THE RELATIONSHIP OF UNMANIPULATED SELF-REPORTS OF CHILDREN'S INTERNALIZED REPRESENTATION OF NUMBERS TO MATHEMATICS ACHIEVEMENT

by

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(ABSTRACT)

The purpose of this research was to examine children's unmanipulated self-reports of their internalized representation of numbers and the relationship of the spatio-organizational patterns that are represented by the children's drawings to children's ability to solve basic addition problems. Also of interest were possible changes that occurred in children's spatio-organizational patterns as a result of age, mathematics achievement or gender. It was hypothesized that children whose drawings demonstrated more structured spatio-organizational patterns would achieve a higher number of correct answers on a timed test of basic addition problems. It was also hypothesized that the structure of the spatio-organizational patterns that children drew would be influenced by age, gender and mathematics achievement.

The results of this exploratory study of children's unmanipulated internalized constructs of number provided some interesting results. The children were asked to image specific numbers of dots for numerals from 4 through 13 and then to draw a representation of their images. The representations were categorized according to the structure of spatio-organizational patterns. The analyses revealed that the patterns had more structure for older

children. Multiple regression analyses also indicated that the correctness of the cardinality of the number of dots imaged was the most frequently occurring variable that had a significant effect on the Imagery Scores. Less than five of more than 450 students expressed any difficulty with the imagery task and then only as it related to one of the ten numerals they were asked to image.

The students were asked to image at the foundational level of imagery--reproductive imagery (Piaget & Inhelder, 1971). Because the research task developed for the students did not involve anticipatory images, those requiring transformations or movement, these imaging tasks were not influenced by the children's IQ or mathematics achievement. According to Piaget and Inhelder, children's ability to use anticipatory images indicates that children are developing an operational understanding and use of imagery. The children in this study were not asked to do anticipatory imaging. This may account for the negative relationship of the Imagery Scores to the fifth-grade students' math percentile scores and the positive relationship between Imagery scores and mathematics percentile scores for the primary level students. The imagery tasks requested of the students were not of sufficient difficulty to relate to any mathematical operations or logio-mathematical thinking for older children.

The ability of children to produce reproductive images which have varying degrees of spatio-organizational patterns was demonstrated by this study. Future studies need to address the higher level of anticipatory images. If students were asked to image a specific number of dots and then to image adding another quantity of dots to the original image, would the spatio-organizational patterns used by children in this transformation process change or transform the image? Are there specific spatio-organizational patterns that more easily allow children to develop anticipatory images that use mathematical operations? Are there children who have developed static reproductive images, and as a result, have created internalized constructs that inhibit their future understanding and development of higher level mathematical concepts?

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Wherever you are it is your own friends who make your world.
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Chapter 1

INTRODUCTION

Education experts and mathematicians agree that number is an abstract concept. Based on the cognitive perspective, the learning of number concepts is a process that is developed internally by children over an extended period of time. Little research is available that addresses the internal representations that children create to give meaning to the abstract numerical symbols, what influences the internal representations of number may have on children's ability to answer successfully basic addition problems, or how the internalized representations of number may effect children's mathematics percentile scores on standardized achievement tests.

The problem addressed in this study dealt with children's mental representation of number. Do the pictures that children draw representing how they internally visualize specific numbers of dots reflect any type of structure or organizational pattern? If so, are these different organizational patterns related to children's ability to answer basic addition problems and/or the mathematics percentile scores they receive on standardized achievement tests?

Definition of Imagery

Finke (1989) defines mental imagery as "the mental invention or recreation of an experience that in at least some respects resembles the experience of actually perceiving an object or an event, either in conjunction with, or in the absence of, direct sensory stimulation" (p. 2). A similar definition, by Richardson (1980), stated that " mental images are symbolic

representations that may be maintained over a definite period of time and that may be manipulated in various ways" and that mental images "constitute an elaborative form of coding in long—term memory" (p. 43). Bugelski (1982) stated that "images are conditioned responses and moreover all conditioning amounts to the formation of images" (p. 9).

Imagery and Learning

Wingfield (1979) wrote that three kinds of sensory memory have been proposed: (1) visual (iconic), (2) auditory (echoic) and (3) tactile. Visual imagery is a very normal and common phenomenon. Imagery operates in the mind much the same as mediators, by offering concrete anchors for learning materials (Wingfield, 1979). According to Matlin (1983), the "bulk of experimental evidence supports the idea that mental images can be used to store information. Mental images may not preserve all the qualities of perceptual experiences, but mental images and perceptions are similar on an amazingly impressive variety of characteristics" (p. 105).

Paivio (1986) purposed that learning and memory are linked through a "dual coding" process. The most "general assumption in dual coding theory is that there are two classes of phenomena handled cognitively by separate subsystems, one specialized for the representation and processing of information concerning nonverbal objects and events, the other specialized for dealing with language" (Paivio, 1986, p. 53). In Paivio's dual coding theory the nonverbal (symbolic) subsystem is referred to as the imagery system and the language system is called the verbal system. Paivio stated that imagery is "spatially organized and functionally integrated in memory" (p. 165) and that images "correspond to cognitive representation" that can 'stand

for' something else in the sense that they can activate other representations" (p. 98). Paivio proposed that the two systems are "independent in the sense that either system can be active without the other or both can be active in parallel. At the same time, they are functionally interconnected so that activity in one system can initiate activity in the other" (p. 54).

Bruner (1988) also included the idea of image as an important aspect of learning. He stated,

> ... the most important thing about memory is not storage of past experience, but rather the retrieval of what is relevant in some usable form. This depends upon how past experience is coded and processed so that it may indeed be relevant and usable in the present when needed. The end product of such a system of coding and processing is what we may speak of as a representation (p. 35).

Bruner suggested there are three modes of representation: enactive representation, iconic representation, and symbolic representation. The three modes develop in the order given with each depending upon the previous one for its development, yet all of them remain more or less intact throughout life. Bruner explained, "By enactive representation I mean a mode of representing past events through appropriate motor response" (p. 35). "Iconic representation summarizes events by the selective organization of percepts and of images, by the spatial, temporal, and qualitative structures of the perceptual field and their transformed images. Images 'stand for' the perceptual events in the close but conventionally selective way that a picture stands for the object pictured" (p. 36). "Iconic representation, in the beginning, is built upon a perceptual organization that is tied to the 'point—at—able' spatioqualitative properties of events" (p. 57). "Finally, a symbol

system represents things by design features that include remoteness and arbitrariness. A word neither points directly to its referent here and now, nor does it resemble it as a picture" (p. 36).

Piaget and Inhelder (1971) suggested that "the role of images is not to cognize, but to concretize symbolically "(p. 350). They further state that the function of the image (like that of the word) is to 'designate' while the function of the concept (relation, class, etc.) is to interpret and comprehend (p. 382).

Piaget and Inhelder (1971) classified images in terms of their content (i.e. they are visual, auditory, etc.) or according to their structure, and stated that there is a hierarchy of image levels which correspond to stages of development and to degrees of increasing complexity (p. 1). The two basic divisions of images are labeled reproductive images, which evoke objects or events already known, and anticipatory images, which represent events that have not been previously perceived (p. 2). Reproductive images are formed at the pre-operational level and anticipatory images do not develop until the level of the concrete operations (p. 352). The reproductive images of the pre-operational level remain static and are unable to represent even the results of movements or transformations. The reproductive images function in the two following ways:

> On the one hand they may keep close to the perceptions of which they are active copies. In this case they provide thought with nothing more than perceptual data, unless it be also an active imitation facilitating analysis and evocation of such data. This constitutes a factor in cognitive development of a general kind but of no specific relevance to the future operations. On the other hand they may modify the perceptions serving as their models and thus be prone to pseudo-conservations and

> distortions with static tendency, and in this case, far from preparing for the operations, the images reinforce pre-operational thought in its disposition to overrate states and to neglect transformations (p. 377).

At about 7 to 8 years a capacity for imaginal anticipation begins which enables the child to reconstitute kinetic or transformation processes (p. 358). According to Piaget and Inhelder (1971):

> ... the situation is indeed quite different when the images become anticipatory under the influence of the operations. The image then constitutes an auxiliary that is not only useful to, but in many instances necessary for the function of the operations. After having structured and fashioned it in their own likeness, the operations in fact come to depend on the image. The services performed by the image are of two kinds. The first related to the cognition of states between which are interposed the governing transformations. And the second relates to the representation of these very transformations. For though continuity, precise detail and especially the overall implications of transformations are not susceptible of representation, yet they can be grasped and manipulated better if an outline of imaginal representation helps operational reasoning (which prolongs and goes beyond imaginal representation) get off the ground (p. 378).

> ... the representation of a perceived or perceptible datum does not constitute a cognition, and it does not become a cognition until it is based on an operational comprehension of the transformations accounting for the datum. .... The image ensures finer analysis of "states" and even aids figural anticipation of 'transformations', in spite of the irreducibly static character of such a figuration. This makes the image an indispensable auxiliary in the function of the very dynamism of thought--but only as long as it remains consistently subordinate to such operation dynamism, which it cannot replace, and which it can only express symbolically with degrees of distortion or fidelity varying according to circumstances (p. 390).

Several other experimental studies also support the idea that mental images can be used to store information. One of the first systematic studies of

mental imagery was done by Galton in 1880 (cited in Wingfield, 1979). The points of general agreement were that most people do report mental imagery of some sort and accept their imagery as a true mental event. The character of the imagery people reported showed little variation. According to Galton, the ability to image seems a matter of voluntary control that increases with age, and reconstruction of images often requires some effort. In 1977 White, Sheehan, and Ashton confirmed Galton's statement that "the ability to evoke vivid images increases with age" (p. 160). An earlier study by Sheehan (1967) provided more support for Galton's work. Sheehan found that "females reported more vivid imagery than males" (p. 387) and "few students lacked the ability to evoke images when required" (p. 387) but Sheehan reported "considerable difference in the degree of clearness and vividness" of the subjects' images (p. 387).

Mental image studies have been conducted that examine the importance of rotation, size, and the preservation of shape. Kosslyn in 1975 (cited in Matlin, 1983; Reed, 1988), explored the effect of size on imagery. Results indicated that it does take longer to judge small images than large mental images. He also reported that it takes longer to create large mental images than small images. In 1973 Moyer (cited in Matlin, 1983) discovered that decisions regarding relative size take a long time if the two objects are similar whether the objects are in our minds or physically in front of us. Shephard and Metzler in 1971 (cited in Bourne, Dominowski, Loftus, & Healy, 1986; Matlin, 1983), explored the effect of angle of rotation and decision time. Results indicated that the angle of rotation of an object has a strong influence on decision time. A later study by Cooper & Shephard in 1973

(cited in Bourne et al., 1986; Matlin, 1983; Reed, 1988) examined whether subjects would perform as though they had available to them, in memory, a physical representation of a stimulus. The subjects were shown a single letter such as R followed by a second one that was either that letter or a mirror image. The time required to decide whether a letter was normal or reversed was almost an exact function of the number of degrees that would be necessary to bring the letter to the vertical.

Imagery studies have also been done that examined the effect of imagery on learning. Paivio and Okovita (1971) found that concrete words that arouse images are easier to learn than abstract words. Allen (1972) related that subjects' scores on memory tests can be enhanced through the use of imagery. He further states that "imagery may be more effective than language ... especially where the material is disconnected and low on initial meaningfulness" (p. 478). Results of three studies by DeLoache and Todd (1988) revealed that young children used categorization and spatial organization of objects as a mnemonic strategy for future retrieval. DeLoache and Todd's research represents the first evidence connecting children's ability to "construct" classes based on a mental representation of a nonvisible attribute. They also noted clear developmental trends. Pressley, Cariglia-Bull, and Schneider's research (1987) is consistent with previous studies that older children in the imagery condition learned significantly more than did the older children in the control condition. They also found that "imagery instruction is more effective with children who are more intellectually competent" (Pressley, et al., 1987, p. 194). Jacob (cited in Sadoski,1983) determined that the ability of subjects to generate visual imagery when

attempting to comprehend written text is a critical factor in differentiating good and poor readers. Sadoski's (1983) study explored the relationship between unmanipulated self—reports of imagery and comprehension of a story. He found that more elaborated original imagery is related to deeper comprehension. Cramer's studies in 1981 reported that "for fifth graders, interactive imagery instructions facilitated learning in both the single—item recognition paradigm and in the paired—associate recall paradigm" (p. 172). For first graders, Cramer found no overall effect for students who were given imagery instructions but reported that "those subjects who reported using interactive imagery in the paired—associate paradigm were superior to their age—mates who reported no imagery" (p. 172). Cramer's results indicated that there is an interaction between age and the effect of the type of reported imagery, either paired—associate or interactive imagery.

Imagery has also been investigated by cognitive neuropsyschologists. "Electroencephalographic studies of normal subjects have confirmed a relationship between imagery and the right hemisphere" (Bryden & Ley, 1983, p. 113). Benbow (1988) has suggested that marked mathematics abilities are linked to brain organization and an important part of her argument is that left-handers are overrepresented in the population of those who are highly gifted in mathematics" (cited in Peters, 1990, p. 176). Lewis and Harris (1990) studied the relationship between handedness and spatial ability. They stated..."future explanations of individual differences in cognitive ability will have to address the fact of the interaction of handedness and sex as well as the possible moderating influence of reasoning ability" (p. 335). Results from their study of spatial ability, in which only high-academic achievers were

used, found that right-handed men performed better than left-handed men and left-handed women performed better than right-handed women (p. 334).

Number Concepts, Perceptions and Patterns

An integral part of concept formation and perceptual development is pattern recognition. Pattern recognition is the process that transforms and organizes raw information through the identification of a complex arrangement of sensory stimuli by comparing the sensory stimuli with information in other memory stores. According to Matlin (1983), two kinds of processing are involved in pattern recognition. Data-driven processing (bottom-up) stresses the importance of the stimulus in pattern recognition, while conceptually driven processing (top-down) stresses the influence of a person's concepts and higher—level processes in shaping pattern recognition. According to this approach, our knowledge about how the world is organized helps us identify patterns. We expect certain shapes to be found in certain locations and these expectations help us make rapid pattern recognitions. We begin by recognizing the whole complex pattern and our knowledge of the world helps us identify a fragment of the pattern (Matlin, 1983). According to Matlin, both processes occur and both are necessary.

How the stimuli are compared during one's process of identifying patterns is addressed by three theories of pattern recognition. The first theory, template—matching theory, suggests there are specific patterns, templates, stored in memory. Each stimulus is then compared to templates for identification. The limitation of this theory is that we need an infinite number of templates in order to recognize all possible variations of stimuli in

the environment. A second theory, prototype-models theory, implies that there are abstract idealized patterns in memory that are used for comparison and an exact match is not necessary for recognition to occur. The third theory, the distinctive—features model, suggests the memory is a store for only distinctive features of stimuli that are stored as an abstract, idealized version of the stimulus (Matlin, 1983).

Wingfield (1979) says that perceptual learning is "at the heart of most concept learning in both children and adults" (p. 215). Perceptual learning involves perceptual reorganization. This occurs when an important feature begins to stand out, such as when children are asked to compare the equivalence of sets of objects that have been presented in pictorial form. The child must be able to recognize that number is the "salient feature, while color, shape and size" are "noisy nondefining attributes for the equivalence concept" (p. 217).

Number Concept and Imagery

Steffe, vonGlasersfeld and Cobb (1983) discussed the development of number concept in terms of "units." They described motor units as referring to the counting of perceptual items by pointing, grasping, glancing, etc. Steffe et al. consider the motor act as a link to the development of figural representations. Verbal units refer to the coordination of motor acts and the sequential verbalization of number words. Steffe et al. believed that when this procedure becomes "automatic," each "vocal production of a number word can be taken to stand for a countable perceptual item" (p. 41). Figural or visualized units represent a conceptual structure, a template, which becomes

itself the object of awareness. "A figural representation functions as a countable item in that it represents the original perceptual experiences and thus constitutes a substitute for it" (p. 37). The last step toward number concept development consists of abstract units which Steffe et al. explained as "the acquisition of the awareness that the utterance of a number word, in the context of a counting task, can be taken to imply unitary items of the kind fitting the template created in that context" (p. 42).

Steffe et al (1983) state that a child's ability to correctly and without hesitation answer such questions as which number comes before, which number comes after, and which number comes between specific stimulus numbers is an indication that the child has something like an "image" of that segment of the standard number-word sequence which can be accessed at any point. Steffe, et al. further addressed the importance of "image" when they stated,

> The first indication that dependence on the actual presence of perceptual signals is lessening is the ability to count items that have been hidden. To count such perceptually inaccessible items the child has to imagine them. That is to say there has to be an internal re—presentation of the perceptual signals that for the child constituted the countable items in that particular context (p. 23).

The development of a "stable spatial or temporal pattern of unitary elements which the child can re—present to itself from memory and for which it knows the number word, both as name and as indication of the countable elements contained in the pattern" is called a "subitized pattern" (Steffe, et al., 1983, p. 32).

Steffe's premise that there exists an internal representation of number

is supported by Morra, Moizo and Scopesi (1988). Morra, et al. propose that there exists a "spatial mental model which has a finite set of tokens that represent physical entities and a finite set of spatial relations among them" (p. 45). Finke (1989) states that the "spatial arrangement of the elements of a mental image corresponds to the way objects or their parts are arranged on actual physical surfaces or in the actual physical space" (p. 61).

Piaget's position (1964) regarding his work with perception as related to the perception of numeral was clearly stated when he addressed the work of W. A. Lay.

> W. A. Lay made a detailed study of the way in which various figures made with three, four, five, etc. objects arranged as triangles, squares, etc. are distinguished by the child, from the point of view of perception of number. The number four, for instance, is more easily recognized when the objects are placed at the four corners of a square than when they are placed at random....Our point of view here will be different, for while these authors examined what has come to be called perception of number, i.e. the application of already existing numerical schemata to discrete objects perceived in the same field, we shall examine what might be called quantifying operations, i.e. the elementary operation of correspondence equating, etc., which constitute the logic of number. In a word, we *shall ignore the problems of perception* (italics added) and shall concentrate on the problem of the genesis of operations as such (pp. 66—67).

From the educational research arena, other types of research and theories which relate directly to children's learning of number concepts have given endorsement to the importance of internalized constructs in the development of number concept. As a staunch supporter of Piaget's theory of

cognitive development, Kamii (1985) stated:

> Educators are under the illusion that they are teaching arithmetic when all they are really teaching are the most superficial aspects such as specific sums (4 + 4 = 8, 4 + 5 = ?) and the conventional meaning of written signs (e.g. 4 and +). Arithmetic is not a body of knowledge that must be taught through social transmission. It must be constructed by each child through reflective abstraction. If the child cannot construct a relationship, then all the explanations in the world will not enable him to understand the teacher's statements (p. 25).

Kamii continues with the explanation that number is not empirical; it is a mental structure. "Number is something each human being constructs from within and not something that is socially transmitted" (p. 15).

Although Kamii did not expound on the significance of a change that was made in the presentation of material in one of the games she had been using with children, it appears to be an important aspect that relates to the children's construction of number. During the second year of using a game Kamii called "Coin War," she changed the spatial arrangement of the pictures of coins on the playing cards so there were a maximum of five pennies in the left-hand column. According to Kamii, "this arrangement enabled the children to look at three pennies and immediately know that there were eight" (p. 214). The pecking behavior (pointing or touching when counting objects) that children had been using to determine the number of coins stopped.

Two ways of arranging pennies in cards for Coin War.

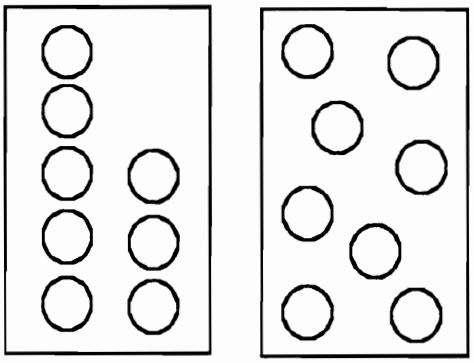


Figure 1 Change in arrangement of coins on playing cards (Kamii, 1985, p. 214).

Kamii does state that the spatial arrangement of sets is highly relevant to children who have not constructed the mental structure of number. This insight was not made in relation to the changes she made in the coin cards, but in relation to Piaget's conservation task.

Resnick (1989) and Fuson (1988) provide further support of the importance of perception of number. Resnick (1989) states that "Infant discrimination studies show that they are able to make judgments on the basis of comparative rather than absolute size. This means they have some kind of schema for comparing objects quantitatively. Babies quantitative knowledge, is of course prelinguistic" (p. 162). Fuson indicates that "Subitizing seems to be used by very young children and may even be used by infants" (p. 10). She further relates that "For very small numbers (two, three, and possibly four and five), people seem to be able to apprehend directly the appropriate cardinal or measure word, that is to *subitize* it. How this is done is still a matter of dispute" (p. 10).

Hughes (1988) states that mathematical symbols are formal codes that are context free and as such are not a part of normal language development.

Because the symbols used in mathematics are formal codes, Hughes states there is a transitional period through which children must go to develop symbolic understanding. The transitional period addresses the change from concrete representation to the symbolic representation of numbers.

Defining Number Concept

Based on research from mathematics education, experimental psychology, cognitive science, and educational psychology, number is accepted as a conceptual creation. Although the word concept has been defined in various ways in the literature, there are descriptors that are common in each of the definitions. These descriptors include categorizing, objects, relationships, and perception (Matlin, 1983; Travers, 1982; Wingfield, 1979). Souviney (1989) gave the definition of concept as "the underlying pattern that relates sets of objects to one another" (p. 16). Piaget (cited in Kamii, 1985) said that "number concepts exist only in the minds of children who construct logico—mathematical knowledge by coordinating the simple relationships of same, different and more. The child has to have an internal re—presentation of the perceptual signals that constitute the countable items in that particular context" (p. 23).

Chapter 2

RESEARCH METHODOLOGY

Purpose and Rationale

A review of the educational and psychological literature reveals general acceptance of the existence of mental images in children's minds and the use of these images as an aid to learning. There is also general agreement that number is an abstract concept. Many mathematics educators and cognitivists purport that number concepts are only developed when children are able to internalize an image or some representation of number without the presence of concrete objects (Fuson,1988; Hughes, 1988; Kamii, 1989; Piaget, 1964; Steffe, et al., 1983).

It appears that the idea of an internalized construct or image of number is a critical point in children's mathematics learning. Resnick (1989) stated that "There seems to be general consensus that number concepts form the basis upon which higher mathematical competencies can develop" (p. 162). However, there were no research articles located that addressed the children's spatial organizational patterns of unmanipulated internalized number constructs. Only one study, Sadoski, 1983, was located that explored the relationship between unmanipulated self—reports of imagery and reading comprehension. He found that the ability of subjects to generate visual imagery when attempting to comprehend written text is a critical factor in differentiating good and poor readers. Previous research has shown that the construction of internalized images is influenced by size, rotation, and complexity of the image that is reported. Because this researcher was

interested specifically in the spatial organizational patterns of internalized images of specific numbers, the children were asked to image specific numbers of dots. By asking the children to image specific numbers of dots as opposed to flowers, houses, or things, the confounding factors of size, rotation, and complexity of the unit imaged was controlled.

Description of Participants

The participants in this study were all the students who were in attendance in grades K—6, in a rural southwestern Virginia school. The students' socioeconomic status (as assessed by the classroom teachers) are primarily from low to middle socioeconomic levels with 28% being rated as low, 61% rated as middle and 10% rated as being in the high socioeconomic level. The classes are heterogeneously grouped by home room with some grouping for specific content areas beginning in second grade. Of the 478 students used in this study, 46% were female, 6% were classified as special education students and 8% were designated as being left handed. Forty-six percent of the students were identified by teachers as working at an average math level, 25% were classified as being in a low math level and 29% were in a high math level. The Cognitive Abilities Test scores (COGAT) were approximately normally distributed with a mean score of 104 and a range from 52 to 150. (see Appendix B, pp. 67-75) The kindergarten students had to be excluded from the data analysis of this study due to lack of mathematics percentile scores from a standardized test, no standardized measures of IQ, such as the COGAT, and the kindergarten students' lack of prior experience with written addition problems.

Description of Materials

Materials for the students included:

Eleven sheets of 7" x 8 1/2 " unlined white paper

one black crayon.

basic addition problems test

(100 problems with answers no greater than 20)

a number 2 lead pencil

Materials for the teachers included:

A one-page, data-collection form which included:

students names

student identification codes

date of birth

gender

IQ score

mathematics level

socioeconomic level

handedness

special education status

total mathematics percentile score

Teacher questionnaire--one page

Researcher materials consisted of:

One posterboard illustration of a sample sheet of the students' papers which was used as a demonstration to show the students where to place their names and the stimulus number on each sheet of paper they were to use.

Directions to be read to each class

Individual class data collection form which included the sequence of data collection (addition test and imagery activity) and a random ordering of numerals from 4-13 that indicated the sequence of the numerals named for the imaging activity. There were four random orders of the numerals 4-13 which were used within each grade level

Procedure for Data Collection

Prior to visiting the school, a schedule was sent to the classroom teachers who were requested to designate a one hour block of time that was convenient for the research to be conducted in their classrooms. All classes were scheduled for data collection during a one-week period.

After a brief introduction, the researcher used the previously designed materials to gather the data. In an effort to counteract the experimental design influence of having the students image specific numbers of dots before taking the timed addition test, the order of presentation of the addition test and the imaging work were alternated by class throughout the data collection process. This was especially important based on research by Schallert (cited in Sadoski, 1983). Schallert stated, "imagery instructions and in fact any instructions that insure deep semantic processing of the text have been found to result in better performance when compared to control group instruction" (cited in Sadoski, 1983, p. 111).

The directions for the imagery activity and the timed addition test were read to each class (see Appendix A, pp 61-66). When children stated they were unable to imagine or see in their mind's eye the number of dots that

had been requested, they were encouraged to draw a picture of what they did see or to leave the paper blank if they were unable to image anything. After completion of the imagery activity, students in the third through sixth grades were asked to write a brief description of the last four numerals they had imaged (see Appendix A. p 64). The collection of the data took about 45-60 minutes minutes depending on the grade level of the students.

The analysis of the collected data involved two distinct phases. The first phase of data analysis was to construct a psychological scale of the imagery drawings that were obtained from the students and test the reliability of the scale. The second phase involved multiple regression analyses.

Development of an Imagery Scale

Torgerson (1967) stated:

> Psychological scaling methods are procedures for constructing scales for the measurement of psychological attributes (Torgerson, 1967, p. ix). Measurement,..., concerns the assignment of numbers to objects to represent amounts or degrees of a property possessed by all of the objects. An important characteristic of measurement is its power to enable us to decide, within limits, which of the inexhaustible number of sets of numbers that might be assigned to the set of objects is appropriate (Torgerson, 1967, p. 19).

Torgerson discussed three major divisions of scaling methods:

> *The Subject-Centered Approach. The systematic variation in the reactions of the subjects to the stimuli is attributed to individual differences in the subjects.....*
>
> *The Stimulus-Centered or Judgment Approach. The systematic variation in the reactions of the subjects to the stimuli is attributed to differences in the stimuli with respect to a designated attribute.....*
>
> *The Response Approach. Variability of reactions to stimuli is ascribed to both variation in the subjects and in the stimuli.* (p. 46)

This study utilized the response method as the technique for establishing the scaling procedure. The "systematic variations," reflected in the responses of the drawings that were produced by the students are assumed to be attributed to the children's particular internalized spatial organization of an image and its relationship, if any, to the cardinality of each verbal stimulus that was presented.

