate hypotheses. Comparison of performance in the formulation of hypotheses on the basis of employment of these different modalities, or combinations of modalities, should be undertaken.

As no peaks were observed with respect to the Formulation of Hypotheses Scores in the elementary grades, research could profitably be undertaken to investigate the nature of growth in the ability to formulate hypotheses across higher grades.

At each grade level, boys tended to exhibit a greater ability than girls in the formulation of hypotheses on the basis of utilization of the modes indicated in this study. Further research might indicate whether or not this difference continues to manifest itself when other tasks involving the formulation of hypotheses are employed.

This study involved students who had not been exposed to the new process-oriented science curricula. A similar study might profitably be conducted at a later date to determine whether or not exposure to the new process-oriented science curricula influences students' abilities with respect to the formulation of hypotheses.

If the ability to formulate hypotheses is in part dependent upon creative ability as has been suggested but not extensively investigated, then results obtained from the administration of specific creativity tests might indicate the extent to which creative ability, as measured by these tests, correlates with the ability to formulate hypotheses, as measured by procedures conducted during the course of this investigation.

The results obtained from such creativity/hypothesizing correlations might also be of use in explaining in part the reason(s) for the manifestation of low Formulation of Hypotheses Scores, such as those obtained by grade four and five students with respect to the individual visual-mechanical mode of operation.

Certain writers (see p. 24) suggest that a period of incubation is desirable, or even essential, to the production of an hypothesis or hypotheses. In this study, a period of incubation was not provided for, or was so short as to be in all likelihood insignificant, the students being required to formulate hypotheses either immediately following a period during which they familiarized themselves with the content and operation of the machine, or immediately following completion of the investigator's verbal instructions pertaining to each of the paper-and-pencil tasks. Further research would be desirable in order to determine the possible significance of incubation periods of specific durations, and their effect upon the quantity and quality of hypotheses formulated.

A great deal of research and development work will have to be completed before a total picture of the nature of the process skills, and of their acquisition and development in the elementary school is obtained. Further research will be needed to devise, develop and administer instruments capable of providing a complete profile of the developmental level of each of the process skills in each student. This study represents but one phase of the total program of work needed for the ultimate achievement of such objectives.

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APPENDICES

APPENDIX A

PROCESS SKILLS

APPENDIX A

Process Skills (Methods of Inquiry)
(*Curriculum Guide*, 1969, pp. 7-9)

PROCESS	DESCRIPTION OF BEHAVIOR
Basic Processes	
Observing	The desired pupil behavior is increasing competence in using not only his sense of sight but also his other senses of hearing, touch, smell and taste.
Classifying	The desired pupil behavior is increasing competence in grouping articles, objects and ideas on the basis of some observable property or properties.
Quantifying	The desired pupil behavior is increasing competence in measuring length, weight, area, volume, and rate of change of the physical world.
Communicating	The desired pupil behavior is increasing competence in describing an experiment so that an individual who has not seen it can carry it out.
Inferring	The desired pupil behavior is increasing competence in drawing more than one inference from a set of data, demonstrating that inference can be tested by further observation, and demonstrating that an inference can be tested by applying known tests to the properties of objects. Pupils should indicate that they are able to distinguish between observations and inferences.
Predicting	The desired pupil behavior is increasing competence in conducting experiments to test predictions of relationships between two measurable quantities.

Integrated Processes

Formulating Hypotheses	The desired pupil behavior involves developing increasing competence in stating a hypothesis regarding causes of a phenomenon or the relationship between two variables. A hypothesis tells how to observe an expected outcome of an experiment.
Making Operational Definitions	The pupil should demonstrate increasing competence in stating the minimum things to do or look for in order to identify the subject being defined.
Controlling and Manipulating Variables	The desired pupil behavior is increasing competence in arranging conditions so as to be able to deliberately control and manipulate objects or conditions in an experiment.
Interpreting Data	The desired pupil behavior is increasing competence in getting the most out of data without over-simplifying, drawing conclusions supported by the data, and considering alternative explanations.
Formulating Models	The desired pupil behavior is increasing competence in building both physical and mental models to account for phenomena.
Experimenting	The desired pupil behavior is increasing competence in planning, conduction and communicating experiments in which the problem is clarified, hypotheses are stated, observations are made, and data is interpreted. This process depends upon the pupil being able to use all of the other processes.