To establish a master scale for scoring the spatial organizational patterns reflected in each drawing, a panel of five judges was chosen. The five judges were selected based on their diversity of expertise and their willingness to take part in this study. Judge 1 was a doctoral student in the area of statistics with experience teaching at the college level and Judge 3 was a college professor with expertise in educational psychology. Judges 2, 4, and 5 were all doctoral graduate students in the College of Education. Judge 2 was an experienced teacher in the field of special education. Judge 4 was experienced in teaching English at the high-school level and Judge 5 was pursuing a degree in Instructional Technology but had not taught in the public schools. The five judges had varying levels of experience in the area of mathematics.

With the construction of a master scale, a scale of standards, the

> psychological value of a new stimulus can be determined directly by comparing it with the scale of standards with respect to the attribute.....The usual procedure is to determine, initially, the scale values and dispersions of a very large number of stimuli. The stimulus series should be distributed over the entire range of the attribute, and if possible, should extend beyond the extremes desired for the final scale. From this large group of stimuli, a relatively small subset is selected to comprise the master scale. Ideally, the standards would be selected so that they are evenly distributed over the range of

> interest. In addition, however, the dispersions of the stimuli must be considered. A small dispersion for a stimulus indicates a high degree of agreement among the judges with respect to the scale value of that stimulus. The larger the dispersion, the greater the ambiguity, and obviously, the less desirable that stimulus is for serving as a standard. Hence, the final selection will ordinarily represent some compromise between selecting stimuli that are equally spaced over the continuum and selecting those stimuli that are the least ambiguous (Torgerson, p. 88).

During the first phase of the development of this scale, each judge was asked to rate a stratified sample of the students' drawings based on the degree of spatial organization of each drawing--from most disorganized (1) to very organized (10). The judges were each given a random sample of four students' sets of drawings (ten drawing per set) from each grade level K-6. Thus, each judge initially received 280 separate drawings which they were asked to rate. The judges worked independently for two hours to establish scales for the drawings they received. During this initial scaling process, the judges were encouraged to make notes which related to their decision-making process. Upon completion of the independent ratings of each of the samples, a detailed discussion was held (see Appendix C, pp. 88-92) for a summary of the taped discussion) to establish the criteria that were used by each judge in the development of their rating scales. The judges initially discussed the characteristics of the most extreme examples of most organized to most disorganized spatial patterns. The students' drawings of the imagined dots that were viewed as most organized were described as being dice-like, nicely spaced, efficient, symmetrical, comprised of sets, generalizable, and reproducible. The most disorganized spatio-organizational patterns were

described as scattered dots, random, and presented difficultly in determining the cardinality of the dots without counting each dot.

Before the discussion of specific spatio-organizational patterns, the judges discussed the importance of the correct cardinality of the dots as a factor in determining the spatio-organizational pattern scores. Several options were discussed such as eliminating any drawing that had incorrect cardinality, ignoring the number of dots and examining only the spatio-organizational patterns, doing a separate score for the correct cardinality of the dots, or evaluating the drawing first for correctness of dots and then evaluate the organizational score, with incorrect numbers of dots then receiving a lower organization score. It was agreed that the cardinality of dots would be a confounding factor if considered along with the spatio-organizational pattern scores. Because this research is specifically exploring spatio-organizational patterns, the judges agreed that the cardinality of the dots would be a separate scale and the spatio-organizational scores would be judged solely on the organizational patterns that were represented by the drawings.

Through a brainstorming activity, names were generated to identify the possible categories of spatio-organizational patterns that were identified during the independent scaling process. The names included: domino, number made of dots, straight line (linear), circle, triangle, shape, box-like, columns, cross patterns, letters of the alphabet, intersecting lines, organized randomness and no recognizable pattern. The seven final categories that were determined to be important were (in order from most organized to most disorganized):

1. Domino, card-like, and sets

   Descriptors: clear organizational thinking, readily recognizable patterns, larger numbers are often grouped, clear cut sets, sets are equal or nearly equal in number

2. Developing sets

   Descriptors: seems to have grouping and developing sets, can't readily identify the number, not nicely patterned, pretty spread out or too compressed, non-traditional

3. Intersecting lines

   Descriptors: intersecting line segments, in shapes of T's, I's,X's, V's and U's; sometimes two lines, sometimes three lines.

4. Linear

   Descriptors: straight lines in any direction; may be curved back if it looks like the student ran out of room

5. Alphabet, number, triangle, circle and pictures

   Descriptors: pictures and simple shapes, letters or numbers

6. Random, scattered

   Descriptors: free-flowing, uninhibited, unstructured, randomly placed, varying sizes and varying shapes

7. Blank or chaotic

   Descriptors: no dots, blank, makes random look good

A master scale (see Appendix C, pp 93-100) was developed using a sample of the students' drawings that the judges had categorized and the descriptors that the judges designated as distinguishing variables in each category. The judges met a second time. Before each judge scaled another

sample (45 students from classes randomly chosen from grades 1 and 3, 450 drawings) of the students' drawings, the master scale was discussed. Each category was ranked according the increasing degree of organization and assigned equally occurring interval point values from 0-6. These values were to be used during the scaling process. The students' total Imagery Score was to be determined by summing the values for each of the 10 drawings for each student. The judges used the master scale as a guide for their scaling activity. The scaling was done independently. Each judge scaled all the drawings in the sample. As the judges scored their own sets of drawings, they were asked to indicate on their scoring sheet any of the samples that they felt did not clearly fit into one of the established categories on the master scale. After the judges completed their scaling, they discussed the master scale and made recommendations for refining the master scale. The initial category names and values were retained. More precise descriptors were added to the category descriptors and recommendations regarding the examples in the master scale were indicated.

An interrater reliability correlation was computed using the judges total scores.

Table 1

Correlations for all Judges

Variable	Judge 1	Judge 2	Judge 3	Judge 4	Judge 5
Judge 1	1.0000	0.4551	0.8593	0.8165	0.8994
Judge 2		1.0000	0.4315	0.3353	0.3530
Judge 3			1.0000	0.8140	0.8170
Judge 4				1.0000	0.7338
Judge 5					1.0000

Correlations for Four Judges

Variable	Judge 1	Judge 3	Judge 4	Judge 5
Judge 1	1.0000	0.8593	0.8165	0.8994
Judge 3		1.0000	0.8140	0.8170
Judge 4			1.0000	0.7338
Judge 5				1.0000

Correlations between all five judges ranged from .33 to .90. When Judge 2 was eliminated from the analysis, correlations range from .73 to .90. Despite being requested to examine only the spatio-organizational patterns of the drawings, it was apparent from the judges' discussions that Judge 2 valued highly the drawings that were creative and unique. With such a strong personal belief in the importance of individual creativity, it was apparently not possible for Judge 2 to interpret and apply the scale categories in a manner consistent with the scores of the remaining four judges.

Based on the discussion and scoring of the judges' second meeting, a revised master scale was developed (see Appendix C, pp. 101-108). Four novice raters were asked to help establish the reliability of the revised master scale. The novice raters areas of expertise included electrical engineering, middle-school education student teacher, instructional technology and foreign language education teacher. The novice raters were requested to score another sample of the students drawings. They were given the revised master scale to examine before they began their scoring process. Any clarification questions were addressed, but no specific training period was given. The novice raters scored three classes of students' drawings for a total of 71 students. The classes from grades 1 and 5 were randomly chosen. The third-grade class was the same class that had been scored by the judges. Correlations between the novice raters ranged from .62 to .86. Correlations between the judges and novice raters of the scores for the third grade class ranged from .74 to .96. According to Salvia and Ysseldyke (1988) scores for group data that are to be used for administrative purposes and are reported for groups should probably have a reliability of .60 as a minimum (p. 128).

> If a test score is used to make a decision for one student, a much higher standard of reliability is demanded. When important educational decisions, such as tracking and placement in a special class, are to be made for a student, the minimum standard should be .90. When the decision being made is a screening decision, such as recommendation that a child receive further assessment, there is still need for high reliability. For screening devices, we recommend a .80 standard (Salvia and Ysseldyde, p. 129).

The reliability scores for both judges and novice rater fall well within the recommended levels for reporting group scores. Caution is strongly recommended for any interpretation of individual student performance based on the Imagery Scale. This scale has not been standardized so it lends itself only to general interpretations about the student population that participated in this study.

Imagery Scale Explorations

To establish an intrarater reliability correlation, the master scale was used twice to rate all students' drawings. Imagery Score 1 is the total score received by each student during the first rating. Three weeks later, Imagery Score 2, using the same master scale, was completed. The intrarater reliability correlation between Imagery Score 1 and Imagery Score 2 was .88. For Imagery Score 1, the researcher's interrater reliability correlations with the judges and novice raters ranged from .58 to .86. and from .73 to .92 for the Imagery Score 2 (see Appendix C, pp. 109-110).

An examination of the correlations between the Imagery Scores received for different numerals for the entire school population reveals correlations that range from .03 to .27 (see Appendix C, p. 112). Although the

correlations of the Imagery Scores by numeral are low, there appears to be a general pattern of similar correlation for numerals that are closer in cardinality.

When the scores that are used for classifying each individual's drawings are most conservatively considered ordinal, a chi square analysis can be performed to explore the relationship between the categories of imagery scale for each of the numerals by the grade level of the children. Chi square analysis using the Likelihood Ratio and Pearson Test revealed that the Imagery Scores obtained for each numeral (chi square Prob <.01), except the numeral 7 (chi square Prob <.1), are dependent on the grade level of the children who completed the drawings. There was a general trend for students in the higher grades to receive scores that reflected a higher organizational pattern (see Appendix C, pp. 113-132). This is also clearly shown by the charts and graphs of percent of response by categories and by grade which are in Appendix C, pages 133-136. For Grades 1-3, the percent of responses that received an Imagery Score of 6 (reflecting the most organized patterns) ranged from 8% to 10%. For Grades 4-6, the percent of responses that received the highest organizational scores ranged from 10% to 16%. The category with highest percentage of responses from the first grade was the Linear category (receiving an Imagery Score of 3) while the category with the highest percentage of responses from the sixth grade was Developing sets (which received a score of 5). The figure below illustrate the shift in the percent of Imagery Scores received in each category for students in Grade 1 and Grade 6.

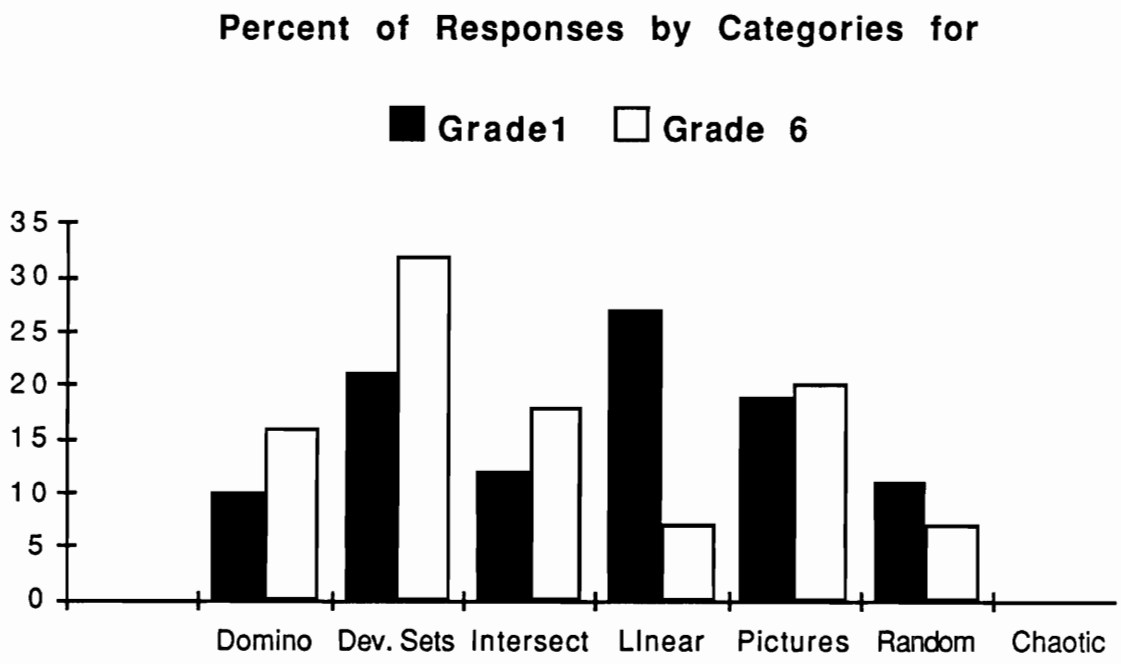


Figure 2. Percent of responses of Imagery Scores for Grade 1 and Grade 6.

An interesting observation regarding the percentage of responses by category by grade level is the relatively consistently high percentages of responses in the category picture that were obtained in each grade level. Percentages of the picture category ranged from 19% to 33% for Grades 1 through 6. The picture category, according to the master scale, includes pictures that are complex artistic drawings as well as simple shapes and letters that are composed solely of dots. For future research, this category may need to be examined more closely. It may be necessary to split this category so it will include a smaller dispersion of stimuli.

When the values assigned to each category are considered to be equally occurring interval scores, as was indicated by the judges in the development of the scale, the influence of the cardinality of the numeral on the average

scores received for each numeral for Primary and Elementary grades can be shown graphically.

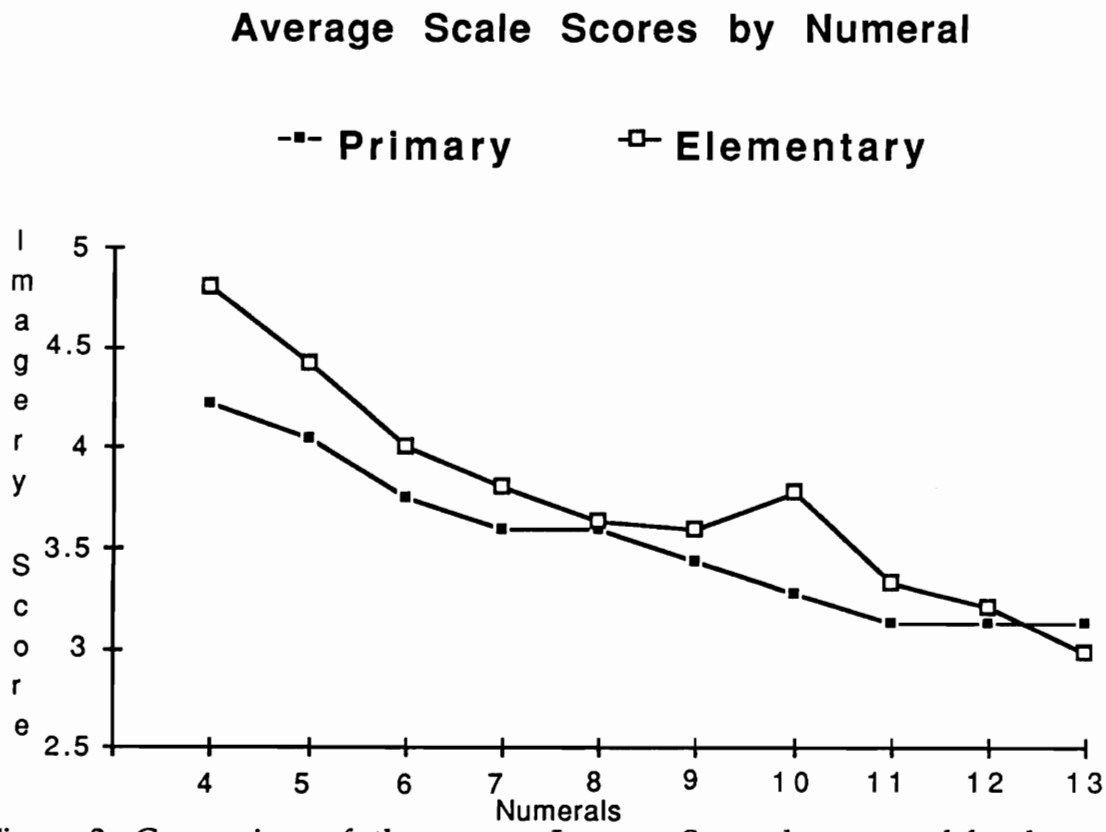


Figure 3. Comparison of the average Imagery Scores by numeral for the Primary and Elementary Levels

Figure 3 illustrates graphically the information obtained from the examination of the correlations of the scale scores with the numerals. It also provides information as to the relative magnitude of the average scale score by numeral. The correlations of the scale scores with the numerals indicated that numerals that were closer in cardinality were more highly correlated thus receiving more similar scores. The ANOVA analysis of the scale scores received for each numeral revealed a mean scale score of 4.51 for numeral 4

and a mean scale score of 3.06 for numeral 13. This downward trend of average scale scores by increasing cardinality of numeral is illustrated in the Figure 4. This figure also illustrates the increase in average scores for numerals for students in the Primary or Elementary Levels. The students in the higher grades generally received higher Imagery Scores for each numeral.

An ANOVA of the Imagery Scores by grade further indicates the trend toward higher Imagery Scores for the students in higher grades.

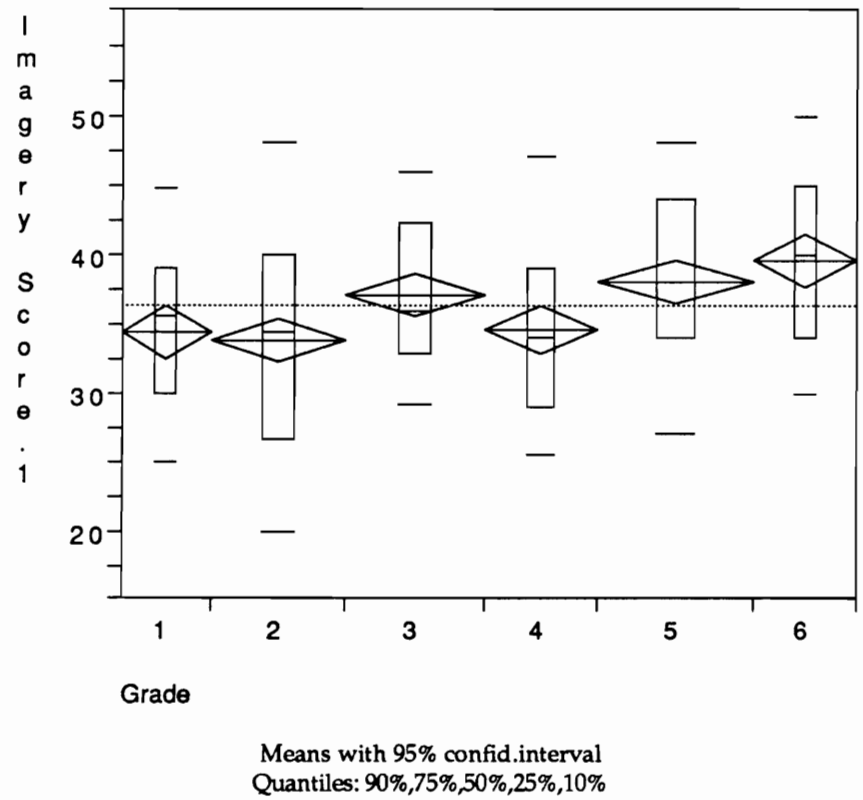
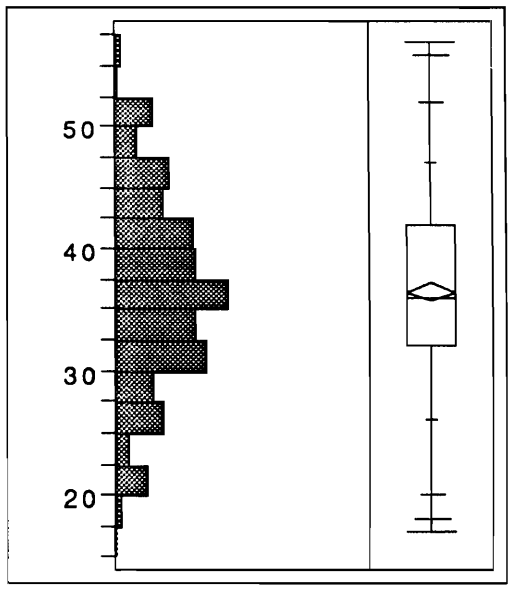


Figure 4. One-way analysis of variance of Imagery Scores for each grade level. The mean Imagery Scores ranged from 33.95 to 39.70.

Despite the apparent difficulties with the descriptors of the individual categories, the Imagery Scores obtained by using this scale yielded a relatively normal distribution for the school population (see Figure 5).



Moments

Mean	36.3934
Std Dev	7.9085
Std Err Mean	0.3827
upper 95% Mean	37.1457
lower 95% Mean	35.6412
N	427.0000

Figure 5. Distribution of Imagery Scores obtained from the school population.

For a total of 427 students whose drawings were scored using the master scale, the mean for the Imagery Scores was 36.4 with a median of of 36. The total scores ranged from 17 to 57. The box plot, also called a quantile plot, to the right of the histogram, is a simple schematic for looking at the shape of the distribution. The box contains a means diamond that represents the 95% confidence interval of the mean. The median is the line in the middle of the box. Based on this figure, the Imagery scores appear to be normally

distributed because the median line falls within the diamond points and the other quantiles are arranged symmetrically above and below these central points.

Chapter 3

MULTIPLE REGRESSION ANALYSES

Imagery Score as the response variable

With the Imagery Scores exhibiting a normal distribution, it is possible to use these data as a response variable in a multiple regression analysis. If imagery has a significant impact on learning as has been demonstrated by previous research, it is important to learn as much as possible about the variables that account for variations in the students' Imagery Scores. Nine multiple regression models were explored in an attempt to discover the variables that yielded the greatest effect on the total Imagery Score. All of the regression models began with a full model of the variables available from the school population and used a step-down method to determine the variables to be included in each model. The step-down method "starts with a full set of predictors and begins deleting variables until there is some appreciable decrement in R" (Howell, 1987, p. 495) while also keeping the root mean square error to a minimum. The variables that were used in the full models with the response variable of Imagery Score were:

1. Gender: (0) Female (1) Male
2. Handedness: (0) Left (1) Right
3. Economic Level: (0) Low (1) Middle (2) High
4. Math Level: (0) Low (1) Middle (2) High
5 Age: (in months)
6. Grade: (The students' current grade placement)
7. IQ :(as given by the COGAT score)

8. Total Math Percentile Score: (as given by the ITBS score)
9. Special Education Student Status: (0) Yes (1) No
10. Accuracy Score: (Each drawing received a score of 5 points, if the number of dots drawn by the student was incorrect, a score of 0 was received. The Accuracy Score is the total of the ten drawings completed by each student.)
11. Adding: (The number of correct responses out of a possible 100 problems completed in the five-minute addition test.)

Table 2 provides a summary of the models of best fit for each of the different divisions of the school population. These regression models are not intended to be used for prediction. Because of the exploratory nature of this study, the emphasis is on the observations of common patterns among the different regression models. The study of these different regression models will also lead to the development of future studies which could be experimental or ethnographic in nature.

By examining Table 2, it is apparent that explaining the variation in the student's Imagery Score is not easily done with the information that is currently available from school records. The amounts of variation accounted for by the final regression models ranged from .10 to .35. Of primary interest are the variables that were most consistently found in each model as well as the variables that were not included. The most consistently appearing variable with a p-value of $< .1$ was accuracy. Despite the cardinality of the number of dots, designated as accuracy, not being considered as a factor in the scoring of the spatio-organizational patterns, it appears that the how accurately children image specific numerals has an effect on the spatio-

organizational patterns that they image. Three of the variables from the pool of school data were never found to have an important effect in any of the regression models. These variables were IQ, Math Level, and Special Education Status. The variable Math percentile was an effective variable only in the regression model for Grades 1-3. The effect of Math level was not strong enough to be found in any of the regression models for Grades 1, 2 or 3. It was interesting how frequently the variable, Handedness, remained as an important effect in the different regression models. Despite the small number of students who were identified as being left-handed within the school population, these students' scores appear to have a positive impact in the variability of the Imagery Scores in the populations of Grades 1-3 and Grade 3. Those students who were identified as right handed contributed to higher scores in Grades 4-6, Grade 5 and Grade 6. The variable Gender was a significant effect in six of the nine regression models with each effect indicating that females score higher than males on Imagery Scores. The effect of Adding, when included in the regression equation, was consistently negative which indicated that higher Adding Scores produced lower Imagery Scores.

Table 2

Nine Regression Models with Imagery Total Score as Response Variable

	School	Gr.1-3	Gr4-6	Gr 1	Gr 2	Gr 3	Gr 4	Gr 5	Gr 6
R square	.13	.20	.12	.15	.35	.11	.10	.14	.10
DF	8,409	6,199	5,203	2,49	4,73	2,78	2,59	3,87	2,55
F Ratio	9.63	8.22	5.47	4.43	9.92	4.95	3.33	4.55	3.08
MSe	54.028	50.587	55.569	41.808	54.310	43.612	51.605	51.721	54.945
Prob > F	.00	.00	.00	.02	.00	.01	.04	.01	.15
Variables:	**with corresponding P-values**								
Gender	.02	.14	.01	.03	•	•	•	.05	.15
IQ	•	•	•	•	•	•	•	•	•
Math L.	•	•	•	•	•	•	•	•	•
Econ. L.	•	.04	•	•	.04	•	•	•	•
Grade	•	•	•	•	•	•	•	•	•
Age	.00	•	.00	•	.01	.•	.15	•	•
Math %tile	•	.04	•	•	•	•	•	•	•
Handedness	•	.11	.04	•	•	.20	•	.02	.07
Spec Ed	•	•	•	•	•	•	•	•	•
Adding	.06	•	.04	•	•	•	.06	•	•
Accuracy	.00	.00	.07	.13	.00	.00	•	.03	•

An examination of the regression model equations provides further information as to the effect of the variables on the Imagery Score. Only the two regression models with the highest R square (Grades 1-3 and Grade 2) will be reported in this text. The remainder of the regression models may be examined in Appendix D, pages-142-160.

Grades 1-3 Regression Model with response Imagery Score

$$20.4209895+\left(\begin{cases} -.77808892, & \text{if } gender=1 \\ .778088929, & \text{if } gender=0 \\ \bullet, & \text{otherwise} \end{cases}\right)+\left(\begin{cases} -4.2073016, & \text{if } Econ\ L=2 \\ -1.7399478, & \text{if } Econ\ L=1 \\ 0, & \text{if } Econ\ L=0 \\ \bullet, & \text{otherwise} \end{cases}\right)$$

$$+.040420838\bullet Math\ Percentile+\left(\begin{cases} -1.6435508, & \text{if } Handedness=1 \\ 1.64355089, & \text{if } Handedness=0 \\ \bullet, & \text{otherwise} \end{cases}\right)$$

$$+.355825920\bullet Accuracy = Imagery\ Score.1$$

Grade 2 Regression Model with Response Imagery Score

$$41.0889638+\left(\begin{cases} -7.9294417, & \text{if } Econ\ L=2 \\ -2.8853179, & \text{if } Econ\ L=1 \\ 0, & \text{if } Econ\ L=0 \\ \bullet, & \text{otherwise} \end{cases}\right)+-.31975627\bullet Age$$

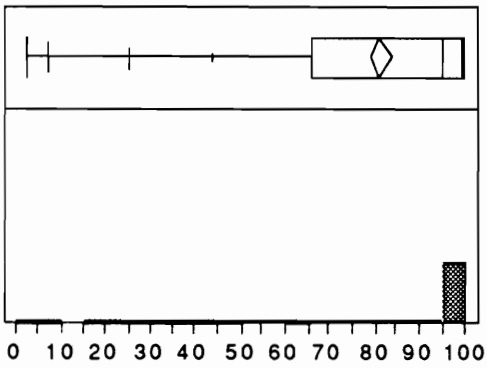
$$+.600857493\bullet Accuracy = Imagery\ Score.1$$

Both regression models show a negative effect for higher economic levels on the response variable Imagery Score. The higher the Economic Level the lower the Imagery Score . The regression model for Grades 1-3

indicates that females tend to have higher Imagery Scores than males and those students that were left handed also have a higher Imagery Scores than those students who were right handed. Both models show a positive effect from the Accuracy Score.