APPENDIX B

INDIVIDUAL VISUAL-MECHANICAL TASK

PROCEDURAL INSTRUCTIONS FOR THE FIRST QUESTION

INDIVIDUAL VISUAL-MECHANICAL TASK

PROCEDURAL INSTRUCTIONS FOR THE FIRST QUESTION

Hello ________. Today we're going to work with this game that you see here. There are six channels: one, two, three, four, five and six; and the channels are crossed by one, two, three, four gaps. Would you like to put this marble in the top part of one of the channels? O.K. Now, let the marble go and see what happens. Good. Try putting the marble in another channel. Good.

Over here, we've got three green triangles, and three black triangles. They've been specially made so that they can each fit into any channel we want, like that - and also into any gap we want, like that. Would you like to put a green triangle in? Anywhere you like! Good. Now place the marble in the top of a channel so that it rolls down, and hits the green channel. O.K. What did the green triangle do to the marble? O.K. Would you like to place the green triangle somewhere else now? Good. What did the green triangle do to the marble this time? Good. Now how about placing a black triangle in the game somewhere? O.K. And what did the black triangle do to the marble? Good.

Do you think that we could use two black triangles working together at the same time, so that the marble rolls down and hits the first triangle, and then rolls down further to hit the second triangle? See if you can set them up so that that happens! Good. Now what about two green triangles working together at the same time? You try. O.K. And what about three green triangles working together at the same time? O.K. How about a mixture now, of green and black triangles working together? You try. O.K. Now take a few minutes and put the triangles anywhere you wish. Try different places. See what happens to the ball.

Over here we've got a cover which we can put over the game like this. In a moment I'm going to put maybe one triangle, maybe two triangles, maybe three or maybe four triangles under the cover. Because the cover will be there, you won't be able to see what's inside, and I'm not going to tell you what I put in there. So that I can set the game up, would you just look over there a moment? O.K. Good. Now I'm going to place this little flag in the top of this channel to mark the place where I want you to start the marble off. Now! Good. So the marble came out there. I'm going to mark the place where the marble came out with this second flag. Now _________, whatever I put under the cover, has made the marble go from that flag position there, down to this flag position here. In a moment I'm going to take off the cover, and take out whatever's inside, but I'm going to leave that flag there, and this flag here, to help remind us of where the marble started from, and where it ended up. Just look over there a moment while I take out whatever's inside. Good. Now, what I'd like you to do is to see if you can get the marble from the top flag position there, down to the bottom flag position here. You can use one, two, three or four triangles in any place you wish, as I might do. When you start, you may find that there's more than one way of getting the marble from the top flag position to the bottom flag position, so carry on working, and try to find as many different ways as you can for getting the marble from the top position to the bottom position. Stop when you think you've found as many ways as you can to do this. O.K.? Are there any questions?

APPENDIX C

DATA SHEET FOR INDIVIDUAL VISUAL-MECHANICAL TASKS

NAME: ______ GRADE: ______ SCHOOL: ______

FIRST TASK

	Combinations	Time
A	3L - R	
B	2L - 2D	
C	2L - R - L	
D	L - D - L - D	
E	L - 2D - L	
F	L - R - 2L	
G	2D - 2L	
H	D - 2L - D	
I	D - L - D - L	
J	R - 3L	

SECOND TASK

	Combinations	Time
K	2L - D - R	
L	2L - R - D	
M	L - 3D	
N	L - D - L - R	
O	L - D - R - L	
P	L - R - L - D	
Q	L - R - D - L	
R	3D - L	
S	2D - L - D	
T	D - 2L - R	
U	D - L - 2D	
V	D - L - R - L	
W	D - R - 2L	
X	R - 2L - D	
Y	R - L - D - L	
Z	R - D - 2L	