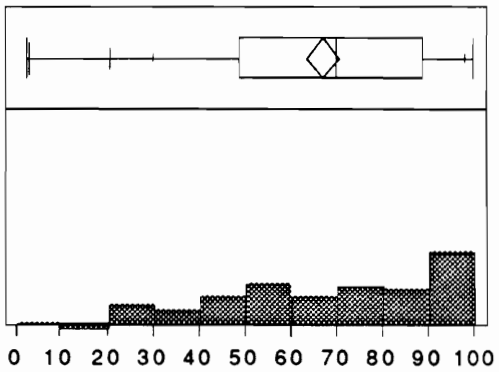
Adding as the Response Variable

Before exploring the question of the impact of imagery on students' Adding Scores through a multiple regression analysis, an examination of the distribution of the Adding Score was done. The examination of the Adding response variable immediately indicates difficulties in using the Adding Score as a response. The results of the Adding Test Scores for the school population are not normally distributed and cluster toward the high end of the maximum score of 100. The distribution of the Adding Scores for Grades 1-3 are also clustered toward the high end of the distribution. Because of distributions that are so far from a normal distribution, results of the T-test and F-test computed in a multiple regression analysis would be unreliable.



Mean	81.4140
Std Dev	23.4612
Std Err Mean	1.1314
upper 95% Mean	83.6378
lower 95% Mean	79.1901
N	430.0000
Sum Wgts	430.0000

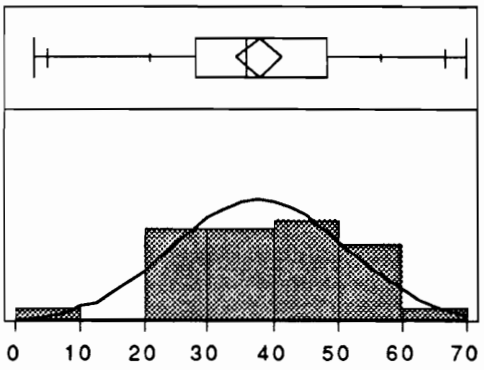
Figure 6. Distribution of Adding Scores Adding for the School population



Mean	66.9395
Std Dev	24.5237
Std Err Mean	1.6725
upper 95% Mean	70.2363
lower 95% Mean	63.6428
N	215.0000
Sum Wgts	215.0000

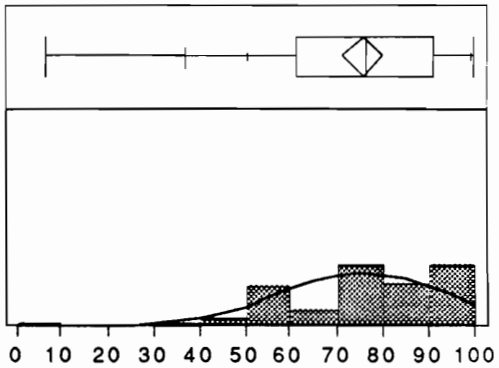
Figure 7 Distribution of the Scores for Grades 1-3

The distribution of the Adding Scores for Grade 1, Grade 2, and Grade 3 show a rapid increase in the mean score from Grade 1 to Grade 3, from 37.8 for First-Grade Adding Scores to a mean of 76.62 for the Third-Grade Adding Scores. With a School mean of 81.41 and through an examination of the Figures 8-10, it is obvious that the obtained scores for the Adding Test do not yield enough dispersion to serve as a response variable except for First Grade.



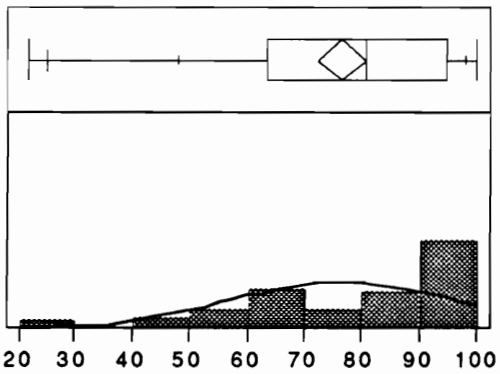
Mean	37.84615
Std Dev	13.76894
Std Err Mean	1.90941
upper 95% Mean	41.67944
lower 95% Mean	34.01286
N	52.00000
Sum Wgts	52.00000

Figure 8. Distribution of Adding Scores for First Grade



Mean	75.78205
Std Dev	18.55819
Std Err Mean	2.10130
upper 95% Mean	79.96629
lower 95% Mean	71.59781
N	78.00000
Sum Wgts	78.00000

Figure 9. Distribution of Adding Scores For Second Grade



Mean	76.62353
Std Dev	20.24550
Std Err Mean	2.19593
upper 95% Mean	80.99040
lower 95% Mean	72.25666
N	85.00000
Sum Wgts	85.00000

Figure 10. Distribution of Adding Scores for Third Grade

Only Grade 1 yields a relatively normal distribution of Adding Scores. A regression model for Grade 1 using the Adding Scores as a the response variable would be statistically appropriate. The following regression equation with Adding as the response variable represents only the first grade population. This regression equation indicates that there is an increase in the Adding Score for students who are in higher Math Levels, that students designated as Special Education students have a lower total Adding Score, and being a member of higher Economic Levels results in lower Adding Scores.

First Grade Regression Model with Response:

Adding

$$-7.8315458+.445431108 \cdot IQ+\left(\begin{cases} 21.6441222, & \text{if } Math\ L=2 \\ 11.7800294, & \text{if } Math\ L=1 \\ 0, & \text{if } Math\ L=0 \\ \bullet, & \text{otherwise} \end{cases}\right)$$

$$+\left(\begin{cases} -9.3601647, & \text{if } Econ\ L=2 \\ -7.1190509, & \text{if } Econ\ L=1 \\ 0, & \text{if } Econ\ L=0 \\ \bullet, & \text{otherwise} \end{cases}\right)+\left(\begin{cases} -6.4197727, & \text{if } Spec\ Ed=1 \\ 6.41977273, & \text{if } Spec\ Ed=0 \\ \bullet, & \text{otherwise} \end{cases}\right)$$

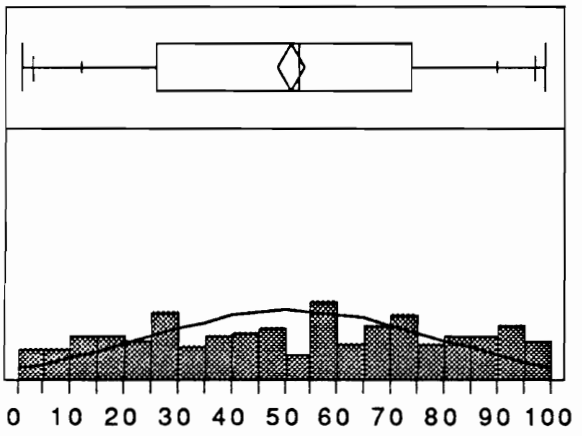
$$=Adding$$

Normal Quantile Percentile as Response Variable

A basic assumption for the purpose of conducting tests of significance using multiple regression models is that the errors are normally distributed (Pedhazur, 1983, p. 34). It is assumed that the predictor variables (x's) are fixed and measured without error. The response variable (Y) is assumed to be composed of two components: a fixed component and a random error (Pehazur, p. 33). Because percentile scores are "ordinal not interval measures,...we do not have equal intervals between percentile points. An increase of a given number of percentile points corresponds to a different number of raw score points depending upon where we are in the distribution" (Gay, 1980, p. 406). "In order to achieve comparability of scores from dissimilarly shaped distributions, nonlinear transformations may be employed to fit the scores to any type of distribution curve" (Anastasi, 1968, p. 55).

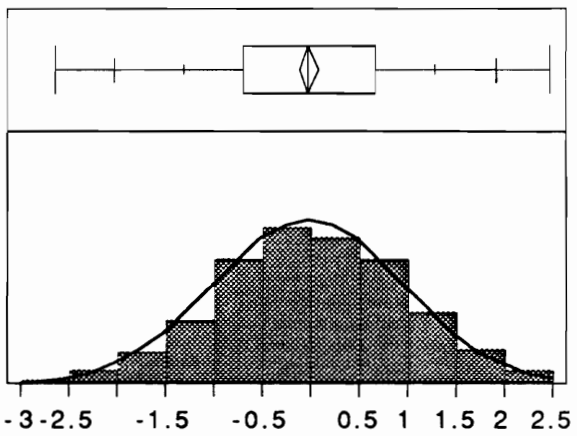
Before exploring the data to examine what effect the students' Imagery Score and other variables obtained from the student population may have on

their Iowa Test of Basic Skills total Math Percentile score, it is necessary to "un-transform" the total Math percentile scores. "A transformation is any systematic alteration in a set of scores whereby certain characteristics of the set are changed and other characteristics remain unchanged. Three reasons for performing transformations are: (1) to achieve homogeneity of error variance, (2) to achieve normality of error effects and (3) to obtain additivity of effects (Kirk, 1982, p. 79). To alleviate the problems of the lack of normality of the distribution of percentile scores and to obtain additivity of effects, the percentile scores were transformed into Normal Quantile Scores. The transformation to Normal Quantile Scores is an effort to achieve a response variable that is more like the original raw score for each student. The raw scores should have an approximately normal distribution. The Normal Quantile Scores represent a standardized version of an approximation to the raw scores and have an approximately standard normal distribution.



Mean	51.2581
Std Dev	27.8652
Std Err Mean	1.2922
upper 95% Mean	53.7974
lower 95% Mean	48.7187
N	465.0000
Sum Wgts	465.0000

Figure 11. Distribution of Math Normal Percentile Scores for the Total School Population



Mean	-0.0002
Std Dev	0.9867
Std Err Mean	0.0458
upper 95% Mean	0.0897
lower 95% Mean	-0.0902
N	465.0000
Sum Wgts	465.0000

Figure 12. Distribution of Quantile Percentile Scores for the Total School Population

Figures 11 and 12 graphically illustrate the impact of the transformation from percentile score to Normal Quantile percentile scores for the school population. The same process was done for each of the groups that were examined. All transformations yielded an approximately normal distribution for the populations (see Appendix D, pages 207-215).

Nine regression models were done to explore the variables that had the most effect on the variations in the Normal Quantile percentile scores. The following chart provides a summary of the models of best fit for each of the different divisions of the school population.

Table 3

Nine Regression Models with Normal Quantile Percentile as Response Variable

	School	Gr.1-3	Gr 4-6	Gr 1	Gr 2	Gr 3	Gr 4	Gr 5	Gr 6
R square	.59	.64	.53	.94	.55	.76	.46	.60	.70
DF	11,383	8,184	7,190	3,45	5,70	9,63	6,54	6,78	5,48
F Ratio	50.37	41.04	31.16	246.73	17.34	22.54	7.78	19.33	22.52
MSe	.4149	.3691	.4448	.0514	.44918	.26856	.57050	.36720	.27645
Prob > F	.00	.00	.00	.00	.00	.00	.00	.00	.00
Variables:	**with corresponding Probabilities of F**								
Gender	.01	.05	.04	•	•	.00	.00	•	•
IQ	.00	.00	.00	.00	.00	.00	.01	.00	.00
Math L.	.00	.00	.00	•	.02	.01	.00	.00	.00
Econ L.	•	•	•	•	•	.13	•	•	•
Grade	.00	•	.00	•	•	•	•	•	•
Age	•	.09	•	.00	.06	.07	•	•	•
Hand	.05	.04	•	•	•	.06	.15	.11	•
Spec Ed	•	•	•	•	•	•	•	.03	•
Adding	.00	.01	.11	.01	•	.02	•	•	.08
Accuracy	•	•	•	•	.01	•	•	•	.11
Imagery	•	.02	•	•	•	•	.14	.06	•

After using the step-down method in each of the regression equations, Imagery Scores remained as a variable in three of the regression models. Only in Grades 1-3 was the effect of the Imagery Scores significant at the .05 level. It is not surprising that IQ was significant in each model and Math Level was significant in eight of the nine models. The students' Handedness and Adding Scores also accounted for the variability in the Normal Quantile percentile scores in a number of the regression models. In each model where Handedness was found to have an effect, the effect for right-handed students was positive. The effect of Adding was positive in all regression models (see Appendix D, pages 180-201).

Chapter 4

DISCUSSION

Previous studies that deal with imagery have examined primarily children's use of imagery in relation to a specific cognitive process such as reading comprehension, (Sadoski, 1983) word recall (Paivio & Okovita, 1971), or recall of details of pictures that were presented to the subjects (Galton, cited in Wingfield, 1979; White et al., 1977). In each of these studies, imagery was examined as a process linked to the immediate recall of specific stimuli that were presented to the subjects. This researcher attempted to explore the naturally occurring structure of children's internalized representation of specific numbers without the use of imposed structure from outside stimuli. This naturally occurring structure of children's internalized representations of number has been referred to in various theories of learning. Richardson (1980) stated that the mental images were symbolic representations that were maintained over time in long term memory and could be manipulated in various ways. Wingfield (1979) stated that visual (iconic) memory operated in the mind much the same as mediators to offer concrete anchors for learning materials. Bruner (1988) proposed that iconic imagery built upon perceptual organization that was tied to the 'point-at-able' spatioqualitative properties or events.

The children in this study were encouraged to imagine specific numbers of dots, but they were given no instruction or guidance as to how to think about the dots. They were free to think of the specific number of dots in their own way. Piaget and Inhelder (1971) refer to this type of imagery as

reproductive because the children were being asked to recall events already known (number of dots). Piaget and Inhelder did not address the spatio-organizational structure of reproductive images. They did state that reproductive images promote the acquisition and consolidation of data and constitute a factor in cognitive development. They cautioned that static reproductive images might reinforce preoperational thought and delay the development of the higher level of anticipatory images which develops at the concrete operational stage of development.

An examination of the distribution of the Imagery Scores the children obtained in this study indicated that there is an age effect on the spatio-organizational structure of the images the children represented by their drawings. Older children achieved higher Imagery Scores. This result is supported by Cramer's (1981) study that indicated that there was an interaction between age and the effect of the type of reported imagery. An examination of the regression models with Imagery Score as the response variable also supports the effect of increased age on increased Imagery Scores in four of the nine regression models (See Appendix D, pp. 142-160). A variable not directly addressed by previous studies, but one that remained a variable in seven of the nine regression models for Imagery Scores, was accuracy. According to Bruner (1988) iconic imagery is built upon the perceptual organization that is tied to the 'point-at-able' spatioqualitative properties. Perhaps the students who did not accurately reproduce the correct number of dots, had not developed a numeral perceptual organizational pattern with 'point-at-able' spatioqualitative properties. This then resulted

in an internalized representation of number that was not only disorganized (according the the Imagery Scale) but was also inaccurate in cardinality.

Fewer than five students in this study stated that they were unable to image a specific number of dots. The students who made these statements referred to only one of the ten numerals they were asked to image. For the remaining nine numerals, the students did not state they had any difficulty. The numerals that the students stated they were unable to image varied by student. The ability of students to image is supported by Sheehan (1967) who found that few students lacked the ability to evoke images when required (p. 16). The variables of Gender and Handedness were also found to have an effect on the Imagery Scores. Females scored higher than males and in the lower grades left-handed students tended to have higher scores than right handed students. On tests of spatial ability, Lewis and Harris (1990) reported that for high academic achievers right-handed men performed better than left-handed men and left-handed women performed better than right-handed women.

Although previous studies by Pressley, et al.(1987) found that imagery instruction was more effective with children who were more intellectually competent, there was no effect found for IQ when the Imagery Scores were the response variable of a multiple regression analysis. The study by Pressley et al. addressed children who were in the "imagery condition" as it related to learning as opposed to children who were in the control group who received no imagery instructions. Pressley et al (1987) demonstrated that children can use imagery to improve their learning. In this exploratory study all children were asked to image with no "correct response" being sought. The children

in this study were asked to reproduce images that they already knew, which according to Piaget and Inhelder (1971) is at the lowest level of imagery development. If the students had been asked to create anticipatory images which would represent events that were not previously perceived or to do operations on the images they perceived, IQ may have had an important effect on the anticipatory images due to the more complex thinking processes involved in the creation of anticipatory images.

Exploration into the effect of imagery on the students' mathematics achievement scores was done. The Math percentile data was obtained from the scores the students achieved on the Iowa Test of Basic Skills. The multiple regression analyses of the different school populations revealed that IQ had a significant positive effect for the Math percentile scores. In the Primary Grades 1-3, the variables that effected the variation in the Math percentile score were IQ, Gender, Math Level, Handedness, Adding Score and Imagery Score. For the student population in Grades 1-3 the higher Math percentile scores were explained by the multiple regression model as more likely being achieved by students with higher IQs, working in higher math levels, receiving higher scores on the Adding Test and Imagery Scores and were students who were right-handed and male. The regression model for the fifth-grade students revealed that those students who scored higher on the Imagery Scores scored lower on their Math percentile scores. Although at first this may sound intuitively inconsistent, according to Piaget and Inhelder (1971) reproductive images that keep close to the perceptions of which they are active copies provide nothing more than perceptual data and are unable to represent the results of movements or transformations (p. 358). The fifth-

grade students who scored highest on the Imagery Scores may have developed static images of their internalized representations of numbers and be less able to use anticipatory images for mathematical operations (p. 378).

Summary

The results of this study of children's unmanipulated internalized constructs of number provided some interesting results. When children are asked to image specific numbers of dots and then draw a representation of their images, the representations can be categorized according to their spatio-organizational patterns. These patterns have a tendency to develop more structure as children get older. The correctness of the cardinality of the number of dots imaged was the most frequently occurring variable that had a significant effect on the Imagery Scores. Fewer than five of more than 450 students expressed any difficulty with the imagery task and then only as it related to random numerals of the ten numerals they were asked to image.

The students were asked to image at the foundational level of imagery--reproductive imagery (Piaget & Inhelder, 1971). Because the task developed for the students did not involve anticipatory images, those requiring transformations or movement, this imaging task did not show effects of the children's IQ or mathematics achievement or math group level. According the Piaget and Inhelder, children's ability to use anticipatory images indicates that children are developing an operational understanding and use of imagery. The children in this study were not asked to do anticipatory imaging. This may account for the negative results of the higher Imagery Scores as a factor in the fifth-grade students' math percentile scores. The

imagery task requested of the students was not of sufficient difficulty, to relate to any mathematical operations or logio-mathematical thinking.

Educational Implications and Suggestions for Future Research

The ability of children to produce reproductive images which have varying degrees of spatio-organizational patterns was demonstrated by this study. Teachers who use imagery as a method of instruction when teaching numbers, should encourage students to image numerals in a variety of ways. Because no "best" spatio-organizational pattern was identified in this study, teachers should be extremely cautious about presenting a "best" spatio-organizational pattern to children. This study has shown that children naturally use many different spatio-organizational patterns when imaging numerals. Although the Curriculum and Evaluation Standards for School Mathematics (1989), do not specifically address imagery as an instructional strategy for developing number concepts, the standards do present the importance of "intuition" in developing number meaning. "Intuition about number relationships helps children make judgments about the reasonableness of computational results and of proposed solutions" (p. 38). It appears that the "intuition" mentioned in the standards, could be addressed as a process similar to the anticipatory images (images that represent movements or transformations that aid in the development of an operational understanding in mathematics) proposed by Piaget and Inhelder (1971). The standards encourage further development of children's understanding of number through the use of patterns. "Relating patterns in numbers, geometry and measurement helps them understand connections among mathematical topics" (p. 60). The standards encourage children to

explore a variety of patterns and to "focus on regularities in events, shapes, designs, and sets of numbers" (p. 60).

Caution is strongly urged in the implementation of the standards in relation to helping children develop number concepts. Teachers should be urged to allow children to construct their own patterns and not be encouraged to develop a "right" pattern for numbers. As demonstrated by this research, reproductive images that become static may interfere with children's development of more abstract mathematical concepts

Future studies need to address the higher level of anticipatory images. If students are asked to image specific number of dots and then to image adding another quantity of dots to the original image, do the spatio-organizational patterns used by children in this transformation process change or transform the image? Are there specific spatio-organizational patterns that more easily allow children to develop anticipatory images that use mathematical operations? Are there children who have developed static reproductive images, and as a result, have created internalized constructs that inhibit their future understanding and development of higher level mathematical concepts? The answers to these and other questions about the connections between imagery and the development of mathematical understanding await future research.

References

Allen, B. E. (1972). Influence of Imagery on Semantic-Memory Abilities. [Summary]. Proceedings of the 80th Annual Convention of the American Psychological Association, 7,477-478.

Anastasi, A. (1968). Psychological Testing (3rd ed). Macmillan: London.

Bugelski, B. R. (1982). Learning and Imagery. Journal of Mental Imagery, 6, 1-92.

Bourne, L, Dominowski, R. L., Loftus, E. F. & Healy, A. F. (1986). Cognitive Processes (2nd ed.). Englewood Cliffs, New Jersey: Prentice-Hall.

Bruner, J. S. (1988). The Course of Cognitive Growth. In K. Richardson & S. Sheldon (Eds.), Cognitive Development to Adolescence (pp. 34-60). East Sussex, United Kingdom.: Lawrence Erlbaum Associates Ltd.

Bryden, M. P. & Ley, R. G. (1983). Right Hemishperic Involvement in Imagery and Affect. In E. Perecman (Ed.) Cognitive Processing in the Right Hemishpere (pp. 111-123). New York: Academic Press.

Cramer, P. (1981). Imagery and Learning: Item Recognition and Associative Recall. Journal of Educational Psychology, 73 (2), 164-173.

DeLoache, J. S. & Todd, C. M. (1988). Young Children's Use of Spatial Categorization as a Mnemonic Strategy. Journal of Experimental Child Psychology, 46, 1-20.

Finke, R. A. (1989). Principles of Mental Imagery. London: MIT Press.

Fuson, K. C. (1988). Children's Counting and Concepts of Number. New York: Springer-Verlag.

Gay, L. R. (1980). Educational Evaluation & Measurement Competencies for Analysis and Application. Columbus, Ohio: Charles E. Merrill.

Howell, D. C. (1987). Statistical Methods for Psychology (2nd ed.). Boston: PWS Publishers.

Hughes, M. (1988). What is Difficult About Learning Arithmetic? In K. Richardson & S. Sheldon (Eds.), Cognitive Development to Adolescence (pp. 279-296). East Sussex, U. K.: Lawrence Erlbaum Associates Ltd.

Kamii, C. K. (1985). Young Children Reinvent Arithmetic: Implications of Piaget's Theory. New York: Teachers College Press.

Kamii, C. K. (1989). Young Children Continue to Reinvent Arithmetic 2nd Grade: Implications of Piaget's Theory. New York: Teachers College Press.

Kirk, R. E. (1982). Experimental Design: Procedures for the Behavioral Sciences (2nd ed). Belmont, California: Brooks/Cole Publishing.

Lewis, R. S. & Harris, L. J. (1990). Handedness, Sex, and Spatial Ability. In S. Coren (Ed.), Left-Handedness Behavioral Implications and Anomalies (pp. 319-341). New York: Elsevier Science Publishing Company.

Matlin, M. (1983). Cognition. New York: Holt, Rinehart and Winston, Inc.

Morra, S., Moizo, C. & Scopesi, A. (1988). Working Memory (or the M Operator) and the Planning of Children's Drawings. Journal of Experimental Child Psychology, 46, 41-73.

National Council of Teachers of Mathematics, Commission on Standards for School Mathematics. Curriculum and Evaluation Standards for School Mathematics. Reston, Va.: The Council, 1989.

Paivio, A. (1986). Mental Representation: a dual coding approach. New York: Oxford University Press.

Paivio, A. & Okovita, H. (1971). Word Imagery Modalities and Associative Learning in Blind and Sighted Subjects. Journal of Verbal Learning and Verbal Behavior. 10, 506-510.

Pedhazur, E. J. (1982). Multiple Regression in Behavioral Research Explanation and Prediction (2nd ed). New York: Holt, Rinehart and Winston.

Peters, M. (1990). Phenotype in Normal Left-Handers: An Understanding of Phenotype is the Basis for Understanding Mechanism and Inheritance of Handedness. In S. Coren (Ed.), Left-Handedness Behavioral Implications and Anomalies (pp. 167-192). New York: Elsevier Science Publishing Company.

Piaget, J. (1964). The Child's Conception of Number. London: Routledge & Kegan Paul LTD.

Piaget, J. & Inhelder, B. (1971). Mental Imagery in the Child. New York: Basic Books.

Pressley, M. C., Cariglia-Bull, T., Dean, S. & Schneider, W. (1987). Short-Term Memory, Verbal Competence, and Age as Predictors of Imagery Instructional Effectiveness. Journal of Experimental Child Psychology, 43, 194-211.

Reed, S. K. (1988). Cognition Theory and Applications (2nd ed.). Pacific Grove, CA: Brooks/Cole Publishing Company.

Resnick, L. B. (1989). Developing Mathematical Knowledge. American Psychologist. 44(2), 162-169.

Richardson, J. T. E. (1980). Mental Imagery and Human Memory. New York: St. Martin's Press.

Sadoski, M. (1983). An exploratory study of the relationships between reported imagery and the comprehension and recall of a story. Reading Research Quarterly. 19, 111-123.

Salvia, J and Ysseldyke, J. E. (1988). Assessment in Special and Remedial Education (4th ed.). Boston: Houghton Mifflin Company

Sheehan, P. W. (1967). A shortened form of Bett's questionnaire upon mental imagery. Journal of Clinical Psychology. 23, 386-389.

Steffe, L. P., von Glasersfeld, E., Richards, J. & Cobb, P. (1983). Children's Counting Types: Philosophy, Theory and Application. New York: Praeger Publishers.

Souviney, R. J. (1989). Learning to Teach Mathematics. Columbus: Merrill Publishing Company.

Torgerson, W. S. (1967). Theory and Methods of Scaling. New York: John Wiley & Sons.

Travers, R. M. W. (1982). Essentials of Learning: The New Cognitive Learning for Students of Education. New York: Macmilliam Publishing Co., Inc.

White, K., Sheehan, P. W. & Ashton, R. (1977). Imagery Assessment: A survey of Self-Report Measures. Journal of Mental Imagery. 1, 145-170.

Wingfield, A. (1979). Human Learning and Memory: An Introduction. New York: Harper & Row.