L = Left-Sloping Triangle
R = Right-Sloping Triangle
D = No Triangle

(1/2 of natural size)

DATA SHEET FOR INDIVIDUAL
VISUAL-MECHANICAL TASKS

APPENDIX D

COMPLETED DATA SHEET FOR INDIVIDUAL VISUAL-MECHANICAL TASKS

NAME: ______________________

GRADE: ________

SCHOOL: ______________

FIRST TASK

	Combinations	Time
A	3L - R	240
B	2L - 2D	30
C	2L - R - L	
D	L - D - L - D	
E	L - 2D - L	420
F	L - R - 2L	
G	2D - 2L	120
H	D - 2L - D	180
I	D - L - D - L	90
J	R - 3L	

L = Left-Sloping Triangle
R = Right-Sloping Triangle
D = No Triangle

SECOND TASK

	Combinations	Time
K	2L - D - R	
L	2L - R - D	480
M	L - 3D	
N	L - D - L - R	390
O	L - D - R - L	
P	L - R - L - D	
Q	L - R - D - L	
R	3D - L	60
S	2D - L - D	
T	D - 2L - R	240
U	D - L - 2D	30
V	D - L - R - L	540
W	D - R - 2L	
X	R - 2L - D	120
Y	R - L - D - L	600
Z	R - D - 2L	

(1/2 of natural size)