Appendix A

Data Collection Forms

Directions for Data Collection

Cover Sheet for Classroom Data

CLASSROOM TEACHER'S CODE NUMBER

GRADE _____

NUMBER OF STUDENTS _____

DATE _____

Indicate Order Given

_____ **IMAGERY ACTIVITY**

_____ **ADDITION TEST**

NUMBER SEQUENCE USED

Check Sequence Used

	6, 13, 4, 7, 12, 5, 10, 9, 11, 8	
	8, 10, 9, 11, 5, 12, 7, 4, 13, 6	
	7, 9, 8, 10, 11, 6, 5, 13, 4, 12	
	5, 6, 13, 9, 4, 7, 10, 12, 11, 8	

BEGINNING TIME _____

ENDING TIME _____

TEACHER'S IDENTIFICATION NUMBER_____

Class _____ **Grade Level**_____

Child's Name	Student	D. O B.	Gender			Math Level			Econ Level			Hand		Sp. Ed.	% tile
First Name & Initial	Code	m/d/yr	M	F	IQ	L	M	H	L	M	H	L	R		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		
			1	0		0	1	2	0	1	2	0	1		

Teacher Questionnaire

Teacher (Code number)_____ Grade Level _____

How do you predict your students' pictures of different numbers of dots will look?

_____

_____

_____

_____

_____

_____

_____

Do you instruct your students to use imagery to help develop math skills?
Yes _____ No _____

Do your students use math manipulatives (counting objects) during math instruction? Yes _____
No_____

If yes, how often do your students use math manipulative?
Please check the response that best represents your use of math manipulatives:

___ One or twice a month
___ Once a week
___ Two or three days each week
___ Four or five days each week

N	a	m	e						
2	6	0	2	6	4	8	0	4	8
+4	+5	+9	+7	+2	+4	+6	+7	+2	+4
5	8	9	1	7	8	1	5	4	2
+1	+0	+7	+3	+7	+7	+9	+5	+1	+3
4	0	1	4	3	6	7	2	1	5
+5	+5	+6	+3	+0	+4	+1	+0	+2	+4
9	9	5	0	5	4	7	2	3	8
+3	+5	+8	+4	+7	+9	+3	+2	+4	+2
8	3	8	1	6	6	8	6	5	1
+3	+3	+9	+1	+0	+7	+1	+9	+3	+0
6	3	1	2	2	3	6	4	5	7
+6	+5	+4	+1	+9	+2	+3	+8	+9	+8
0	6	7	1	2	7	5	8	9	3
+2	+1	+5	+7	+6	+9	+0	+5	+2	+1
1	9	2	7	6	3	4	0	9	7
+8	+6	+5	+0	+8	+6	+0	+8	+1	+2
4	0	9	9	4	0	3	9	7	3
+6	+3	+4	+0	+7	+6	+9	+8	+6	+7
8	0	5	7	9	0	2	5	1	3
+8	+1	+2	+4	+9	+0	+8	+6	+5	+8

Directions for Data Collection

Part 1

Section A

Imaging Numbers

(The direction that are to be read to the students are in bold face type. These directions will be read as written, with further explanations given if needed. This may be especially true for the younger children. The order in which Part 1 and Part 2 will be presented will be alternated from class to class.)

Today I'm going to ask you to use your imagination to think about some numbers. I'm going to ask you to write a special number and then I am going to ask you to close your eyes and imagine that number of dots. You will then be asked to share that picture of the dots that you imagined in your mind by drawing it on a piece of paper. It is important to remember that there is no right or wrong way to imagine how the dots look in you mind. There is just your own way and that is the right way for you.

I'm now going to give you 11 pieces of paper and a black crayon. At the top of each piece of this paper, please write your name. Write you name in the same place on each piece of paper as I have written my name on this very large example. You see, (point to the poster board sample) **I have my name in the upper left-hand corner of the paper.** (Allow sufficient time for all students to write their names on each of the 11 pieces of paper).

When the students have finished writing their names, have the students face the front of the room and establish eye contact.

Now we will do one example as practice. (Each step is to be completed with the children by using the large poster board as an example).

Ready. Eyes up front and listen carefully. I would like for you to write the number 2 on one of your pieces of paper. Write the number 2 in the upper right-hand corner of the paper. I will write the number 2 on my piece of paper. (Demonstrate the correct place to write the number 2. Walk around the room to see that each child understands this part of the directions).

Now, I want each of you close your eyes and imagine (two) dots. Try to see them so clearly in your mind that you feel as though you could touch them. (Allow at least five seconds for the children to form images in their minds).

Now open your eyes and draw a picture of how you saw the dots in your imagination. Use the same piece of paper on which you have written the number 2. (Allow sufficient time for each student to complete their drawing. Walk around the room to check that each student is on task and following the directions correctly).

That was very well done. As I walked around the room, I saw some beautiful work. Your are very good listeners and good workers. I have some very large dots which we can put on my example of a piece of paper.

Let's show how different people imagine in different ways. Would someone like to come up front and place the dots on this large piece of paper in the same way you drew the dots on your paper? (Allow one child to come to the front and arrange the dots to represent their drawing). **Thank you for your help. You did a very nice job. Now let's let another person show a different way to imagine the dots.** (Allow one or two other students to show other arrangements of the dots. After each child has demonstrated their arrangements, make positive statements about each arrangement and remind the children that each way is correct. The way they imagine dots in their mind is their way).

We are now going to imagine other numbers of dots. We will do the imagining and drawing together. You must listen closely so you can hear the number to write, the number of dots to imagine and the times to start and stop. Remember, I want you to draw a picture of the way you imagine the dots. It is very important that your picture tells me what is in your imagination because that is the best way, that is the right way for you. Your drawings may not look like your neighbors, but that is alright. Your drawing is the right way for you.

Ready, let's do another number. Eyes up front.

The numbers will be presented in one of the following random orders:

6, 13, 4, 7, 12, 5, 10, 9, 11, 8

8, 10, 9, 11, 5, 12, 7, 4, 13, 6

7, 9, 8, 10, 11, 6, 5, 13, 4. 12

5, 6, 13, 9, 4, 7, 10, 12, 11, 8

The same verbal directions that were used for the example will be repeated.

Part 1

Section B

Descriptions of Four of the Students' Drawings

After the imagery drawings have been completed distribute a number 2 lead pencil and tell the students that they are going to look at each of the last four pictures they have drawn, one at a time--refer to the specific random order sequence that was used with the class. Say to the students:

Look at the drawing you made for the number ____.

On the back of that drawing writing with the pencil, tell me how you would describe your drawing to a friend. You may use either words or pictures. When you have finished look at me.

Allow enough time for most of the student to finish. (Do the next three numbers. Use the same directions).

After all the numbers have been given to the students, the drawings are complete and the written explanations are completed, ask the students to stack their drawing in a neat stack. Collect their work and the black crayon. This is the end of Part 1.

Part 2

Addition Test Directions

Thank you for the beautiful work you just did. I have one other activity I will ask you to do. The next activity is being given to you so you can show me how good you are with adding numbers. This paper is just for me. Your teacher will not grade the paper. I will give you five minutes to work on this paper. You will probably not have enough time to finish all the problems. I am interested in learning how many you can correctly complete in five minutes. It is not necessary that you do all the problems. I just want you to do as many as you can. Let me see your very best adding. I am going to give each of you two pieces of paper and a pencil. I will tell you when to begin. Do NOT begin before I say begin and remember to put your pencil down when I say stop.

Distribute the papers (face down) and pencils. Then say:

Write your first name and the first initial of your last name in the blank at the top of the page.

Put you pencil down and look at me when you have finished writing your name.

When all students have finished writing their name and are looking at me say:

You will have five minutes to answer these problems.

Work as fast as you can and answer only the facts you know. Skip the problems you do not know immediately and come back to those if there is enough time. You are not expected to answer all these problems in five minutes. Just work as fast as you can.

Remember to do both pages of problems.

When I tell you to stop, put you pencil down and look at me.

Ready. Begin.

After 5 minutes say:

Stop. Put your pencils down and look at me.

Collect the addition tests and pencils.

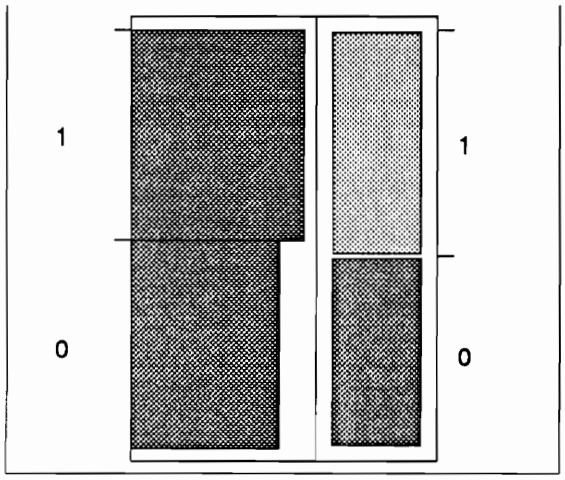
Secure the class work with a rubber band.

After the students have completed the work remember to say a special thank you to the class.

Appendix B

Distribution of Variables

Gender



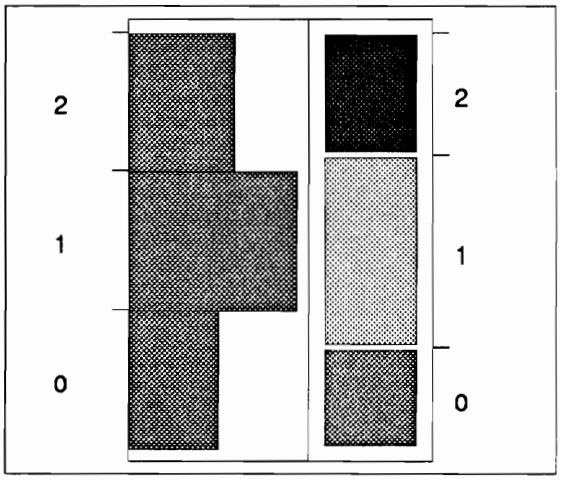
Summary

Number of Levels	2
Total Frequency	478
Total LogLikelihood	329.96741

Profile

Level	Count	Prob.	Cum Prob
0	221	0.46234	0.46234
1	257	0.53766	1.00000

Math Level



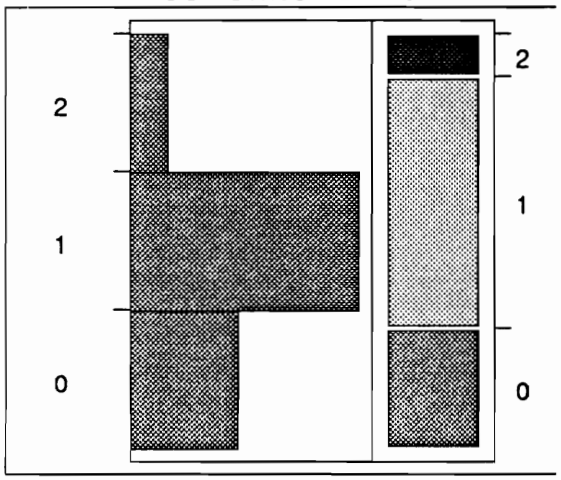
Summary

Number of Levels	3
Total Frequency	475
Total LogLikelihood	504.30159

Profile

Level	Count	Prob.	Cum Prob
0	117	0.24632	0.24632
1	219	0.46105	0.70737
2	139	0.29263	1.00000

Economic Level



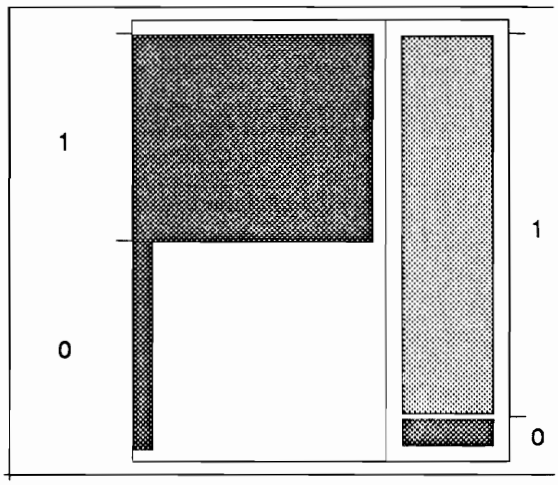
Summary

Number of Levels	3
Total Frequency	477
Total LogLikelihood	425.18963

Profile

Level	Count	Prob.	Cum Prob
0	138	0.28931	0.28931
1	291	0.61006	0.89937
2	48	0.10063	1.00000

Handedness

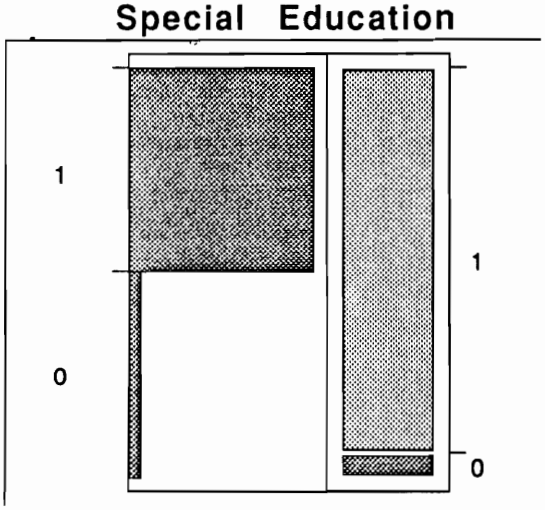


Summary

Number of Levels	2
Total Frequency	474
Total LogLikelihood	132.33197

Profile

Level	Count	Prob	Cum Prob
0	38	0.08017	0.08017
1	436	0.91983	1.00000



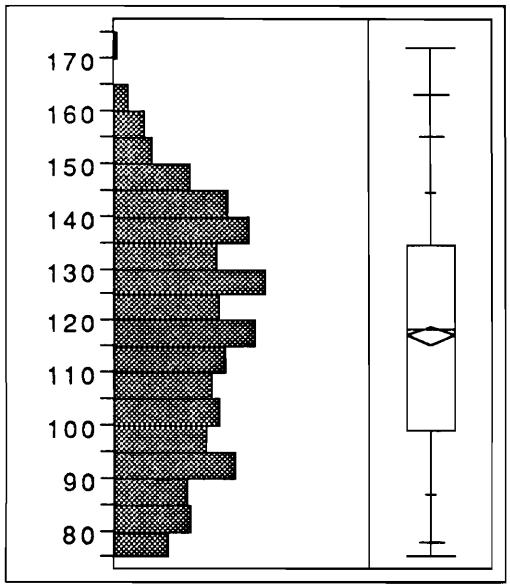
Summary

Number of Levels	2
Total Frequency	478
Total LogLikelihood	112.09064

Profile

Level	Count	Prob	Cum Prob
0	30	0.06276	0.06276
1	448	0.93724	1.00000

Age



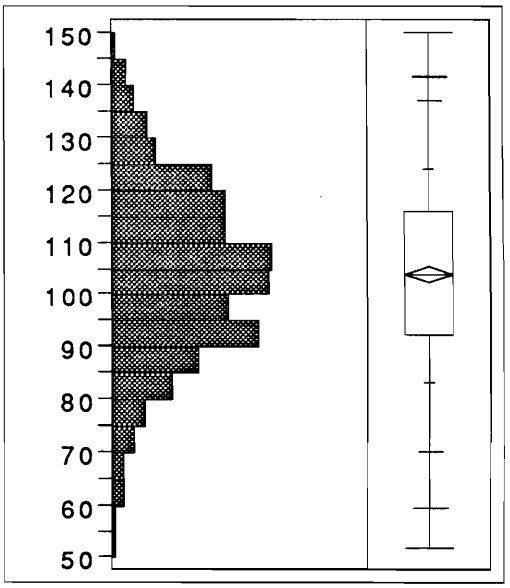
Quantiles

maximum	100.0%	172.00
	99.5%	163.00
	97.5%	155.00
	90.0%	144.20
quartile	75.0%	134.50
median	50.0%	118.00
quartile	25.0%	99.00
	10.0%	87.00
	2.5%	78.00
	0.5%	75.00
minimum	0.0%	75.00

Moments

Mean	116.9287
Std Dev	21.5511
Std Err Mean	0.9868
upper 95% Mean	118.8677
lower 95% Mean	114.9898
N	477.0000

IQ



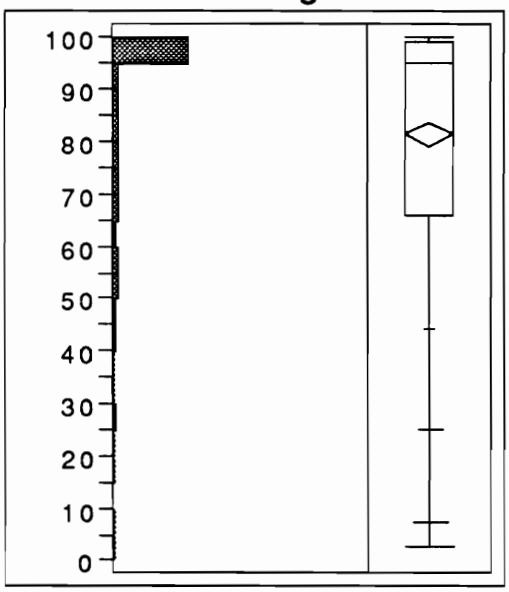
Quantiles

maximum	100.0%	150.00
	99.5%	141.78
	97.5%	136.90
	90.0%	124.00
quartile	75.0%	116.00
median	50.0%	104.00
quartile	25.0%	92.00
	10.0%	83.00
	2.5%	70.10
	0.5%	59.22
minimum	0.0%	52.00

Moments

Mean	103.8375
Std Dev	16.4881
Std Err Mean	0.7834
upper 95% Mean	105.3771
lower 95% Mean	102.2979
N	443.0000

Adding



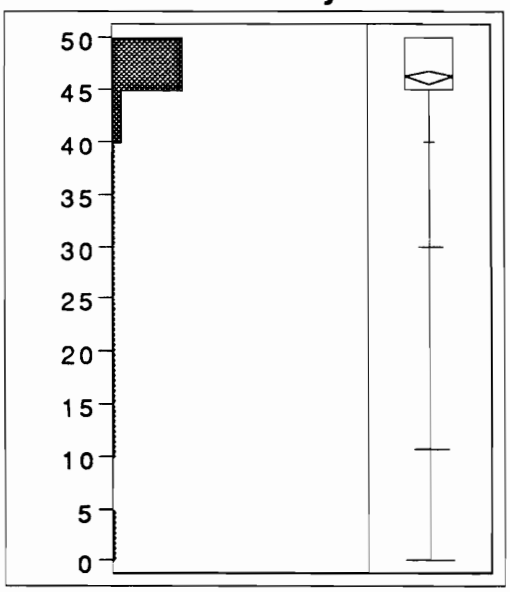
Quantiles

maximum	100.0%	100.00
	99.5%	100.00
	97.5%	100.00
	90.0%	100.00
quartile	75.0%	99.00
median	50.0%	95.00
quartile	25.0%	65.75
	10.0%	44.10
	2.5%	24.78
	0.5%	7.31
minimum	0.0%	3.00

Moments

Mean	81.4140
Std Dev	23.4612
Std Err Mean	1.1314
upper 95% Mean	83.6378
lower 95% Mean	79.1901
N	430.0000

Accuracy



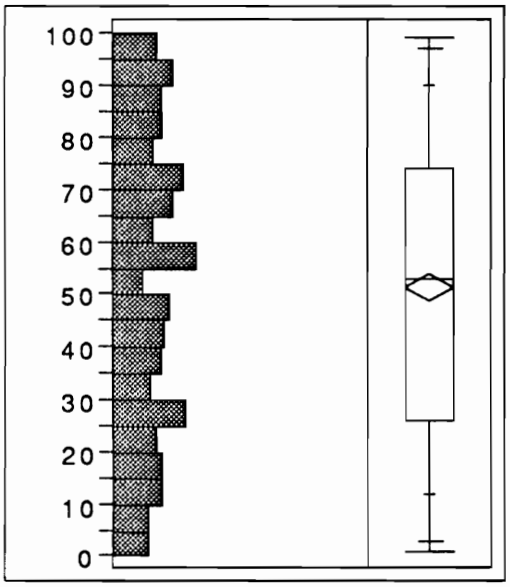
Quantiles

maximum	100.0%	50.000
	99.5%	50.000
	97.5%	50.000
	90.0%	50.000
quartile	75.0%	50.000
median	50.0%	50.000
quartile	25.0%	45.000
	10.0%	40.000
	2.5%	30.000
	0.5%	10.825
minimum	0.0%	0.000

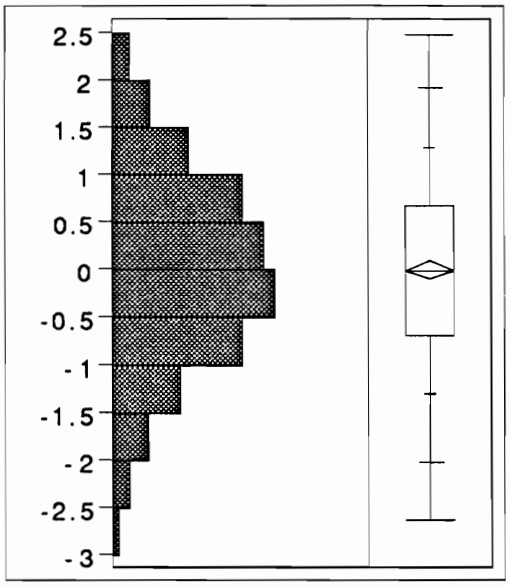
Moments

Mean	46.2731
Std Dev	6.1591
Std Err Mean	0.2963
upper 95% Mean	46.8556
lower 95% Mean	45.6907
N	432.0000

Math Percentile



N-Quantile %tile



Quantiles

maximum	100.0%	99.000
	99.5%	99.000
	97.5%	97.000
	90.0%	90.000
quartile	75.0%	74.000
median	50.0%	53.000
quartile	25.0%	26.000
	10.0%	12.000
	2.5%	3.000
	0.5%	1.000
minimum	0.0%	1.000

Quantiles

maximum	100.0%	2.4872
	99.5%	2.4872
	97.5%	1.9297
	90.0%	1.3014
quartile	75.0%	0.6779
median	50.0%	-0.0027
quartile	25.0%	-0.6881
	10.0%	-1.3014
	2.5%	-2.0245
	0.5%	-2.6282
minimum	0.0%	-2.6282

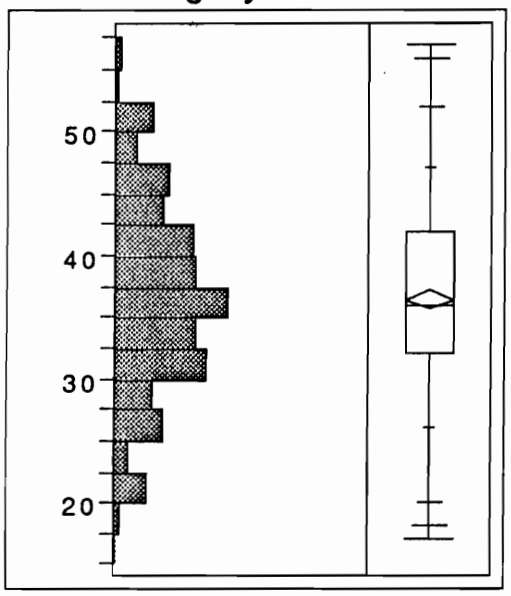
Moments

Mean	51.2581
Std Dev	27.8652
Std Err Mean	1.2922
upper 95% Mean	53.7974
lower 95% Mean	48.7187
N	465.0000

Moments

Mean	-0.0002
Std Dev	0.9867
Std Err Mean	0.0458
upper 95% Mean	0.0897
lower 95% Mean	-0.0902
N	465.0000

Imagery Score



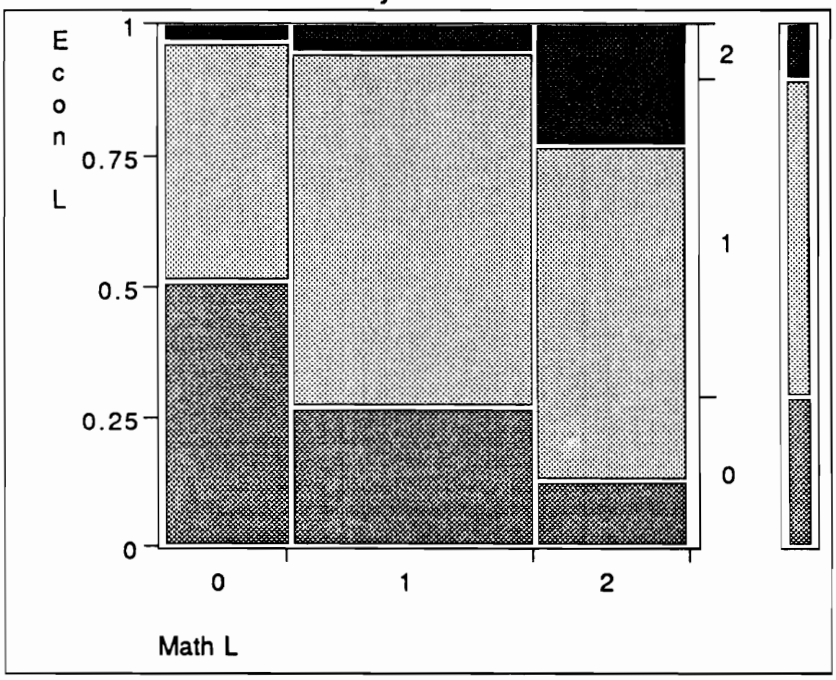
Quantiles

maximum	100.0%	57.000
	99.5%	55.860
	97.5%	52.000
	90.0%	47.000
quartile	75.0%	42.000
median	50.0%	36.000
quartile	25.0%	32.000
	10.0%	26.000
	2.5%	20.000
	0.5%	18.140
minimum	0.0%	17.000

Moments

Mean	36.3934
Std Dev	7.9085
Std Err Mean	0.3827
upper 95% Mean	37.1457
lower 95% Mean	35.6412
N	427.0000

Math Level by Economic Level



Summary of Fit

Rsquare (U)	.0807934
Observations (or Sum Wgts)	475

Analysis of LogLikelihood

Source	DF	-LogLikelihood
Model	4	34.21230
Error	472	389.24173
C Total	476	423.45403

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	68.425	0.0000
Pearson	72.121	0.0000

Response Counts

Econ L	0	1	2	Total
0	60	59	18	137
1	53	148	89	290
2	4	12	32	48
	117	219	139	475

Response Profiles

Econ L	0	1	2
0	0.5128	0.2694	0.1295
1	0.4530	0.6758	0.6403
2	0.0342	0.0548	0.2302
	117	219	139

Appendix C

Imagery Scores

Imagery Scores for each Numeral and Imagery Score Total for Grades 1-6

Grade	No.4	No. 5	No.6	No.7	No.8	No.9	No.10	No.11	No.12	No.13	Imagey Sc.
1	6	6	6	5	5	1	5	1	5	6	46
1	3	3	3	3	3	3	3	3	3	3	30
1	5	5	3	5	6	5	5	5	1	5	45
1	4	3	3	4	4	5	4	2	3	2	34
1	3	3	3	5	1	4	1	1	1	3	25
1	•	•	•	•	•	•	•	•	•	•	•
1	5	6	3	5	1	6	5	5	5	4	45
1	3	3	3	3	6	3	3	6	3	3	36
1	•	•	•	•	•	•	•	•	•	•	•
1	3	3	3	3	3	3	3	3	3	3	30
1	3	3	3	3	3	3	3	3	3	3	30
1	2	6	6	2	6	6	5	5	2	2	42
1	5	5	5	5	5	3	3	3	1	3	38
1	2	5	4	2	5	1	5	4	6	4	38
1	3	3	3	3	3	3	3	3	3	3	30
1	5	5	5	6	2	1	5	1	1	1	32
1	5	6	5	5	6	6	6	3	2	2	46
1	3	3	3	3	3	3	3	3	3	3	30
1	3	3	0	3	3	3	3	3	3	3	27
1	3	3	3	5	3	3	5	3	6	3	37
1	2	2	2	2	2	2	2	2	2	2	20
1	2	6	2	4	6	2	1	2	2	2	29
1	2	6	3	2	5	6	5	5	6	2	42
1	•	•	•	•	•	•	•	•	•	•	•
1	•	•	•	•	•	•	•	•	•	•	•
1	6	6	5	6	2	3	3	1	1	3	36
1	6	5	6	2	2	4	2	4	4	4	39
1	6	4	4	4	3	1	3	6	2	4	37
1	•	•	•	•	•	•	•	•	•	•	•
1	5	5	5	2	2	6	1	1	4	4	35
1	3	4	4	6	1	2	4	5	1	4	34
1	5	6	6	5	5	6	5	5	3	1	47
1	3	3	5	4	3	4	3	4	4	4	37
1	5	5	5	4	3	2	2	4	2	4	36
1	4	5	1	4	2	4	1	1	3	2	27
1	4	5	1	4	2	4	1	1	3	2	27
1	3	2	1	1	3	3	1	2	2	2	20
1	6	5	5	3	4	6	3	1	3	5	41
1	5	5	4	2	4	5	6	1	1	1	34
1	•	•	•	•	•	•	•	•	•	•	•
1	•	•	•	•	•	•	•	•	•	•	•
1	2	6	5	1	2	2	1	1	2	1	23
1	3	5	5	2	4	4	2	2	2	4	33
1	5	5	4	5	4	1	1	1	1	1	28
1	•	•	•	•	•	•	•	•	•	•	•
1	6	5	5	5	5	4	4	4	1	1	40
1	3	1	6	3	3	3	3	3	3	3	31
1	2	5	4	4	2	4	6	5	2	4	38

Grade	No.4	No. 5	No.6	No.7	No.8	No.9	No.10	No.11	No.12	No.13	ImageySc.
1	2	3	3	5	2	3	2	2	1	2	25
1	2	2	2	2	2	2	2	2	2	2	20
1	3	5	3	3	3	3	3	3	1	5	32
1	5	5	6	5	6	3	5	3	1	1	40
1	3	2	2	5	5	5	5	4	3	5	39
1	5	2	5	5	5	5	2	3	3	1	36
1	6	5	5	6	2	5	5	2	3	5	44
1	5	6	2	3	2	3	4	4	4	4	37
1	3	6	3	6	3	5	2	4	4	3	39
1	5	5	3	6	2	5	2	2	4	5	39
1	2	2	2	1	5	2	5	6	2	5	32
1	6	5	5	2	2	5	2	4	1	2	34
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2	4	5	3	4	4	4	2	4	4	3	37
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2	2	2	2	2	2	2	2	2	2	2	20
2	3	5	4	4	1	1	1	1	4	5	29
2	4	3	3	4	2	1	5	4	4	2	32
2	2	2	2	2	2	2	2	2	2	2	20
2	2	2	2	2	5	2	2	5	2	2	26
2	5	5	3	4	3	2	2	5	6	3	38
2	5	3	2	2	5	5	2	2	2	4	32
2	3	5	2	4	3	3	2	5	5	3	35
2	2	2	2	4	2	2	2	2	2	2	22
2	5	5	3	5	4	2	2	1	5	4	36
2	5	2	3	5	4	1	2	1	2	5	30
2	5	5	4	4	2	5	5	2	2	2	36
2	6	6	6	6	3	5	3	3	5	5	48
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2	6	2	2	1	1	2	2	1	1	1	19
2	5	5	3	1	3	5	5	5	1	5	38
2	5	5	5	5	1	1	1	1	1	1	26
2	5	5	5	5	6	5	4	6	4	5	50
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2	5	3	6	6	6	5	3	3	3	5	45
2	4	4	5	2	5	2	2	4	4	2	34
2	5	5	5	5	5	5	1	2	5	1	39
2	6	2	2	4	4	4	5	1	2	2	32
2	6	2	2	4	4	4	5	1	2	2	32
2	6	6	6	1	5	6	5	5	5	5	50
2	5	4	3	2	4	5	3	4	2	4	36
2	6	5	5	5	5	6	5	1	1	1	40

Grade	No.4	No. 5	No.6	No.7	No.8	No.9	No.10	No.11	No.12	No.13	Imagey
2	6	3	4	3	4	5	5	4	3	5	42
2	2	2	2	2	2	2	2	2	2	2	20
2	3	6	1	3	3	4	3	3	3	2	31
2	5	3	4	2	1	4	4	5	5	5	38
2	6	6	6	6	4	5	5	5	5	2	50
2	6	3	3	3	2	5	1	3	4	3	33
2	2	5	6	2	2	2	2	4	6	5	36
2	5	2	5	4	5	1	5	4	5	5	41
2	5	2	2	3	2	5	6	1	2	1	29
2	2	2	2	2	2	2	2	2	2	2	20
2	3	4	6	5	6	5	6	1	6	1	43
2	5	3	2	2	2	2	2	2	2	2	24
2	3	3	3	3	3	3	5	5	5	3	36
2	2	2	2	2	2	2	2	2	2	2	20
2	5	2	5	4	5	6	6	3	5	6	47
2	2	5	1	3	4	5	1	5	1	5	32
2	2	2	2	5	2	2	3	2	3	5	28
2	5	2	2	2	2	2	2	1	2	2	22
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2	5	5	6	5	5	3	5	6	6	5	51
2	2	6	4	3	1	1	4	1	5	5	32
2	5	3	2	3	5	3	5	5	5	5	41
2	2	5	4	4	2	3	5	3	2	2	32
2	3	3	3	4	4	3	2	4	4	3	33
2	2	5	5	2	6	6	2	4	1	2	35
2	3	4	2	4	3	5	2	2	2	3	30
2	2	2	4	4	4	4	4	5	4	2	35
2	4	3	3	3	3	3	5	3	3	3	33
2	2	5	3	2	2	3	1	1	5	3	27
2	•	•	•	•	•	•	•	•	•	•	•
2	6	3	5	5	6	5	5	5	5	5	50
2	5	5	4	2	3	4	4	6	1	4	38
2	5	5	6	3	6	6	6	5	6	4	52
2	3	5	2	1	5	5	5	5	5	5	41
2	5	5	2	5	5	2	4	2	2	4	36
2	6	2	6	6	3	2	5	2	4	5	41
2	5	2	6	2	2	2	2	1	2	2	26
2	6	2	6	6	3	2	5	2	4	5	41
2	6	6	6	6	3	5	3	3	5	5	48
2	2	2	2	2	2	2	2	2	2	2	20
2	2	2	2	1	2	5	2	2	2	5	25
2	3	5	6	6	5	5	3	5	3	5	46
2	6	5	5	5	5	3	5	5	5	5	49
2	5	3	4	5	3	3	3	5	3	3	37
2	5	5	2	2	5	2	2	2	3	5	33
2	2	2	5	2	2	2	2	2	2	2	23
2	2	5	2	2	2	2	4	2	2	2	25
2	3	2	4	3	4	4	4	4	4	5	37
2	5	5	4	4	3	4	4	2	2	2	35
2	3	5	3	5	5	5	4	4	5	1	40
2	5	5	5	5	2	1	2	2	1	1	29
2	6	2	2	1	1	2	2	1	1	1	19
2	5	5	3	1	3	5	5	5	1	5	38

Grade	No.4	No. 5	No.6	No.7	No.8	No.9	No.10	No.11	No.12	No.13	Imagey Sc.
2	5	5	5	5	1	1	1	1	1	1	26
2	5	5	5	5	6	5	4	6	4	5	50
2	5	5	4	4	2	2	4	5	5	2	38
2	5	3	6	6	6	5	3	3	3	5	45
2	4	4	5	2	5	2	2	4	4	2	34
2	5	5	5	5	5	5	1	2	5	1	39
2	6	2	2	4	4	4	5	1	2	2	32
2	6	2	2	4	4	4	5	1	2	2	32
2	6	6	6	1	5	6	5	5	5	5	50
2	5	4	3	2	4	5	3	4	2	4	36
2	6	5	5	5	5	6	5	1	1	1	40
2	6	3	4	3	4	5	5	4	3	5	42
2	2	2	2	2	2	2	2	2	2	2	20
2	3	6	1	3	3	4	3	3	3	2	31
2	5	3	4	2	1	4	4	5	5	5	38
2	6	6	6	6	4	5	5	5	5	2	50
2	6	3	3	3	2	5	1	3	4	3	33
2	2	5	6	2	2	2	2	4	6	5	36
2	5	2	5	4	5	1	5	4	5	5	41
2	5	2	2	3	2	5	6	1	2	1	29
2	2	2	2	2	2	2	2	2	2	2	20
2	3	4	6	5	6	5	6	1	6	1	43
2	5	3	2	2	2	2	2	2	2	2	24
2	3	3	3	3	3	3	5	5	5	3	36
2	2	2	2	2	2	2	2	2	2	2	20
2	5	2	5	4	5	6	6	3	5	6	47
2	2	5	1	3	4	5	1	5	1	5	32
2	2	2	2	5	2	2	3	2	3	5	28
2	5	2	2	2	2	2	2	1	2	2	22
2	2	2	2	2	2	2	3	3	2	2	22
2	5	5	6	5	5	3	5	6	6	5	51
2	2	6	4	3	1	1	4	1	5	5	32
2	5	3	2	3	5	3	5	5	5	5	41
3	5	6	6	4	5	6	4	2	1	4	43
3	3	5	6	5	3	3	3	5	5	5	43
3	5	5	5	2	5	5	6	5	6	2	46
3	5	3	2	5	5	5	1	1	4	4	35
3	3	2	3	4	2	3	1	3	1	3	25
3	3	5	5	5	5	5	5	2	5	2	42
3	5	5	5	5	5	5	1	2	5	3	41
3	3	5	4	2	5	4	4	4	4	3	38
3	5	5	2	5	2	4	3	1	4	2	33
3	5	5	5	5	2	2	4	1	5	5	39
3	4	4	5	5	3	5	4	4	5	5	44
3	6	4	5	4	6	1	2	5	2	5	40
3	5	6	5	6	6	5	3	4	6	6	52
3	5	5	5	2	2	1	2	1	1	1	25
3	6	6	5	5	5	5	6	3	1	3	45
3	6	4	4	6	1	5	1	1	2	1	31
3	3	6	5	4	5	3	3	5	5	5	44
3	3	3	3	3	3	3	3	3	3	3	30
3	5	6	6	2	5	4	5	3	1	2	39
3	4	5	5	4	2	5	5	1	1	1	33

Grade	No.4	No. 5	No.6	No.7	No.8	No.9	No.10	No.11	No.12	No.13	Imagey Sc.
3	5	5	4	6	5	3	5	5	3	5	46
3	5	4	3	4	3	3	3	3	4	2	34
3	6	6	4	5	4	4	4	5	5	5	48
3	5	5	2	4	5	2	2	2	4	2	33
3	5	5	2	4	5	2	2	2	4	2	33
3	4	5	5	5	6	1	1	2	6	5	40
3	2	2	2	2	4	2	2	2	2	2	22
3	5	5	2	4	4	4	4	4	1	2	35
3	3	3	4	3	3	3	4	4	2	4	33
3	6	6	2	2	2	3	5	5	5	5	41
3	3	3	3	•	•	•	•	•	3	3	•
3	3	5	3	3	3	3	3	3	3	3	32
3	5	5	5	5	6	5	1	1	1	1	35
3	4	5	4	5	2	2	4	2	5	2	35
3	5	2	4	2	2	4	5	2	5	4	35
3	5	3	4	3	2	2	3	5	5	5	37
3	3	4	4	2	6	4	4	4	6	6	43
3	5	5	3	•	•	•	•	•	5	5	•
3	6	5	5	•	•	•	•	5	5	5	•
3	5	3	3	4	4	3	2	5	3	3	35
3	6	2	5	2	4	5	1	2	5	1	33
3	•	•	•	•	•	•	•	•	•	•	•
3	6	3	3	3	3	3	3	3	3	3	33
3	•	•	•	•	•	•	•	•	•	•	•
3	5	6	4	2	5	6	5	5	5	5	48
3	•	•	•	•	•	•	•	•	•	•	•
3	5	5	2	3	5	1	2	5	2	2	32
3	5	5	5	5	4	4	5	1	1	5	40
3	3	3	6	3	4	3	3	5	5	4	39
3	5	6	2	5	4	5	2	5	5	1	40
3	5	5	2	•	•	•	•	•	2	1	•
3	3	2	3	3	3	2	3	2	2	3	26
3	6	3	3	•	•	•	•	•	5	3	•
3	6	5	1	1	1	2	2	5	1	5	29
3	5	5	6	5	5	1	1	2	5	4	39
3	5	5	5	1	5	1	5	5	1	1	34
3	2	2	2	2	4	2	2	4	2	2	24
3	5	3	5	5	5	5	5	5	1	5	44
3	6	5	2	5	5	2	2	5	4	2	38
3	5	4	5	5	5	5	2	1	2	5	39
3	5	5	6	6	4	6	4	2	4	4	46
3	5	2	5	2	4	5	4	5	2	2	36
3	3	4	5	4	2	2	2	1	4	3	30
3	5	5	5	2	5	2	2	1	2	2	31
3	4	•	4	4	2	4	2	4	2	2	•
3	5	2	5	6	3	0	2	2	4	1	30
3	6	6	3	2	4	5	3	2	2	4	37
3	6	5	5	5	6	6	5	5	5	4	52
3	6	5	2	1	5	1	5	1	0	2	28
3	2	2	2	5	2	2	1	2	2	3	23
3	5	3	5	5	3	6	2	1	4	5	39
3	4	4	5	5	5	2	2	2	2	2	33

Grade	No.4	No. 5	No.6	No.7	No.8	No.9	No.10	No.11	No.12	No.13	ImageySc.
3	5	5	4	0	2	4	2	5	2	2	31
3	6	5	6	5	5	5	5	5	5	5	52
3	6	3	6	2	3	3	4	6	6	1	40
3	3	3	3	3	3	3	3	3	3	3	30
3	3	3	4	3	4	3	4	3	4	2	33
3	6	6	3	4	1	1	3	2	4	2	32
3	3	3	3	3	6	5	2	3	3	3	34
3	5	5	5	2	6	4	5	5	5	1	43
3	5	4	4	2	4	3	5	5	2	1	35
3	3	5	3	3	4	2	3	4	4	5	36
3	6	6	6	6	6	5	5	4	3	3	50
3	5	5	5	5	5	5	2	2	1	1	36
3	6	5	6	3	5	6	5	5	5	5	51
3	3	2	4	5	2	2	5	4	4	2	33
3	3	5	3	3	4	6	6	5	5	5	45
3	3	3	3	3	6	3	5	3	3	3	35
3	6	4	3	2	4	2	3	4	4	4	36
3	6	3	6	4	4	6	5	2	2	5	43
3	5	2	2	5	5	2	4	5	1	2	33
3	•	•	•	•	•	•	•	•	•	•	•
4	5	4	5	6	2	1	4	2	5	1	35
4	6	5	6	4	1	6	2	1	1	1	33
4	5	5	5	5	2	1	5	5	6	5	44
4	5	4	2	4	2	2	2	2	1	1	25
4	6	4	4	2	5	4	2	2	2	1	32
4	5	5	4	4	2	2	6	1	4	5	38
4	6	5	5	1	2	6	2	2	1	2	32
4	6	6	5	1	5	2	6	1	6	5	43
4	•	•	•	•	•	•	•	•	•	•	•
4	5	5	5	2	2	2	1	2	4	2	30
4	5	5	4	5	5	2	2	3	1	4	36
4	•	•	•	•	•	•	•	•	•	•	•
4	4	4	2	2	2	6	2	2	4	1	29
4	4	2	1	1	2	2	1	1	2	1	17
4	•	•	•	•	•	•	•	•	•	•	•
4	5	5	5	5	5	2	6	5	5	5	48
4	6	6	6	5	6	5	3	3	5	5	50
4	5	2	4	2	1	5	4	2	1	1	27
4	5	5	5	5	5	4	5	2	2	4	42
4	5	5	1	5	1	1	5	1	1	1	26
4	5	5	5	4	1	5	1	1	1	1	29
4	5	6	4	2	1	1	2	1	2	5	29
4	5	5	5	5	3	4	1	2	1	1	32
4	5	4	5	5	5	2	2	4	4	1	37
4	5	6	2	4	2	5	3	4	5	5	41
4	•	•	•	•	•	•	•	•	•	•	•
4	6	6	6	6	6	5	6	5	4	2	52
4	4	1	5	3	1	1	1	4	5	1	26
4	5	5	5	4	4	5	4	2	2	2	38
4	5	2	2	3	3	5	3	4	2	4	33
4	4	6	2	2	5	1	5	1	2	4	32
4	6	3	3	3	3	3	3	2	3	3	32

Grade	No.4	No. 5	No.6	No.7	No.8	No.9	No.10	No.11	No.12	No.13	ImageySc.
4	6	2	6	5	3	4	3	4	2	4	39
4	5	4	3	2	5	2	4	4	4	5	38
4	5	6	6	3	2	5	5	2	3	2	39
4	4	2	4	4	4	4	4	2	4	4	36
4	5	1	3	5	4	4	4	4	1	1	32
4	5	4	2	2	2	1	4	2	2	2	26
4	3	2	3	4	3	5	3	4	5	3	35
4	5	3	4	4	2	5	4	5	4	2	38
4	4	2	4	4	2	4	1	1	1	1	24
4	5	4	2	2	1	2	1	5	1	2	25
4	5	6	5	5	5	5	5	5	5	5	51
4	3	6	2	5	6	5	6	5	6	3	47
4	2	2	2	2	2	2	1	1	4	1	19
4	•	•	•	•	•	•	•	•	•	•	•
4	5	4	5	4	2	2	4	4	2	2	34
4	3	3	4	4	6	3	5		3	6	40
4	3	5	6	4	2	4	1	4	1	5	35
4	3	5	5	2	4	1	1	2	6	1	30
4	5	4	4	2	4	2	2	2	2	2	29
4	5	5	4	4	1	2	2	2	5	2	32
4	5	5	5	1	5	1	4	2	4	1	33
4	5	5	4	2	5	1	4	2	1	5	34
4	5	5	6	5	3	6	5	2	5	5	47
4	5	5	5	4	4	4	4	1	4	2	38
4	2	6	2	5	1	5	2	2	1	2	28
4	5	6	1	5	2	1	2	4	1	2	29
4	2	6	2	2	3	5	1	4	2	4	31
4	5	5	5	5	1	1	6	5	1	6	40
4	6	6	2	5	5	2	5	5	2	2	40
4	6	5	4	4	2	2	2	2	1	1	29
4	6	6	4	2	2	5	2	2	3	2	34
4	6	6	2	6	2	2	2	2	4	2	34
4	4	2	4	2	4	4	4	4	4	4	36
4	5	4	6	1	5	1	1	1	5	1	30
4	3	4	4	4	1	2	2	1	1	1	23
4	6	4	5	2	4	4	4	5	5	2	41
4	5	5	2	3	4	3	6	2	4	4	38
4	6	5	5	3	6	5	5	3	5	5	48
4	•	•	•	•	•	•	•	•	•	•	•
5	5	2	6	2	4	2	5	3	1	2	32
5	3	4	1	1	1	5	4	2	2	1	24
5	5	4	5	3	2	2	4	4	5	2	36
5	4	5	4	5	6	1	5	5	5	4	44
5	5	4	1	1	2	4	2	5	1	1	26
5	2	4	4	2	1	1	5	5	1	1	26
5	5	6	6	6	6	6	5	3	5	3	51
5	4	6	4	4	2	5	5	4	4	2	40
5	5	2	6	5	6	2	2	2	5	2	37
5	5	5	6	2	2	3	4	4	1	4	36
5	4	5	4	4	4	4	4	2	1	5	37
5	5	5	1	1	2	1	4	2	1	4	26
5	6	6	6	6	6	6	4	2	5	3	50

Grade	No.4	No. 5	No.6	No.7	No.8	No.9	No.10	No.11	No.12	No.13	Imagey Sc.
5	6	3	6	4	3	6	6	4	6	6	50
5	3	6	4	6	4	5	5	2	2	4	41
5	5	2	6	4	5	4	2	2	2	2	34
5	5	4	2	2	3	6	4	5	2	2	35
5	5	6	5	6	6	6	6	5	6	6	57
5	4	5	2	6	2	3	4	2	5	2	35
5	5	5	6	6	5	5	4	5	2	4	47
5	6	6	1	1	5	2	5	1	1	1	29
5	6	5	4	4	1	5	5	1	1	1	33
5	6	6	6	6	6	1	5	5	6	5	52
5	6	5	1	1	5	5	5	3	5	5	41
5	5	5	5	4	5	1	4	2	1	1	33
5	•	•	•	•	•	•	•	•	•	•	•
5	•	•	•	•	•	•	•	•	•	•	•
5	6	6	6	4	2	6	6	2	1	6	45
5	6	5	2	5	5	2	5	4	4	5	43
5	3	6	6	6	6	5	5	6	5	6	54
5	3	5	3	4	2	2	4	4	4	6	37
5	5	5	6	5	5	5	4	5	1	2	43
5	5	6	3	6	2	4	4	2	2	5	39
5	6	3	6	2	6	5	5	5	5	5	48
5	5	3	4	5	4	2	2	3	4	4	36
5	6	6	4	6	5	4	4	5	4	2	46
5	5	5	5	2	6	4	5	4	5	5	46
5	3	6	6	5	4	6	6	1	1	6	44
5	5	4	5	3	1	1	5	5	5	5	39
5	5	1	1	4	4	5	1	4	1	1	27
5	5	2	4	1	4	5	4	5	1	1	32
5	•	•	•	•	•	•	•	•	•	•	•
5	6	6	6	4	2	6	6	4	5	1	46
5	5	6	6	2	4	2	1	1	2	5	34
5	2	6	5	5	1	1	1	1	4	1	27
5	4	4	2	5	5	5	5	1	2	5	38
5	•	•	•	•	•	•	•	•	•	•	•
5	4	3	5	4	2	5	5	4	2	4	38
5	4	5	4	4	2	1	1	4	2	2	29
5	5	5	3	4	6	6	5	4	4	3	45
5	5	5	5	5	6	6	2	6	2	2	44
5	5	5	6	6	2	4	2	5	5	5	45
5	5	5	6	6	6	6	5	4	4	3	50
5	5	2	5	4	5	2	5	2	6	1	37
5	3	6	2	5	6	6	6	6	6	6	52
5	5	5	4	5	2	4	1	4	5	1	36
5	5	5	2	4	6	2	4	2	2	1	33
5	5	6	5	4	2	2	5	4	2	2	37
5	5	5	3	5	2	5	5	1	5	4	40
5	3	2	5	5	1	1	2	1	1	1	22
5	6	5	4	6	1	4	4	5	4	1	40
5	6	5	2	4	2	2	2	3	2	2	30
5	4	4	4	4	2	2	5	6	6	5	42
5	6	4	2	4	2	5	2	4	6	5	40
5	5	5	5	5	4	6	5	2	5	4	46

Grade	No.4	No. 5	No.6	No.7	No.8	No.9	No.10	No.11	No.12	No.13	Imagey Sc.
5	3	2	4	4	4	5	4	4	3	2	35
5	5	5	2	5	5	2	4	4	2	5	39
5	6	6	5	3	5	3	2	5	2	2	39
5	4	2	5	2	5	2	5	2	4	1	32
5	4	4	3	2	2	2	2	3	2	4	28
5	6	4	5	6	2	4	2	4	5	4	42
5	3	1	4	2	1	1	1	1	2	2	18
5	6	4	1	5	4	1	4	4	2	4	35
5	•	•	•	•	•	•	•	•	•	•	•
5	3	5	2	4	5	1	5	5	6	2	38
5	6	2	4	2	2	4	2	4	2	2	30
5	5	4	5	5	3	2	4	2	2	4	36
5	4	5	2	6	6	6	6	4	1	2	42
5	6	1	2	2	1	2	4	5	2	2	27
5	4	6	3	2	6	4	1	2	2	4	34
5	4	4	6	1	5	2	2	5	5	5	39
5	4	5	5	4	2	5	2	3	2	2	34
5	5	2	2	4	2	5	5	5	2	2	34
5	4	5	2	4	6	2	4	5	2	4	38
5	6	5	5	6	6	3	5	4	2	4	46
5	•	•	•	•	•	•	•	•	•	•	48
5	•	•	•	•	•	•	•	•	•	•	39
5	•	•	•	•	•	•	•	•	•	•	31
5	6	6	5	4	5	5	5	5	2	5	36
5	3	5	5	3	6	2	5	4	4	2	44
5	6	5	2	2	3	4	2	1	4	2	40
5	5	5	5	4	5	1	5	4	1	1	38
5	5	5	5	5	5	1	6	5	6	1	43
5	4	5	4	2	3	4	4	4	5	5	28
5	6	5	5	5	5	6	2	2	1	1	35
5	5	6	2	5	5	6	5	5	3	1	42
6	•	•	•	•	•	•	•	•	•	•	•
6	5	5	5	4	2	5	5	5	4	4	44
6	6	4	1	1	5	5	5	1	1	5	34
6	3	6	3	2	6	1	3	2	4	4	34
6	•	•	•	•	•	•	•	•	•	•	•
6	5	3	5	2	4	2	5	5	5	1	37
6	5	3	5	5	5	2	5	5	4	5	44
6	3	5	6	4	4	5	5	5	5	4	46
6	6	5	2	5	•	4	4	4	2	3	•
6	3	6	4	3	3	4	4	5	5	3	40
6	3	4	4	2	6	5	5	5	4	5	43
6	5	6	4	5	5	3	4	4	2	1	39
6	5	4	2	2	5	5	5	2	4	2	36
6	5	2	2	4	2	5	2	2	2	2	28
6	6	5	5	5	6	4	5	6	2	5	49
6	•	•	•	•	•	•	•	•	•	•	•
6	6	3	5	5	6	4	5	4	5	5	48
6	•	•	•	•	•	•	•	•	•	•	•
6	•	•	•	•	•	•	•	•	•	•	•
6	6	2	6	3	4	6	6	4	4	5	46
6	•	•	•	•	•	•	•	•	•	•	•

Grade	No.4	No. 5	No.6	No.7	No.8	No.9	No.10	No.11	No.12	No.13	ImageySc.
6	5	4	4	5	5	5	4	1	1	1	35
6	5	5	5	5	2	6	5	6	5	6	50
6	5	2	4	5	2	2	2	2	4	1	29
6	6	4	6	5	6	6	5	5	6	6	55
6	•	•	•	•	•	•	•	•	•	•	•
6	6	6	5	2	1	6	4	3	5	1	39
6	4	4	2	2	6	5	2	2	4	2	33
6	5	5	4	2	5	6	1	1	1	2	32
6	6	2	4	4	2	2	3	5	2	2	32
6	2	3	3	4	3	2	2	5	5	3	32
6	6	5	6	6	6	6	5	6	5	5	56
6	5	5	5	4	5	2	4	5	4	4	43
6	6	2	5	4	2	4	2	2	2	4	33
6	•	•	•	•	•	•	•	•	•	•	•
6	5	5	1	5	5	1	1	1	5	5	34
6	2	2	2	4	2	5	2	2	2	2	25
6	3	5	5	4	4	4	2	1	5	2	35
6	•	•	•	•	•	•	•	•	•	•	•
6	5	2	4	5	4	5	4	5	5	5	44
6	4	2	2	2	2	2	2	2	2	2	22
6	4	4	6	6	5	6	4	5	2	4	46
6	•	•	•	•	•	•	•	•	•	•	•
6	•	•	•	•	•	•	•	•	•	•	•
6	6	5	4	5	5	5	5	5	2	1	43
6	6	6	5	5	4	2	5	2	5	2	42
6	•	•	•	•	•	•	•	•	•	•	•
6	5	2	2	4	4	4	4	2	2	2	31
6	3	6	5	4	4	5	5	5	4	4	45
6	5	5	5	2	2	5	4	4	1	4	37
6	5	6	5	2	6	6	5	4	2	4	45
6	•	•	•	•	•	•	•	•	•	•	•
6	6	6	5	5	6	6	6	6	6	1	53
6	5	6	5	4	4	4	5	4	2	4	43
6	•	•	•	•	•	•	•	•	•	•	•
6	5	6	6	3	6	6	5	6	6	6	55
6	6	5	4	2	4	3	6	6	2	2	40
6	•	•	•	•	•	•	•	•	•	•	•
6	5	5	5	6	6	6	4	5	4	2	48
6	6	5	2	2	4	6	5	1	2	1	34
6	6	4	2	2	5	2	5	2	5	1	34
6	5	6	3	5	5	6	5	2	4	5	46
6	•	•	•	•	•	•	•	•	•	•	•
6	5	5	6	5	2	6	5	5	2	2	43
6	5	5	3	1	1	4	6	4	6	4	39
6	6	4	5	5	5	5	5	5	4	5	49
6	3	3	3	3	3	3	3	3	3	3	30
6	5	5	3	6	2	5	4	5	2	1	38
6	5	6	2	5	2	1	6	5	5	2	39
6	5	2	5	5	4	1	2	1	6	1	32
6	•	•	•	•	•	•	•	•	•	•	•
6	•	•	•	•	•	•	•	•	•	•	•
6	6	3	4	6	6	3	4	4	2	3	41

Grade	No.4	No. 5	No.6	No.7	No.8	No.9	No.10	No.11	No.12	No.13	ImageySc.
6	5	2	2	2	2	2	2	1	2	2	22
6	5	4	4	5	2	2	5	2	5	6	40
6	4	5	4	6	1	5	5	5	1	5	41
6	5	5	5	4	4	2	6	5	2	1	39
6	6	6	6	4	6	6	5	5	5	1	50
6	•	•	•	•	•	•	•	•	•	•	•
6	•	•	•	•	•	•	•	•	•	•	•

Establishing Spatio-Organizational Scale

Summary of Discussion

(This is a summary of a 96 page transcript)

April 14, 1991

Research Question:

Do the pictures that children draw representing how they internally visualize specific numbers of dots reflect different degrees of structure or organizational pattern?