COMPLETED DATA SHEET FOR INDIVIDUAL
VISUAL-MECHANICAL TASKS -
AVERAGE SCORING STUDENT

APPENDIX E

INDIVIDUAL AND GROUP VISUAL TASK PROCEDURAL INSTRUCTIONS FOR THE FIRST QUESTION

INDIVIDUAL AND GROUP VISUAL TASK

PROCEDURAL INSTRUCTIONS [illegible] THE FIRST QUESTION

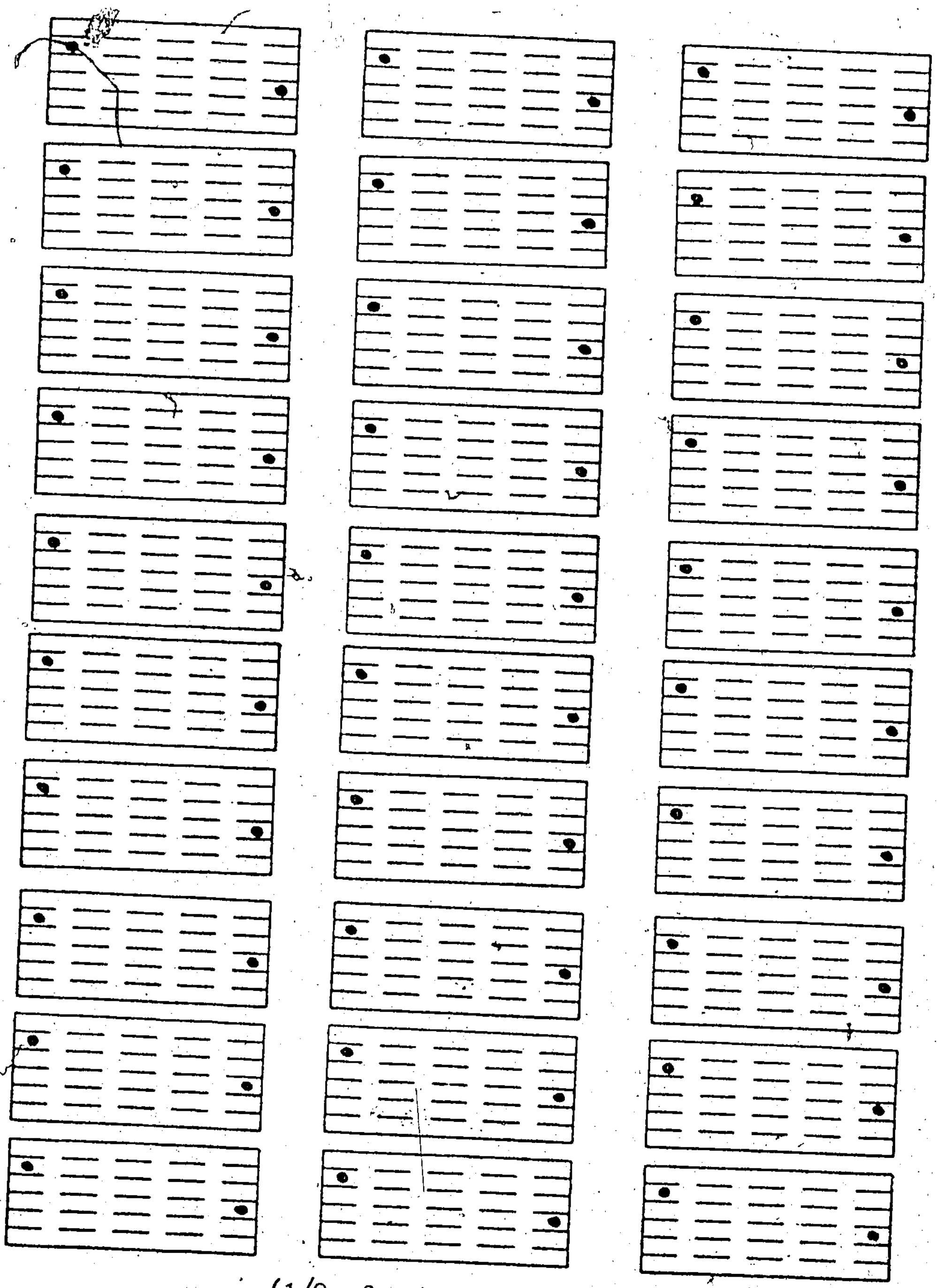
These three sheets have lots of little copies of the game printed on them. Every copy is exactly the same on all three sheets. On each copy you can see two black spots - a spot in a top channel, and a spot in a bottom channel. The spot at the top marks the position where the marble starts to roll, and the spot at the bottom marks the position where the marble ends up. Now, in some way we've got to try to get the marble from the top position to the bottom position, and to do this we must remember that we use the same rules with the copies, as we used with the game. So we must remember what green triangles can do to the marble, and what black triangles can do to the marble. In a moment, I'd like you to draw, with the pencil, a line showing a way that the marble itself could take in getting from the top position to the bottom position. O.K.? Now, you *can* draw in the triangles as well, if you wish, but remember, the main thing is to draw a line showing the way that the marble could get from the top position to the bottom position.

You might find, as you did with the game, that there's more than one way that the marble could get from the top position to the bottom position, so make a different drawing on the sheets for each different way you can think of. You can use as many copies as you want. Now, I've given you lots of extra copies here, but it doesn't mean that there's a different way of getting the marble from the top to the bottom, for *every* copy you see here. I've given you extra copies because people sometimes make mistakes and need more copies. So if you make a mistake, it doesn't matter - just put a cross through it and go on to another copy. O.K.? Carry on working until you think you've found as many different ways as you can. O.K.? Good. Are there any questions?

APPENDIX F

DATA SHEET FOR THE FIRST INDIVIDUAL VISUAL AND GROUP VISUAL TASK

NAME: ____________ GRADE: ____________ SCHOOL: ____________



(1/2 of natural size)