If so, do these different organizational patterns change in relation to age, mathematics achievement or gender?

Defining Organization

(group discussion)

Various perceptions of characteristics of"organization" were discussed. Each person in the group described their individual perceptions. The following list provides a summary of the "most organized" pattern.

1. could see the number without counting the dots
2. pattern was asymmetrical
3. had a creative purpose
4. dots were more spread out
5. dots were not totally balanced
6. dice like
7. used grouping
8. nicely spaced

9. efficient

10. box-like structure

11. composed of shapes--circles, triangles, squares

12. lines

13. dots were in the shape of the number

14. symmetrical

15. showed association

16. nice, neat, concise visualization (domino)

17. recognizable

18. reproducible

19. generalizable

20. shared as opposed to unique

21. efficient arrangement

22. implicit grouping that child could recall

23. used sets

24. showed an effort to simplify number

25. useful

Descriptors used to describe least organized drawing:

1. scattered dots

2. clustered dots more random than those spaced further apart

3. random, scattered

4. blank pages scored as a zero

5. wrong number of dots got a zero

6. if the number of dots had to be counted, it was not an efficient organization

From the discussion of organization, the next major topic to be examined was the importance of "correctness of number" of dots and how the correctness related to organizational pattern.

Correctness of dots

1. if imaged wrong number of dots, it may be due to a recording error
2. organization and right or wrong number of dots are two different things
3. incorrect numbers should be thrown out
4. If the correctness of the number of dots is included, then the score for organization includes a compounding variable that includes the math score.

Options considered for incorrect number of dots:

1. throw out --must also throw out all the data for that child is there is only one incorrect
2. ignore the number of dots and look only at the structure
3. use hit or miss system for correctness of dots--evaluate drawing first for correctness of dots, then evaluate organization score. Incorrect numbers of dots should receive a lower organization score.
4. do a separate score for the correctness of dots

Establishing Category names

Brainstorming activity

The scale was discussed briefly and it was suggested that a 0-10 scale was too delicate and a coarser scale might be more appropriate. Before establishing a scale, the following names were mentioned as possible categories.

1. domino
2. number made of dots
3. straight line--linear, with angle not being considered
4. circle
5. triangle
6. shape
7. box, box-like
8. groups
9. columns
10. logical arrangement
11. pictures, example: half a heart
12. cross patterns--dots forming an X

13 cards

14. Letters, A, J, T and inverted T
15. intersecting lines
16. organized randomness
17. no recognizable pattern

Criteria used for establishing order of categories

1. usefulness
2. reproducibility

3. generalizablility

4. efficiency

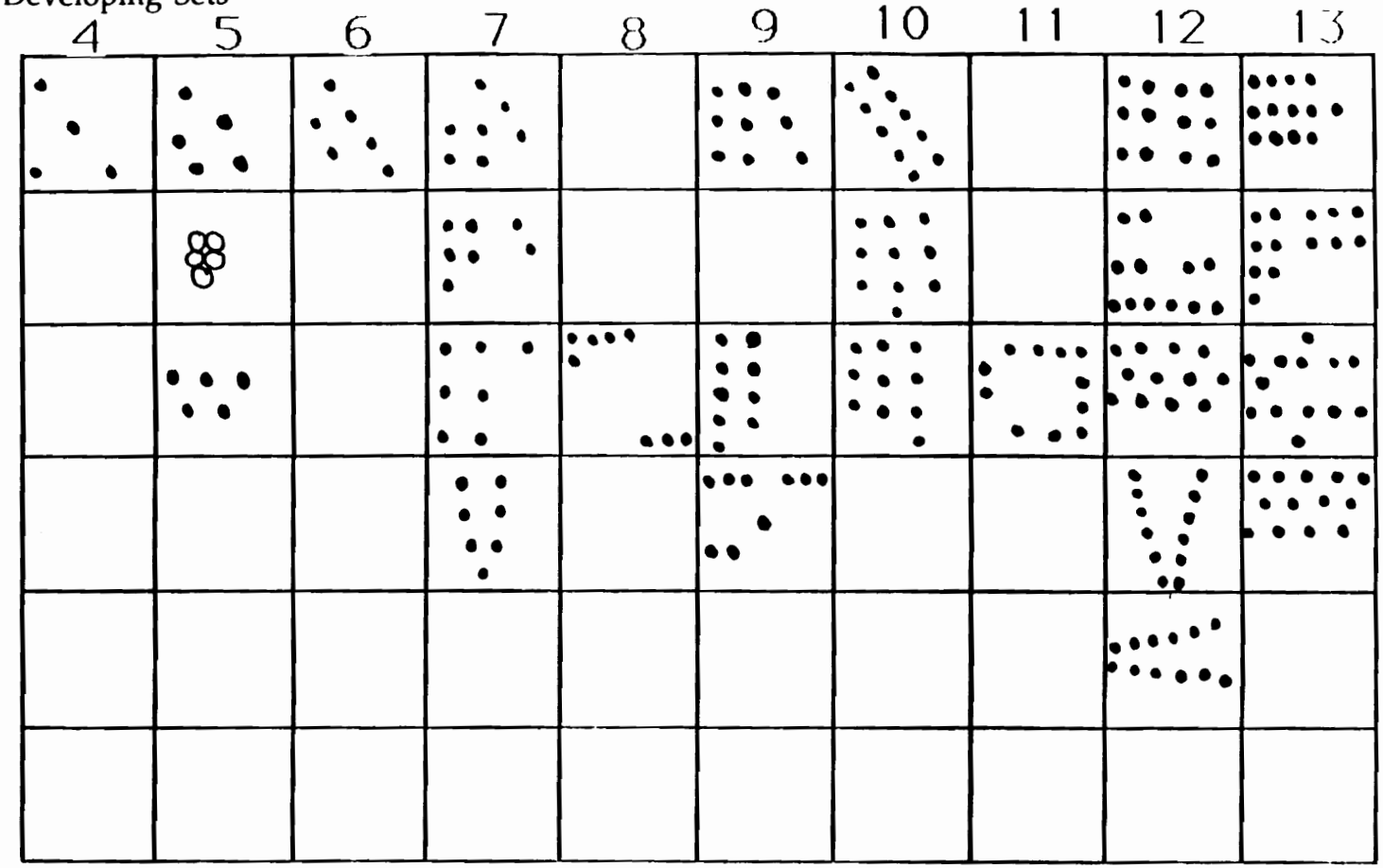
5. recognizability

6. quickness of number recognition--how many dots do you have to count before you recognize the number being represented

The following pages are examples of the categories that were developed along with the descriptors used to describe each category. Several of the categories were collapsed into other categories. These names have been listed at the top of each of the example pages.

Imagery Scale Developed by Judges

Developing Sets



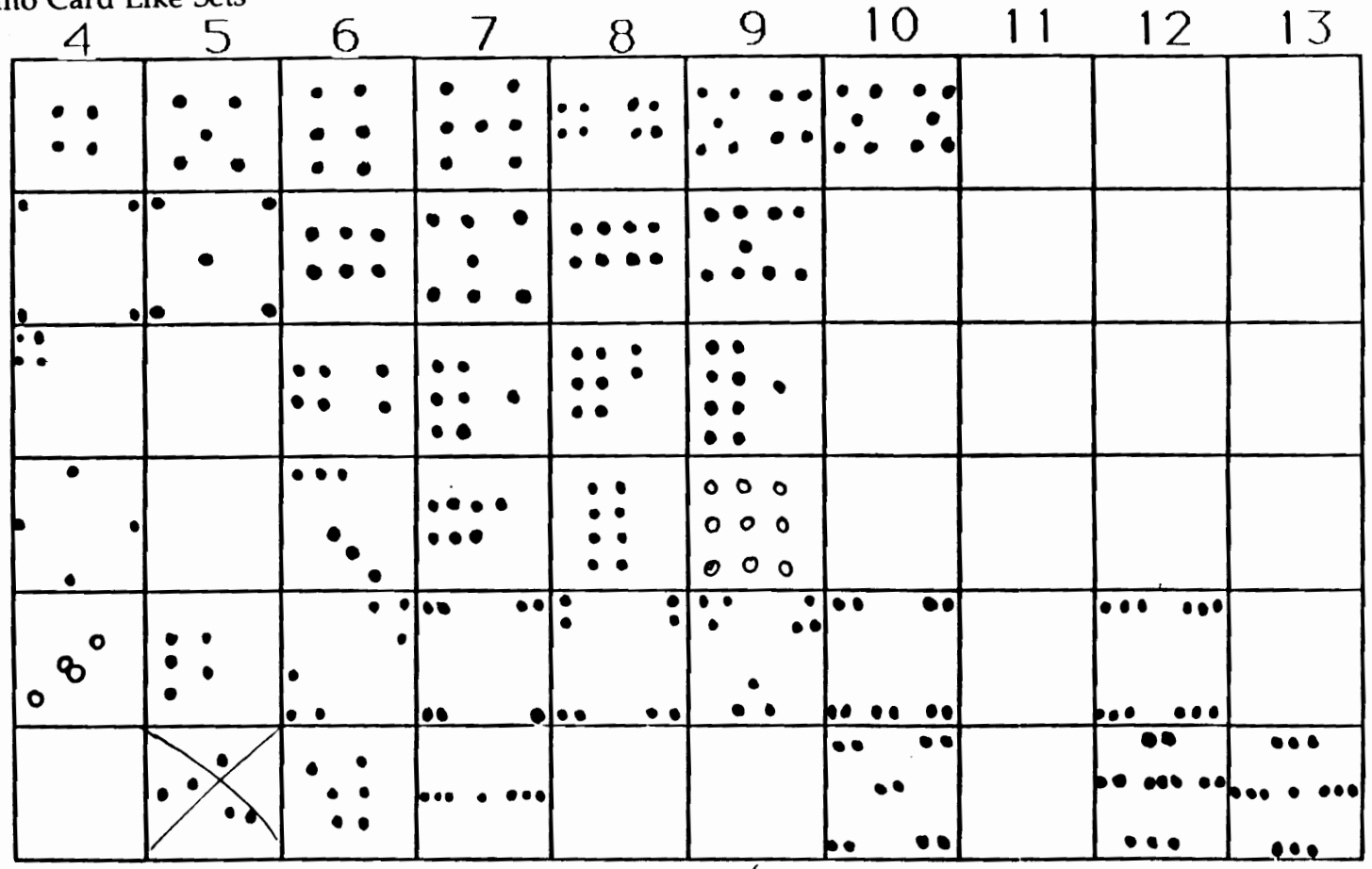
Descriptors:

Seems to have grouping
and developing sets
can't readily identify the number
not nicely patterned
pretty spread out or too compressed

5

non-traditional
parallel lines

Domino Card Like Sets

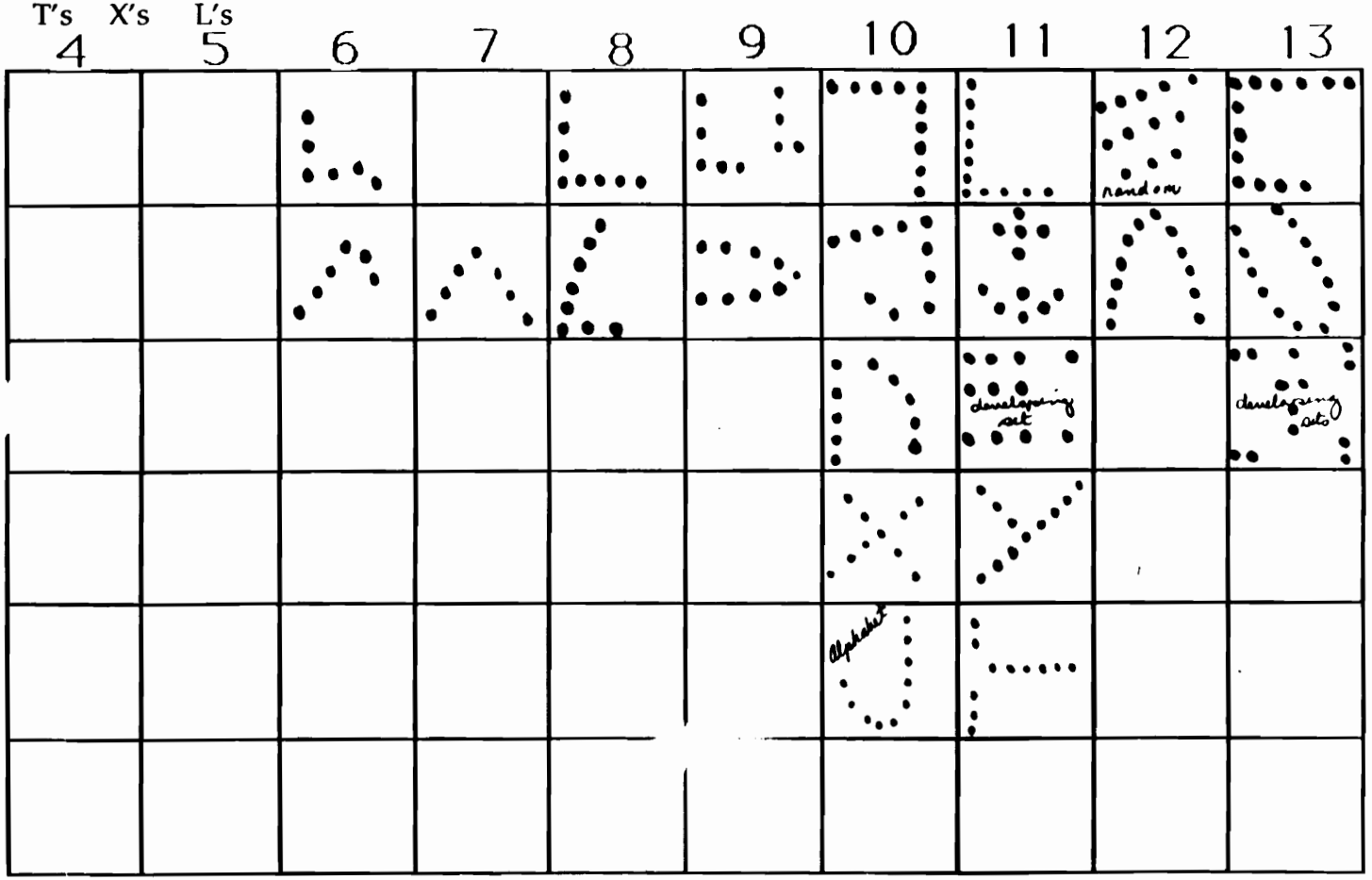


6

Descriptors:
clear organizational thinking
readily recognizable patterns
larger numbers are often grouped
clear cut sets
sets are equal or nearly equal/even

Intersecting Lines

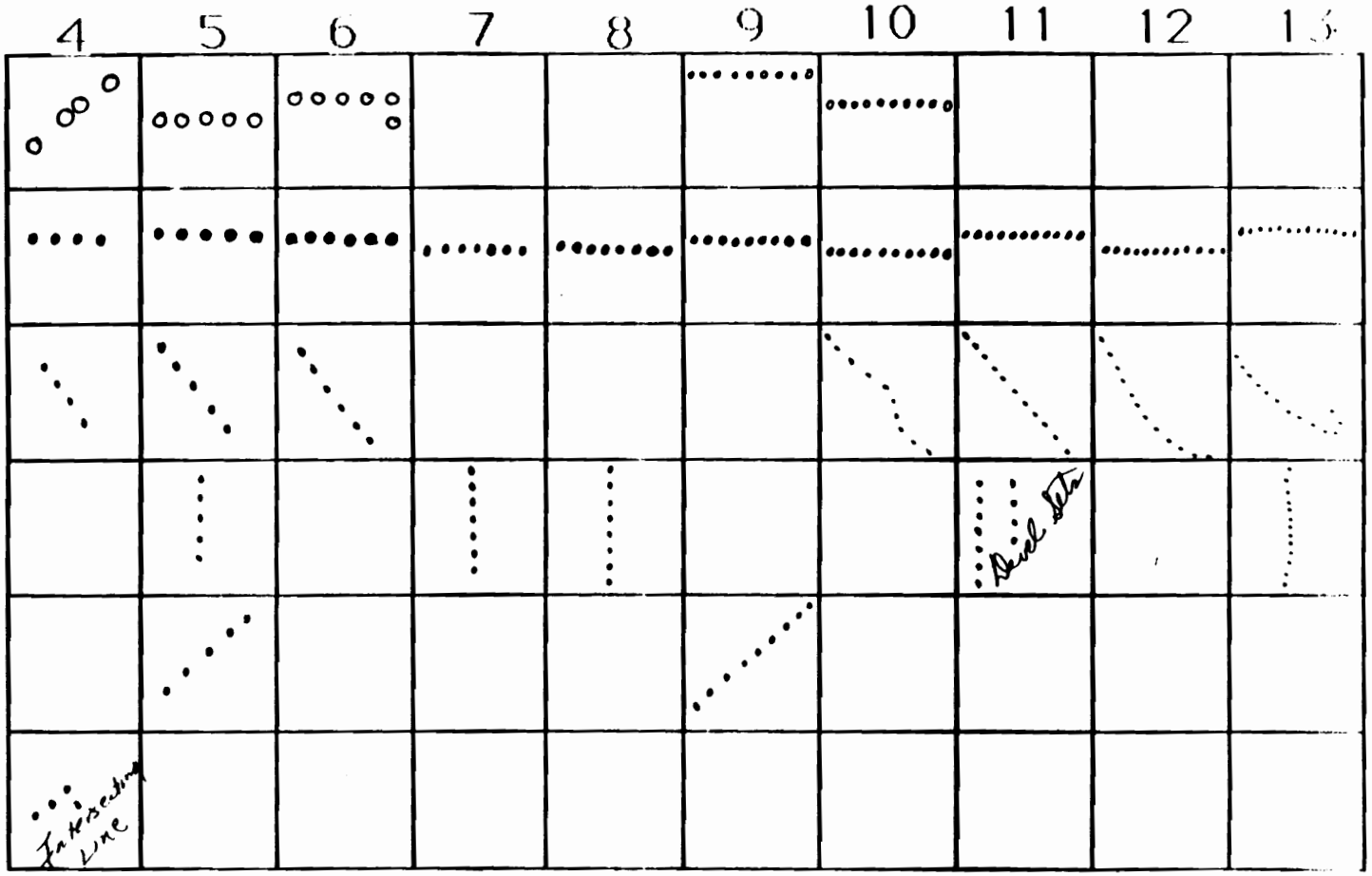
T's X's L's



Descriptors:
intersecting line segments
in shapes of t's x's l's v's and u's
sometimes two lines
sometimes three lines

4

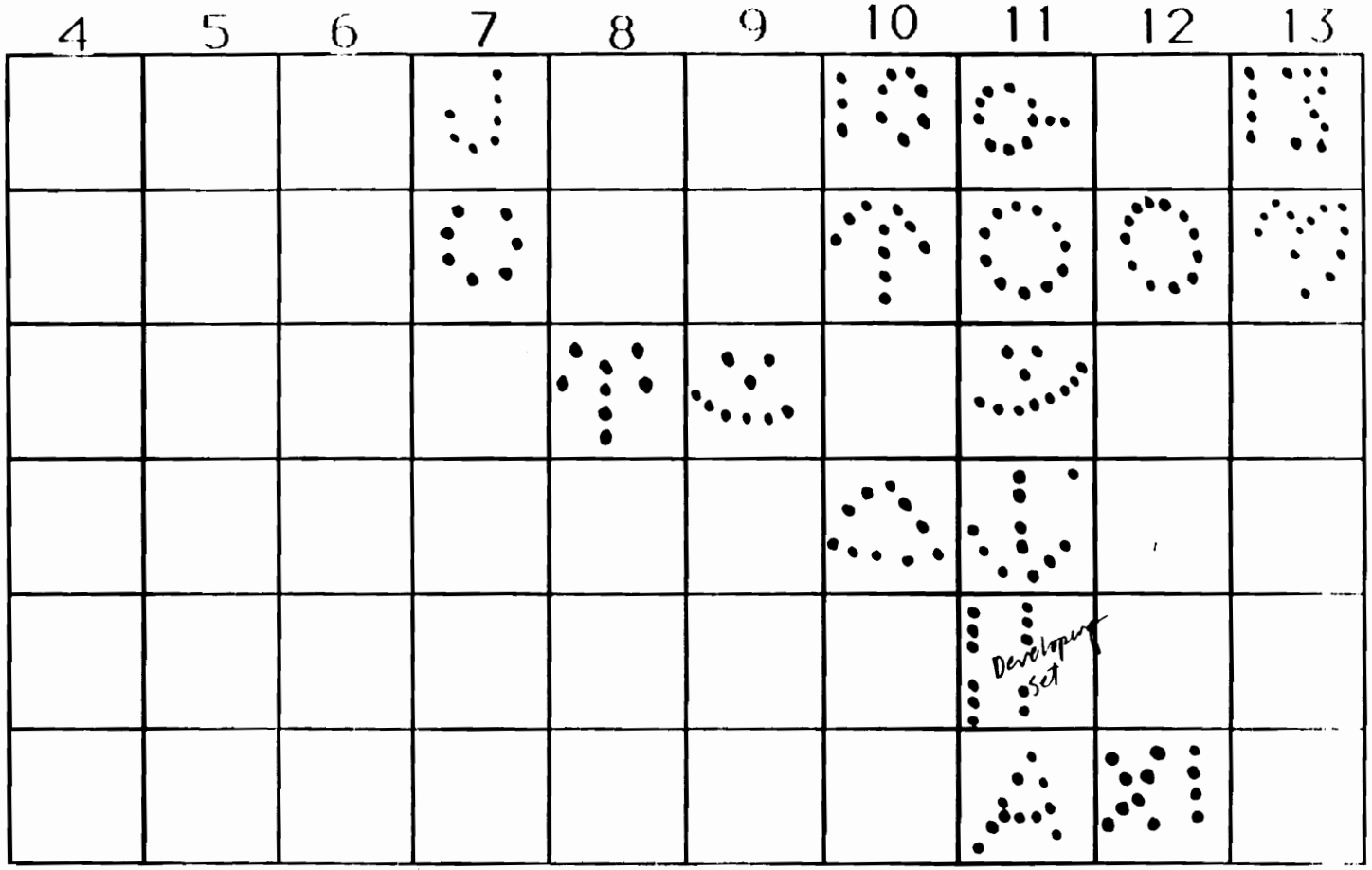
3 Linear



Descriptors:

Straight lines
any direction
curved back if it looks like they ran out of room

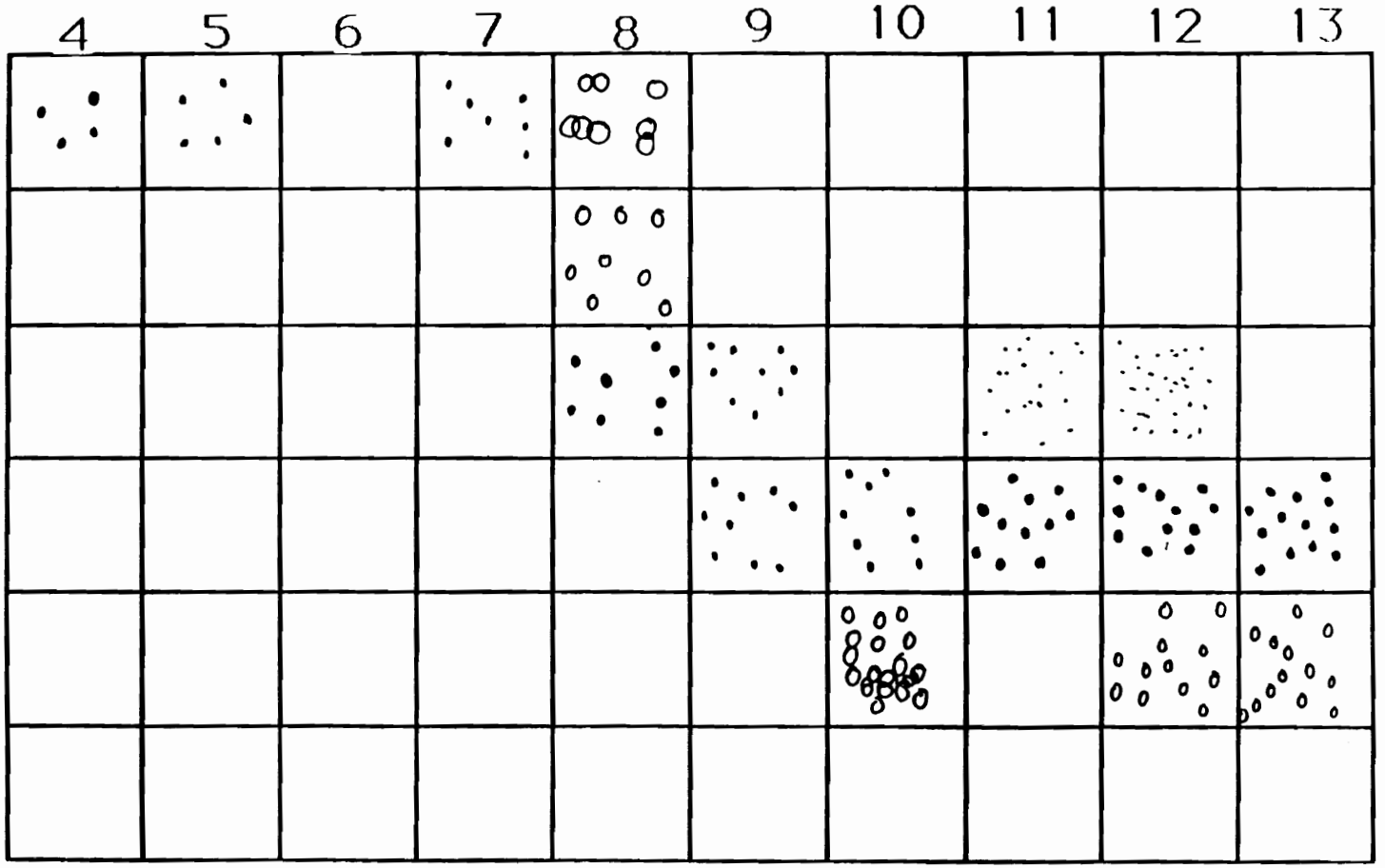
2 Alphabet Triangle Pictures Number Circle



Descriptors:

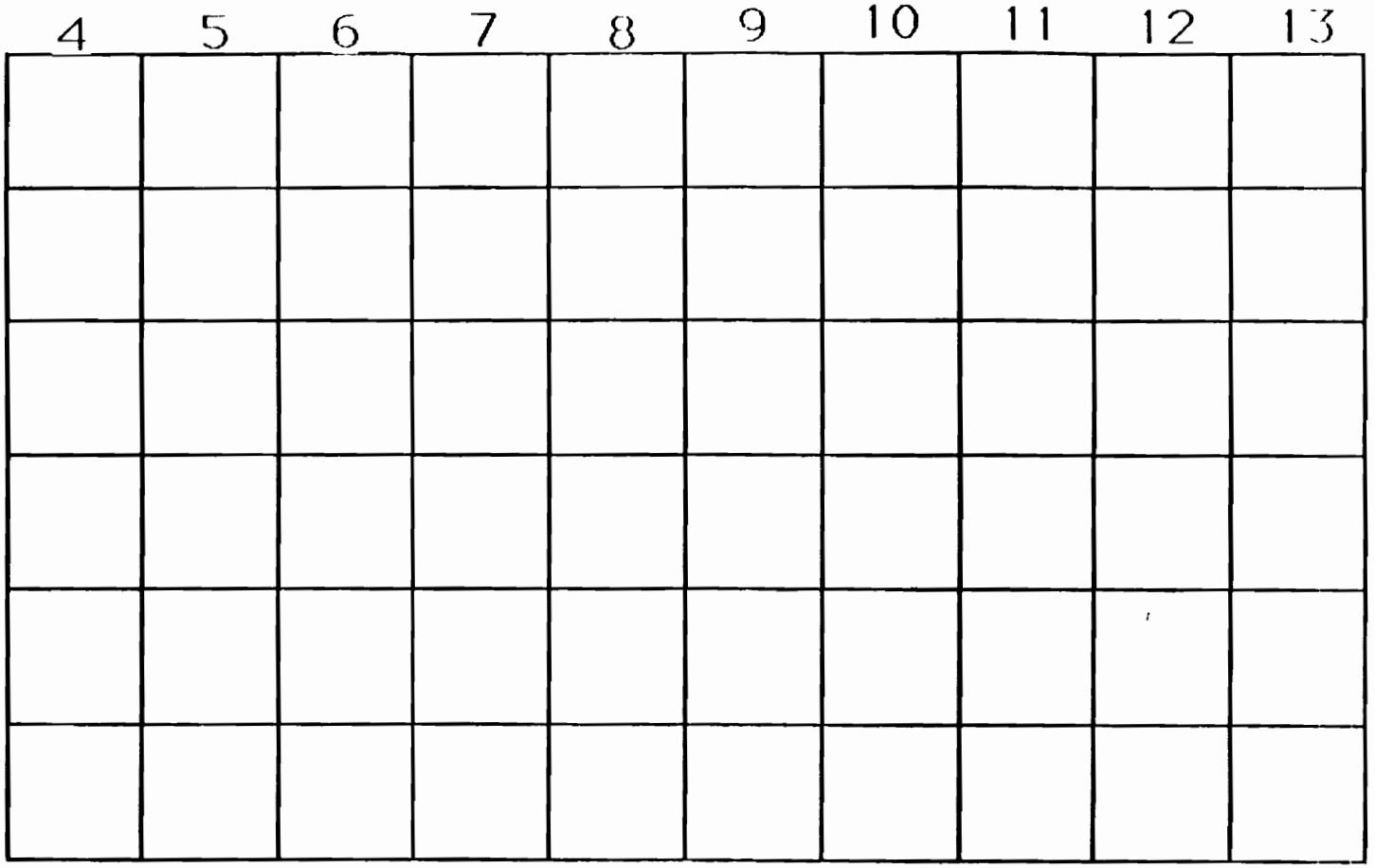
Pictures and simple shapes closed figure
Letters
Numbers

Random Scattered



Descriptors:

free flowing	randomly placed
uninhibited	varying sizes
unstructured	varying shapes



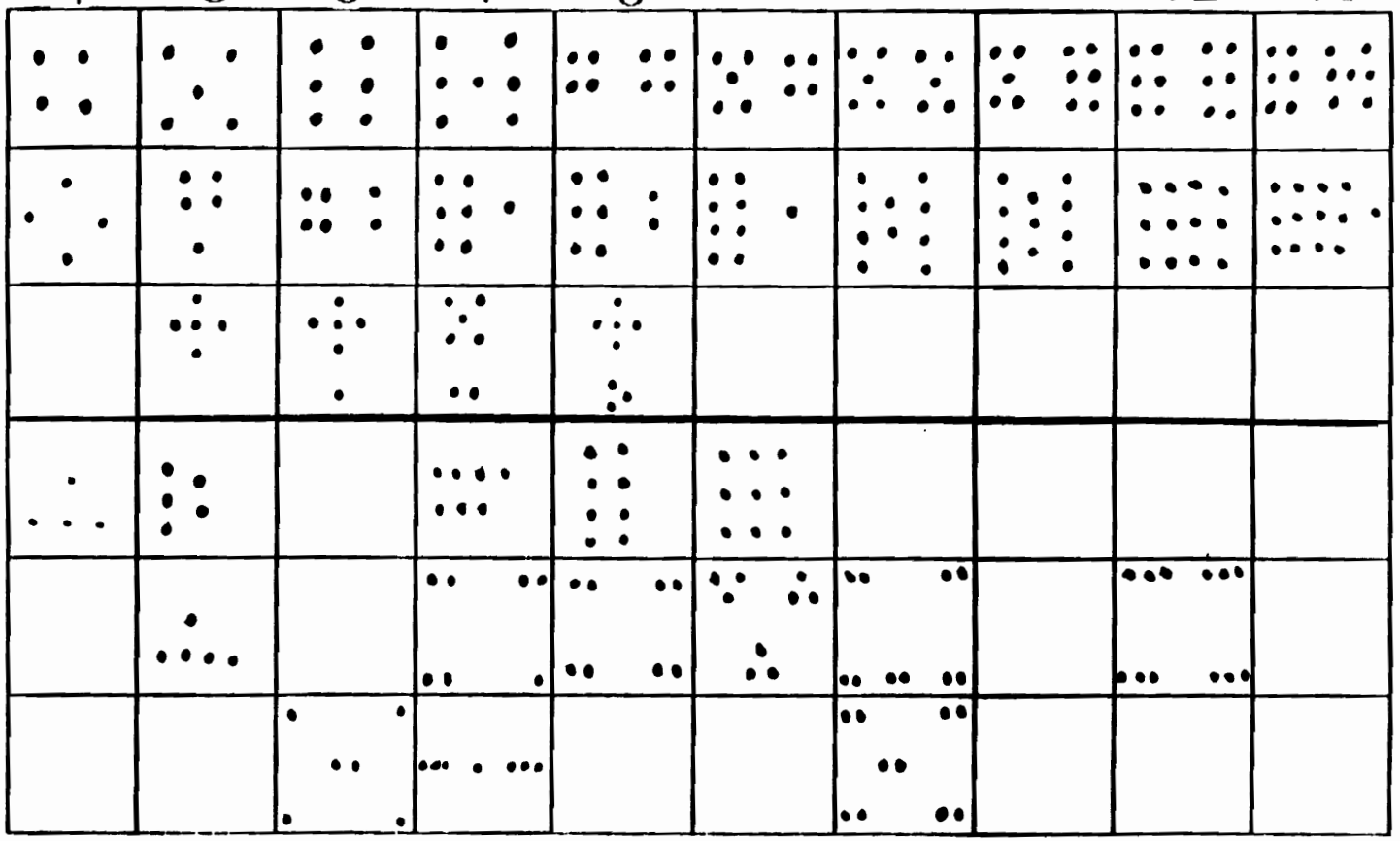
Items thrown out:

- Blank
- No number to identify dots
- Makes random look good
- Chaos

Imagery Scale used by Novices and Researcher
(with modifications suggested by Judges)

Domino Like Card Like Sets

(6 points) 4 5 6 7 8 9 10 11 12 13



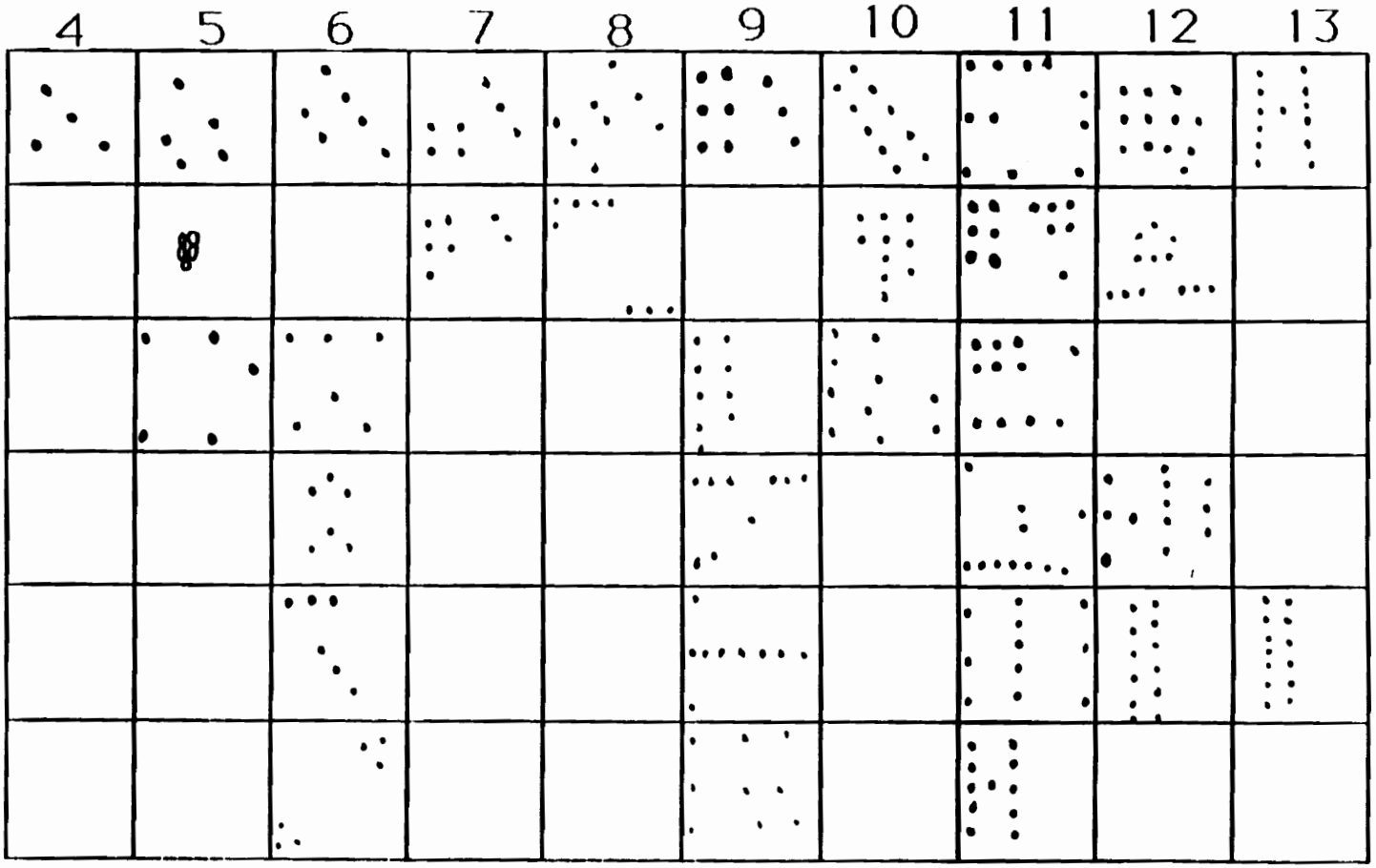
Descriptors:

clear organizational thinking
readily recognizable patterns

Domino like
card like

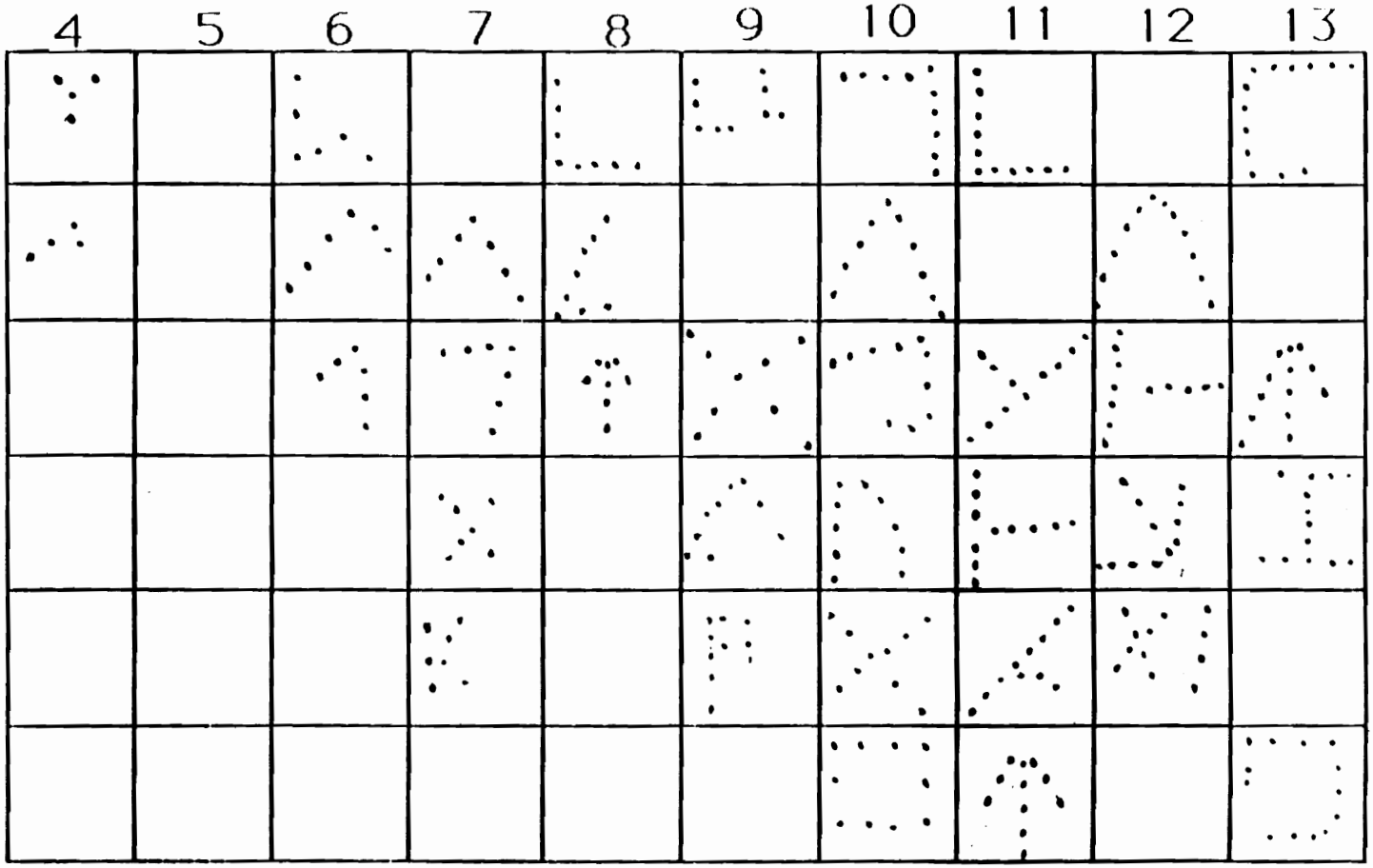
Sets:
row and columns with no more than 4 in a group
primarily horizontal and/or vertical arrangement

Developing Sets (5 points)



Developing Sets Descriptors:
Large numbers are grouped
Sets are equal or nearly equal
Dots may be spread out or compressed
uses parallel and/or diagonal lines
non-traditional grouping
rows and/or columns may have more than 4 dots

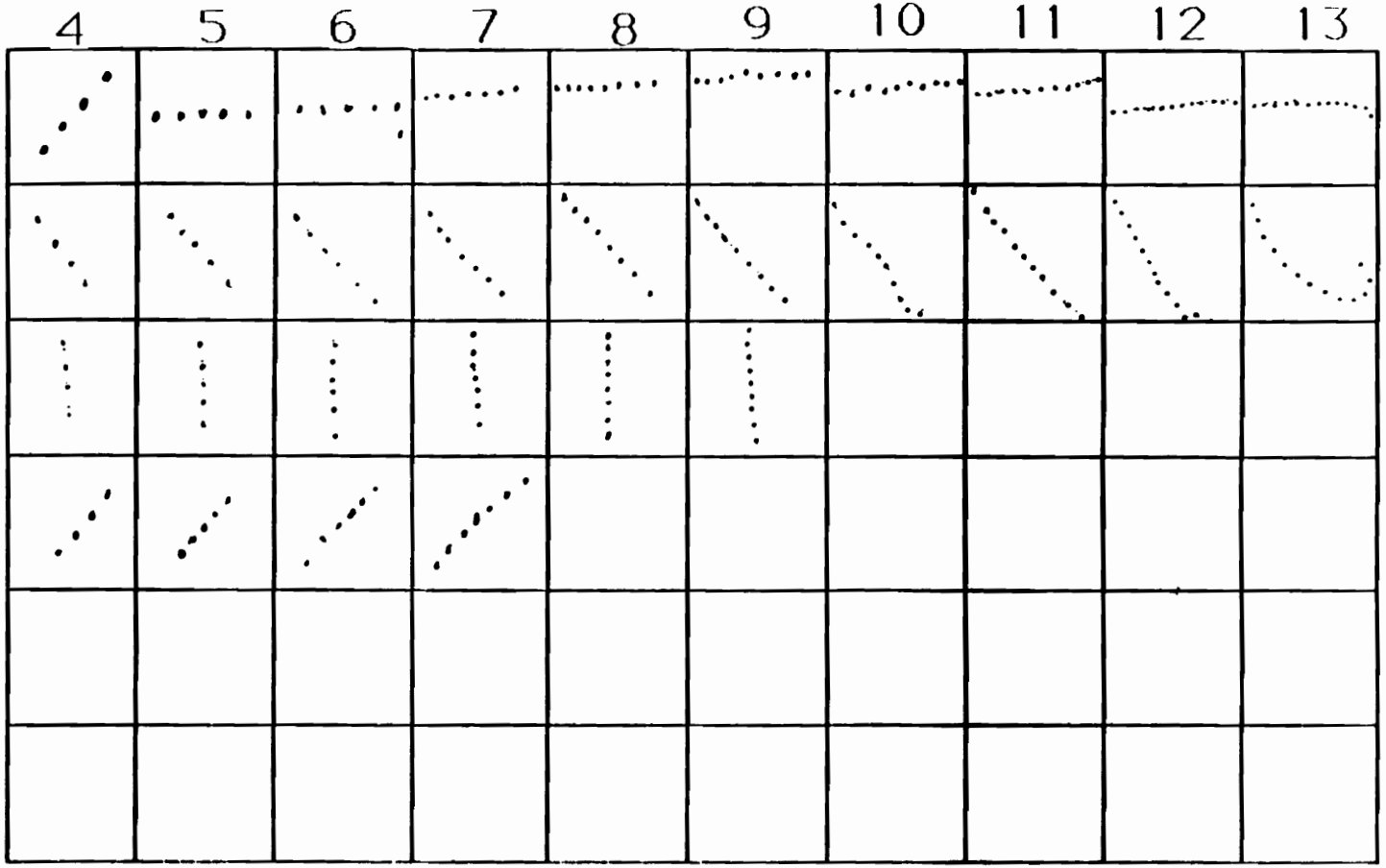
Intersecting Lines (4 points)



Intersecting Lines Descriptors:
Line segments in shape of T, X, L or V
May be 2 or 3 lines
Sharp break which forms an angle

Angle may be formed with straight and/or curved line segments
Open figure

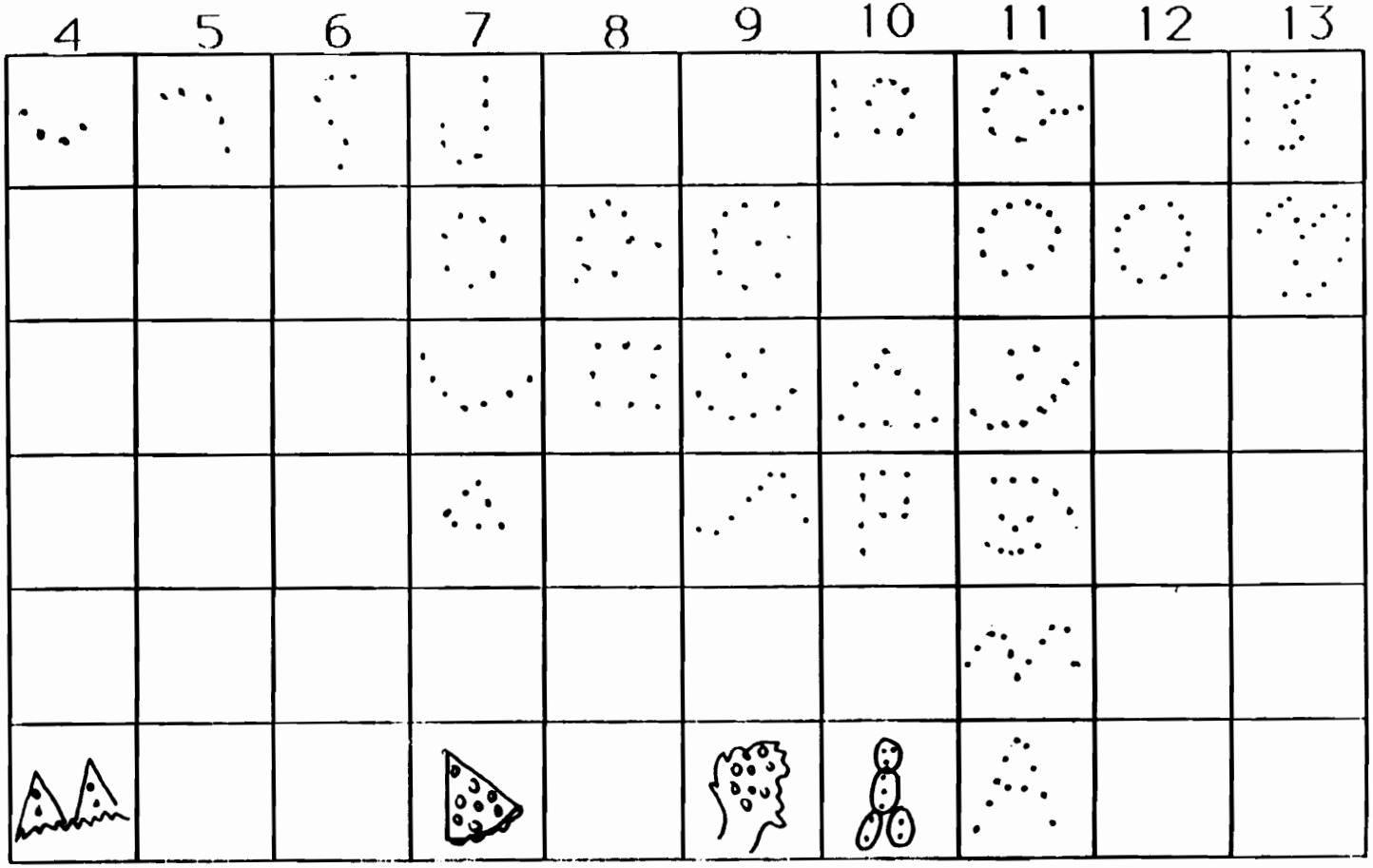
Linear (3 points)



Linear Descriptors:

- Primarily straight line
- Lines may be slightly wavy
- Horizontal, vertical or diagonal arrangement
- Line may be curved back on itself or have sharp break if student obviously ran out of room