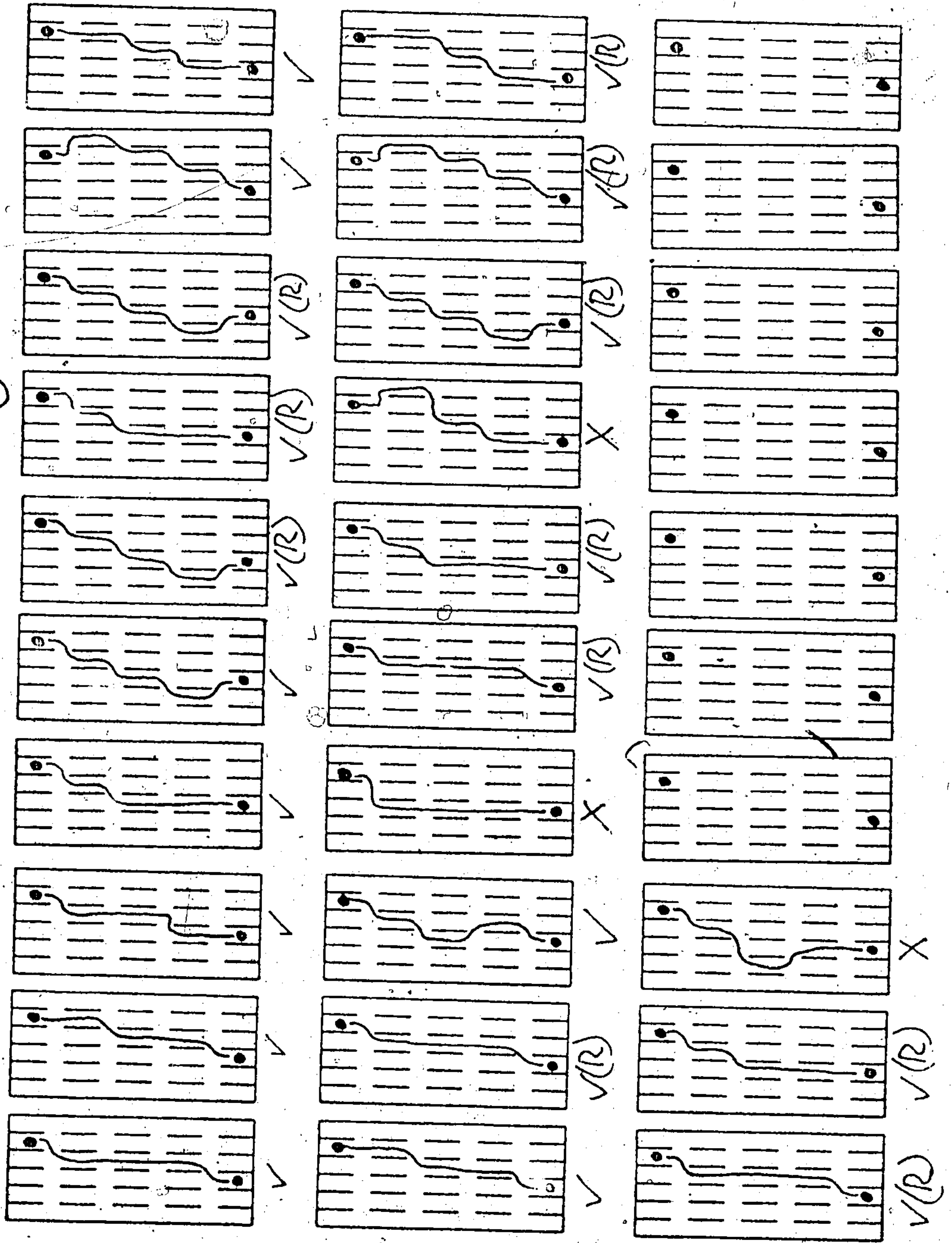
DATA SHEET FOR THE FIRST INDIVIDUAL VISUAL
AND GROUP VISUAL TASK

APPENDIX G

COMPLETED DATA SHEETS FOR THE FIRST INDIVIDUAL VISUAL AND GROUP VISUAL TASK

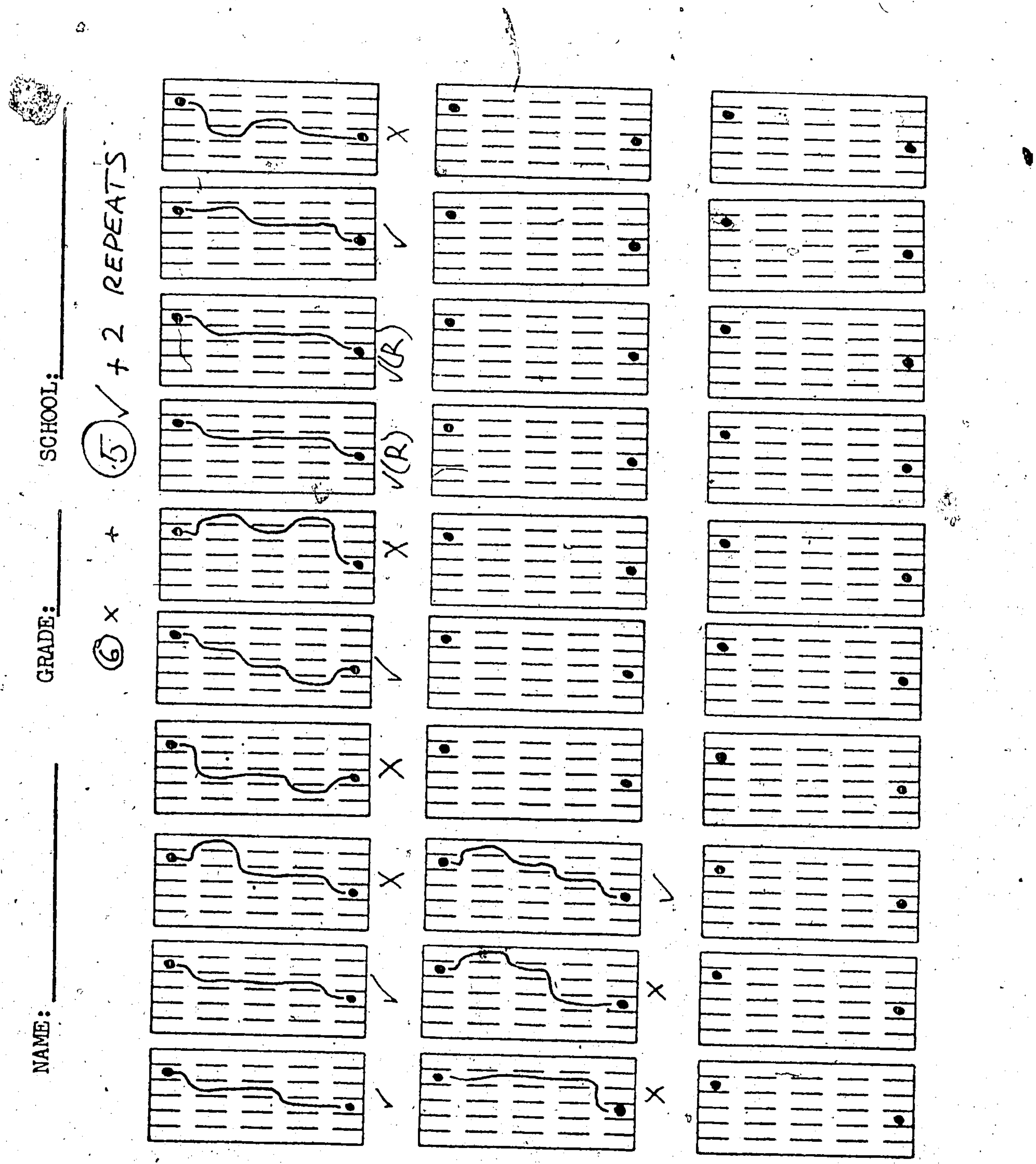
NAME: ______ GRADE: ______ SCHOOL: ______

③ × + ⑨ ✓ + 11 REPEATS



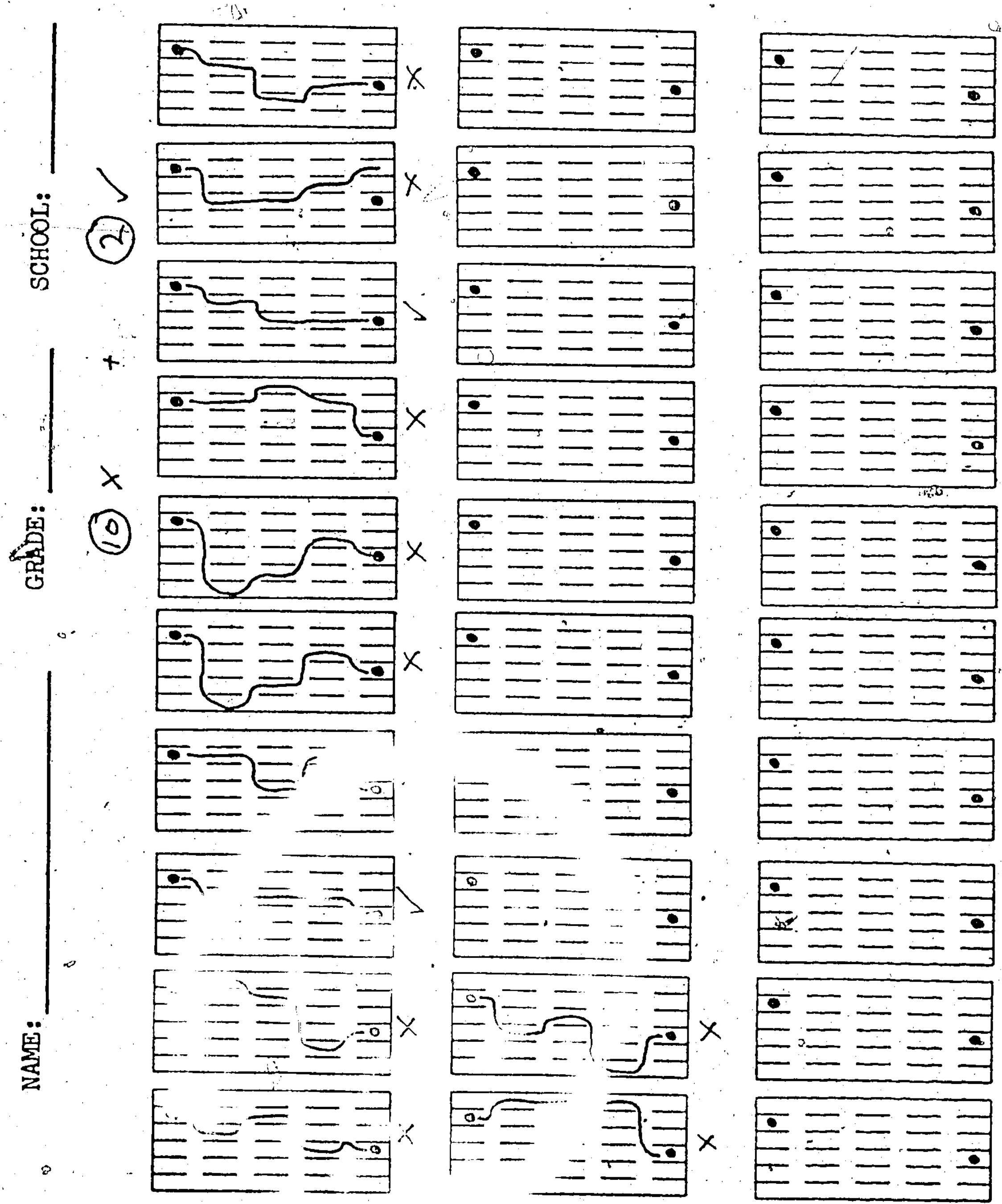
(1/2 of natural size)

COMPLETED FIRST VISUAL TASK DATA SHEET -
HIGH SCORING STUDENT



(1/2 of natural size)

COMPLETED FIRST VISUAL TASK DATA SHEET -
AVERAGE SCORING STUDENT



of natural size)

COMPLETED FIRST VISUAL TASK DATA SHEET -
LOW SCORING STUDENT

APPENDIX H

APPROXIMATE TIMING OF THE VARIOUS PHASES OF THE STUDY

APPROXIMATE TIMING OF THE VARIOUS PHASES OF THE STUDY

1.	Pilot Study	8 hours
2.	I.Q. Testing	16 hours
3.	Main Study	
	Individual Visual-Mechanical Task	90 hours
	Individual Visual Task	25 hours
	Group Visual Task	5 hours
	Total Data Collecting Time	144 hours