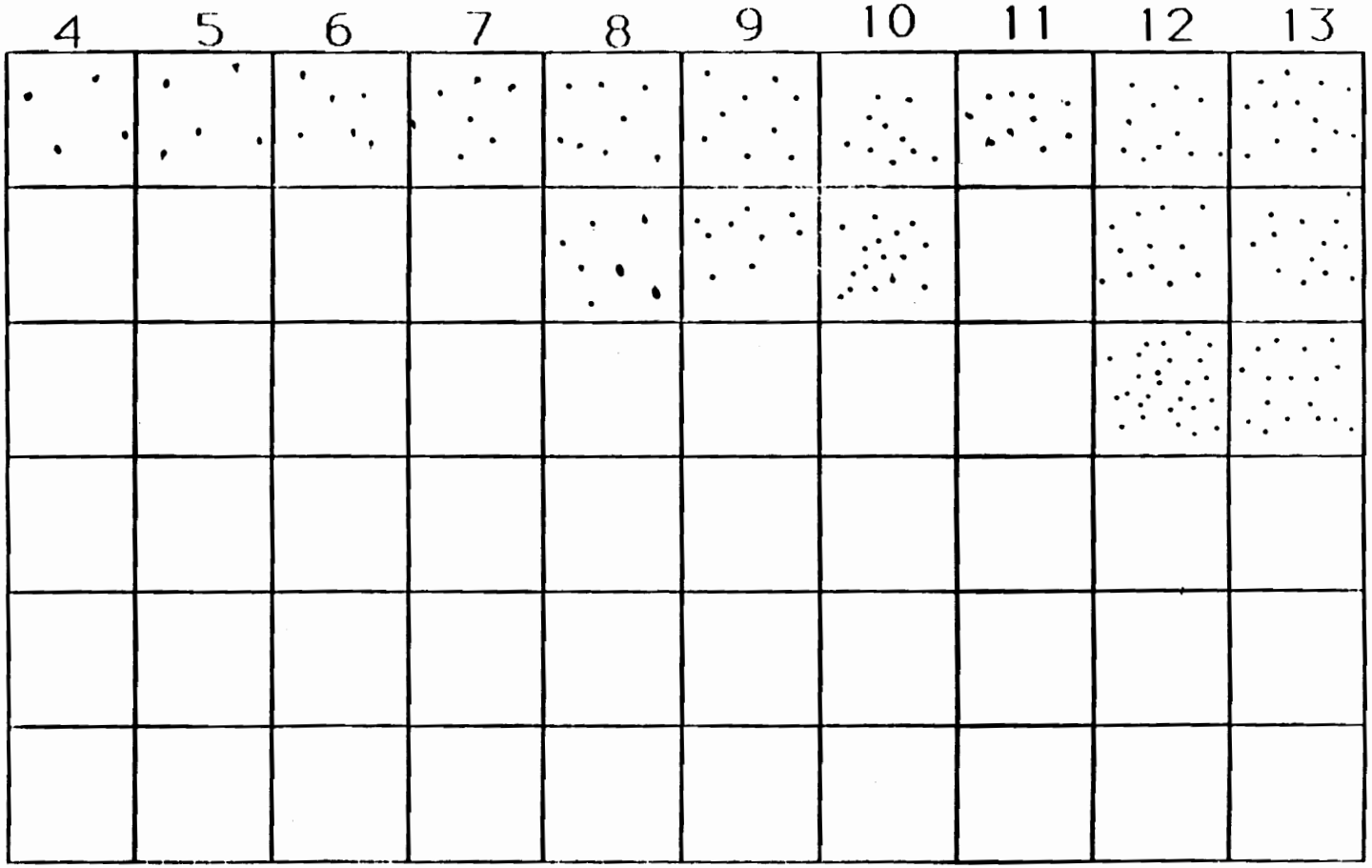
Pictures, Numbers Simple, Shapes, Alphabet (2 points)



Picture Descriptors:

may be closed or open figure
may be curved lines
may be simple shapes (squares, triangles, circles), letters of the alphabet (closed letters) or numerals made of dots
includes all pictures

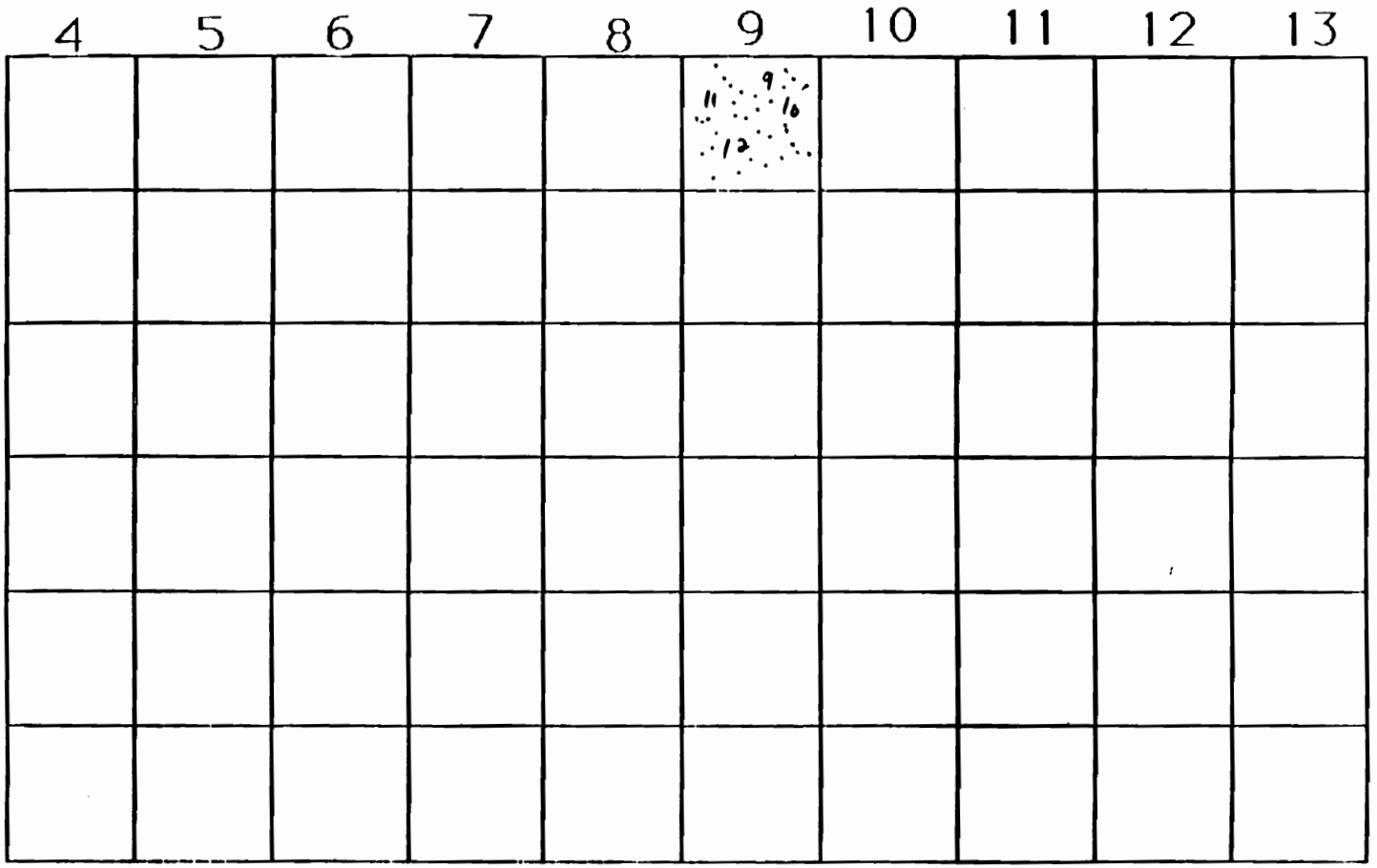
Random Scattered (1 points)



Random; Scattered Descriptors:

varying sizes and shapes
no obvious attempt at organization
no clear attempt at formation of sets or developing sets
free flowing uninhibited

Chaotic (0 points)



Chaotic Descriptors:

- Blank pages
- No number to identify dots
- Several examples on one page

Correlations of Novices' and Researcher's Imagery Scores

Variable	Novice 1	Novice 2	Novice 3	Novice 4	Imagery Score
Novice 1	1.0000	0.7188	0.6653	0.6193	0.6889
Novice 2		1.0000	0.7867	0.7048	0.6256
Novice 3			1.0000	0.8588	0.7395
Novice 4				1.0000	0.6734
Imagery.1					1.0000

Correlations of Novice, Judges and Researacher Imagery Scores

Variable	Nov1	Nov2	Nov3	Nov4	Judge1	Judge3	Judge4	Judge5	Imagery
Novice 1	1.0000	0.8508	0.9082	0.8378	0.9140	0.8590	0.8452	0.8603	0.8648
Novice 2		1.0000	0.8226	0.8044	0.8453	0.8273	0.7397	0.7994	0.5830
Novice 3			1.0000	0.9385	0.9159	0.9137	0.8262	0.9344	0.7916
Novice 4				1.0000	0.9376	0.9373	0.8779	0.9209	0.7105
Judge 1					1.0000	0.9108	0.9548	0.9277	0.7546
Judge 3						1.0000	0.8273	0.8985	0.6904
Judge 4							1.0000	0.8783	0.7499
Judge 5								1.0000	0.7711
Imagery1									1.0000

Correlations of Novices' and Researcher's Second Imagery Score

Variable	Novice 1	Novice 2	Novice 3	Novice 4	Imagery.2
Novice 1	1.0000	0.7188	0.6653	0.6193	0.6465
Novice 2		1.0000	0.7867	0.7048	0.7475
Novice 3			1.0000	0.8588	0.8076
Novice 4				1.0000	0.7537
Imagery.2					1.0000

Correlations of Novices', Judges' and Researcher's Second Imagery Scores

Variable	Nov1	Nov2	Nov3	Nov4	Judge1	Judge3	Judge4	Judge5	Image.2
Novice 1	1.0000	0.8508	0.9082	0.8378	0.9140	0.8590	0.8452	0.8603	0.8650
Novice 2		1.0000	0.8226	0.8044	0.8453	0.8273	0.7397	0.7994	0.7251
Novice 3			1.0000	0.9385	0.9159	0.9137	0.8262	0.9344	0.8899
Novice 4				1.0000	0.9376	0.9373	0.8779	0.9209	0.9006
Judge 1					1.0000	0.9108	0.9548	0.9277	0.9034
Judge 3						1.0000	0.8273	0.8985	0.8128
Judge 4							1.0000	0.8783	0.9150
Judge 5								1.0000	0.8872
Imagery.2									1.0000

Intrarater Correlations

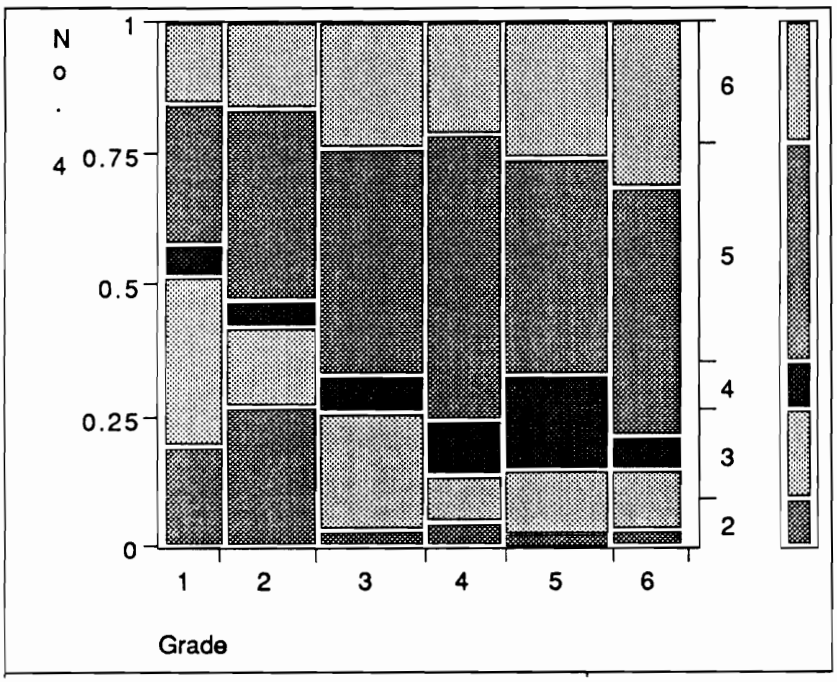
Variable	Imagery.1	Imagery.2
Imagery.1	1.0000	0.8749
Imagery.2		1.0000

Correlations between Numeral Scores

Correlations

Variable	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No.13
No. 4	1.0000	0.2288	0.2684	0.1949	0.1569	0.1726	0.2274	0.0636	0.0397	0.0385
No. 5	0.2288	1.0000	0.2069	0.1985	0.2073	0.1941	0.2266	0.1242	0.1310	0.1399
No. 6	0.2684	0.2069	1.0000	0.2739	0.2242	0.2068	0.2172	0.1515	0.2101	0.1486
No. 7	0.1949	0.1985	0.2739	1.0000	0.1475	0.1385	0.1513	0.0813	0.1327	0.1234
No. 8	0.1569	0.2073	0.2242	0.1475	1.0000	0.2321	0.3025	0.2546	0.1987	0.1844
No. 9	0.1726	0.1941	0.2068	0.1385	0.2321	1.0000	0.2564	0.1702	0.0616	0.1442
No. 10	0.2274	0.2266	0.2172	0.1513	0.3025	0.2564	1.0000	0.3655	0.2152	0.2568
No. 11	0.0636	0.1242	0.1515	0.0813	0.2546	0.1702	0.3655	1.0000	0.2687	0.2514
No. 12	0.0397	0.1310	0.2101	0.1327	0.1987	0.0616	0.2152	0.2687	1.0000	0.2942
No. 13	0.0385	0.1399	0.1486	0.1234	0.1844	0.1442	0.2568	0.2514	0.2942	1.0000

Distribution of Categorical Scores for each Numeral by Grade



Summary of Fit

Rsquare (U)	.0570065
Observations (or Sum Wgts)	431

Analysis of LogLikelihood

Source	DF	-LogLikelihood
Model	20	35.54976
Error	454	588.05879
C Total	474	623.60854

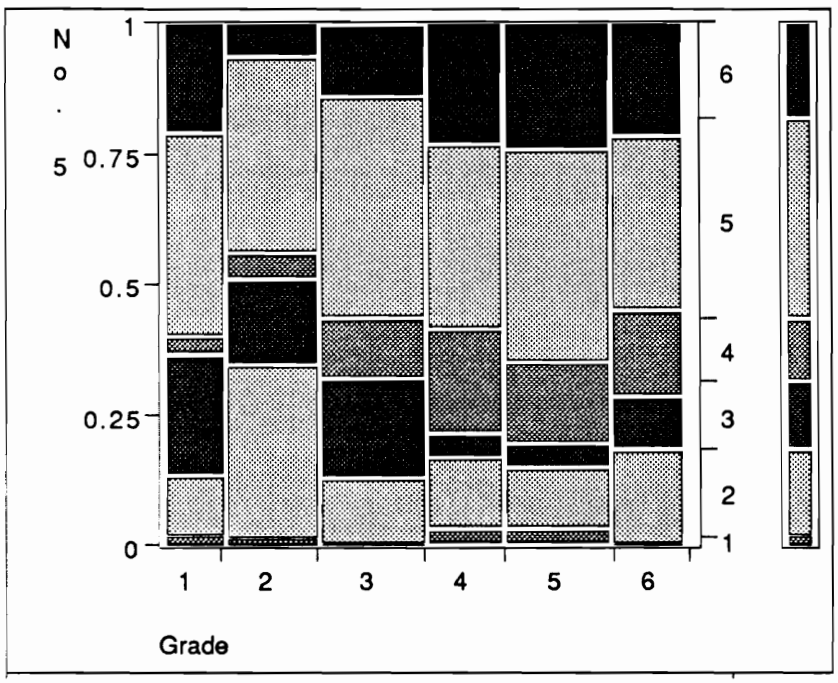
Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	71.100	0.0000
Pearson	78.174	0.0000

Response Counts

Scale 4	1	2	3	4	5	6	Total
2	10	21	3	3	2	2	41
3	17	12	20	6	11	7	73
4	3	4	6	7	16	4	40
5	14	28	38	35	36	28	179
6	8	13	21	14	23	19	98
	52	78	88	65	88	60	431

Response Profiles

Scale 4	1	2	3	4	5	6
2	0.1923	0.2692	0.0341	0.0462	0.0227	0.0333
3	0.3269	0.1538	0.2273	0.0923	0.1250	0.1167
4	0.0577	0.0513	0.0682	0.1077	0.1818	0.0667
5	0.2692	0.3590	0.4318	0.5385	0.4091	0.4667
6	0.1538	0.1667	0.2386	0.2154	0.2614	0.3167
	52	78	88	65	88	60



Summary of Fit

Rsquare (U)	.0479159
Observations (or Sum Wgts)	430

Analysis of LogLikelihood

Source	DF	-LogLikelihood
Model	25	32.23883
Error	448	640.58109
C Total	473	672.81991

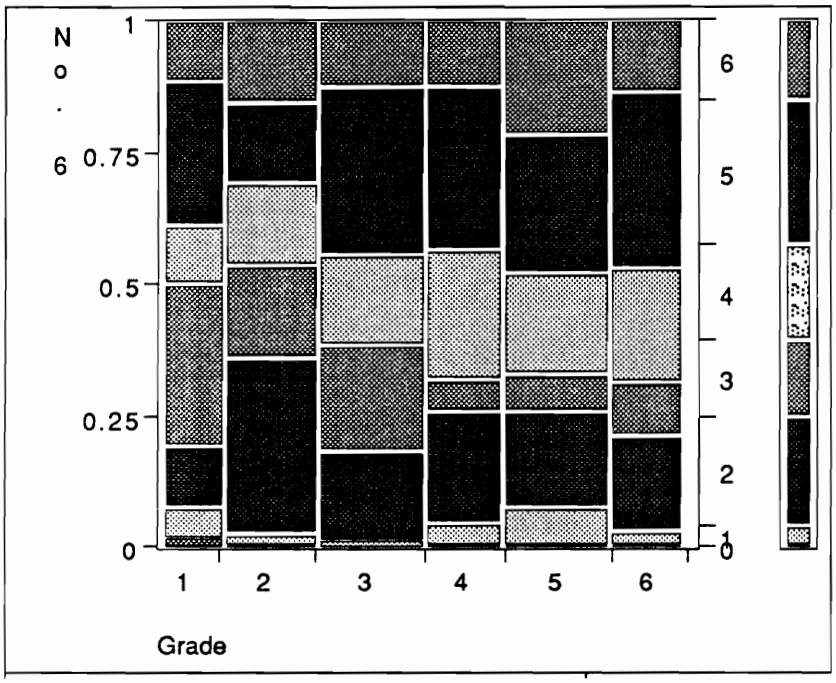
Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	64.478	0.0000
Pearson	60.511	0.0001

Response Counts

Scale 5	1	2	3	4	5	6	Total
1	1	1	0	2	3	0	7
2	6	26	11	9	10	11	73
3	12	13	17	3	4	6	55
4	2	4	10	13	14	10	53
5	20	29	37	23	36	20	165
6	11	5	12	15	21	13	77
	52	78	87	65	88	60	430

Response Profiles

Scale 5	1	2	3	4	5	6
1	0.0192	0.0128	0.0000	0.0308	0.0341	0.0000
2	0.1154	0.3333	0.1264	0.1385	0.1136	0.1833
3	0.2308	0.1667	0.1954	0.0462	0.0455	0.1000
4	0.0385	0.0513	0.1149	0.2000	0.1591	0.1667
5	0.3846	0.3718	0.4253	0.3538	0.4091	0.3333
6	0.2115	0.0641	0.1379	0.2308	0.2386	0.2167
	52	78	87	65	88	60



Summary of Fit

Rsquare (U)	.0352109
Observations (or Sum Wgts)	431

Analysis of LogLikelihood

Source	DF	-LogLikelihood
Model	30	25.83647
Error	442	707.92602
C Total	472	733.76249

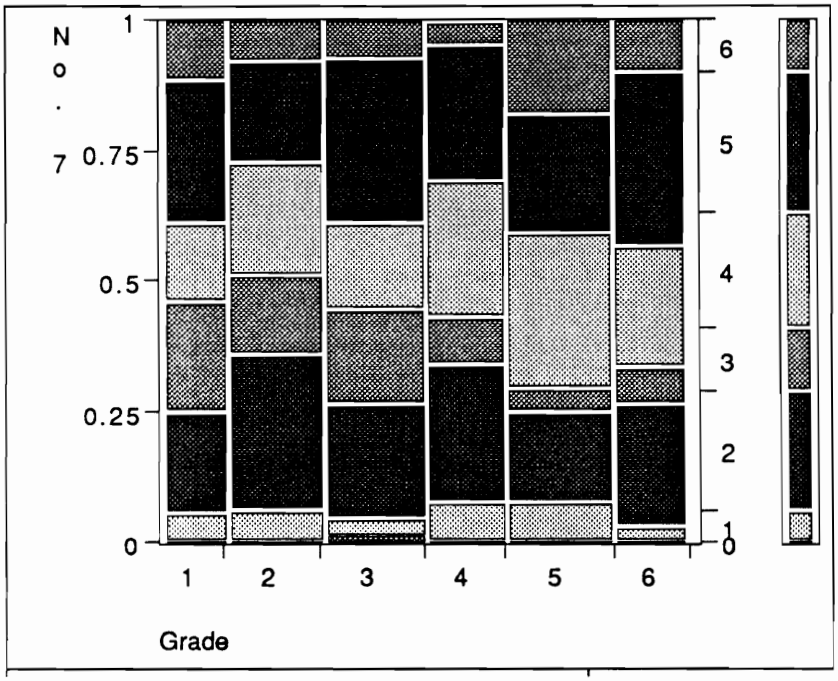
Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	51.673	0.0083
Pearson	54.996	0.0036

Response Counts

Scale 6	1	2	3	4	5	6	Total
0	1	0	0	0	0	0	1
1	3	2	1	3	7	2	18
2	6	26	15	14	16	11	88
3	16	14	18	4	6	6	64
4	6	12	15	16	17	13	79
5	14	12	28	20	23	20	117
6	6	12	11	8	19	8	64
	52	78	88	65	88	60	431

Response Profiles

Scale 6	1	2	3	4	5	6
0	0.0192	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0577	0.0256	0.0114	0.0462	0.0795	0.0333
2	0.1154	0.3333	0.1705	0.2154	0.1818	0.1833
3	0.3077	0.1795	0.2045	0.0615	0.0682	0.1000
4	0.1154	0.1538	0.1705	0.2462	0.1932	0.2167
5	0.2692	0.1538	0.3182	0.3077	0.2614	0.3333
6	0.1154	0.1538	0.1250	0.1231	0.2159	0.1333
	52	78	88	65	88	60



Summary of Fit

Rsquare (U)	.0274931
Observations (or Sum Wgts)	426

Analysis of LogLikelihood

Source	DF	-LogLikelihood
Model	30	19.82608
Error	442	701.30065
C Total	472	721.12672

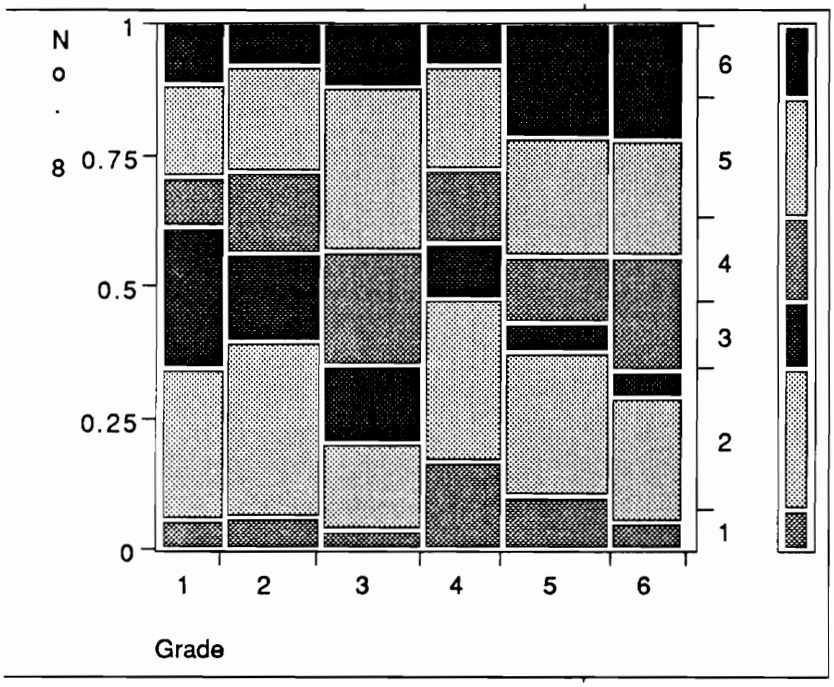
Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	39.652	0.1118
Pearson	40.056	0.1038

Response Counts

Scale 7	1	2	3	4	5	6	Total
0	0	0	1	0	0	0	1
1	3	5	3	5	7	2	25
2	10	23	18	17	15	14	97
3	11	12	15	6	4	4	52
4	8	17	14	17	26	14	96
5	14	15	26	17	20	20	112
6	6	6	6	3	16	6	43
	52	78	83	65	88	60	426

Response Profiles

Scale 7	1	2	3	4	5	6
0	0.0000	0.0000	0.0120	0.0000	0.0000	0.0000
1	0.0577	0.0641	0.0361	0.0769	0.0795	0.0333
2	0.1923	0.2949	0.2169	0.2615	0.1705	0.2333
3	0.2115	0.1538	0.1807	0.0923	0.0455	0.0667
4	0.1538	0.2179	0.1687	0.2615	0.2955	0.2333
5	0.2692	0.1923	0.3133	0.2615	0.2273	0.3333
6	0.1154	0.0769	0.0723	0.0462	0.1818	0.1000
	52	78	83	65	88	60



Summary of Fit

Rsquare (U)	.0337740
Observations (or Sum Wgts)	425

Analysis of LogLikelihood

Source	DF	-LogLikelihood
Model	25	24.70211
Error	448	706.69137
C Total	473	731.39348

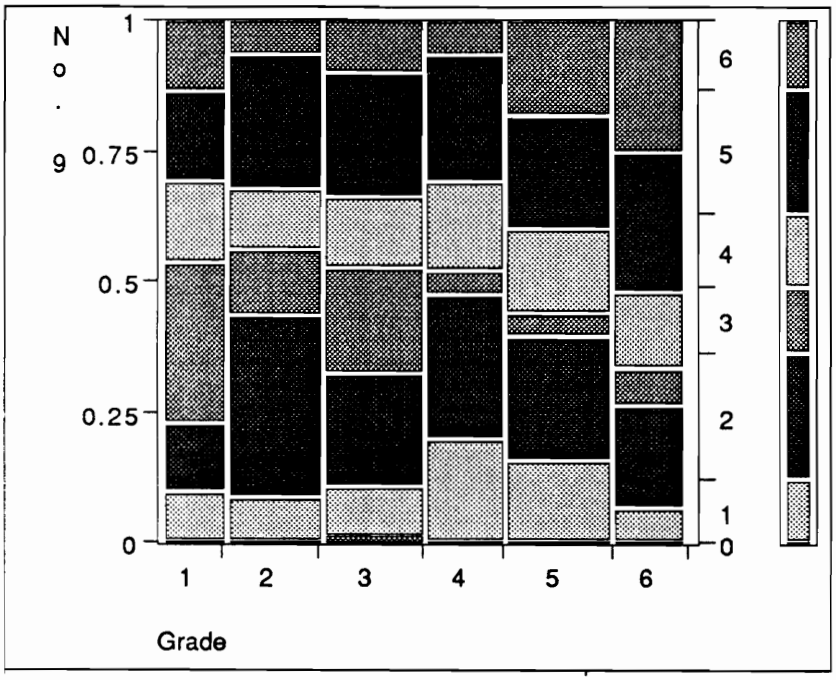
Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	49.404	0.0025
Pearson	50.875	0.0017

Response Counts

Scale 8	1	2	3	4	5	6	Total
1	3	5	3	11	9	3	34
2	15	26	14	20	24	14	113
3	14	13	12	7	5	3	54
4	5	12	18	9	11	13	68
5	9	16	26	13	20	13	97
6	6	6	10	5	19	13	59
	52	78	83	65	88	59	425

Response Profiles

Scale 8	1	2	3	4	5	6
1	0.0577	0.0641	0.0361	0.1692	0.1023	0.0508
2	0.2885	0.3333	0.1687	0.3077	0.2727	0.2373
3	0.2692	0.1667	0.1446	0.1077	0.0568	0.0508
4	0.0962	0.1538	0.2169	0.1385	0.1250	0.2203
5	0.1731	0.2051	0.3133	0.2000	0.2273	0.2203
6	0.1154	0.0769	0.1205	0.0769	0.2159	0.2203
	52	78	83	65	88	59



Summary of Fit

Rsquare (U)	.0393996
Observations (or Sum Wgts)	426

Analysis of LogLikelihood

Source	DF	-LogLikelihood
Model	30	29.51365
Error	442	719.56951
C Total	472	749.08315

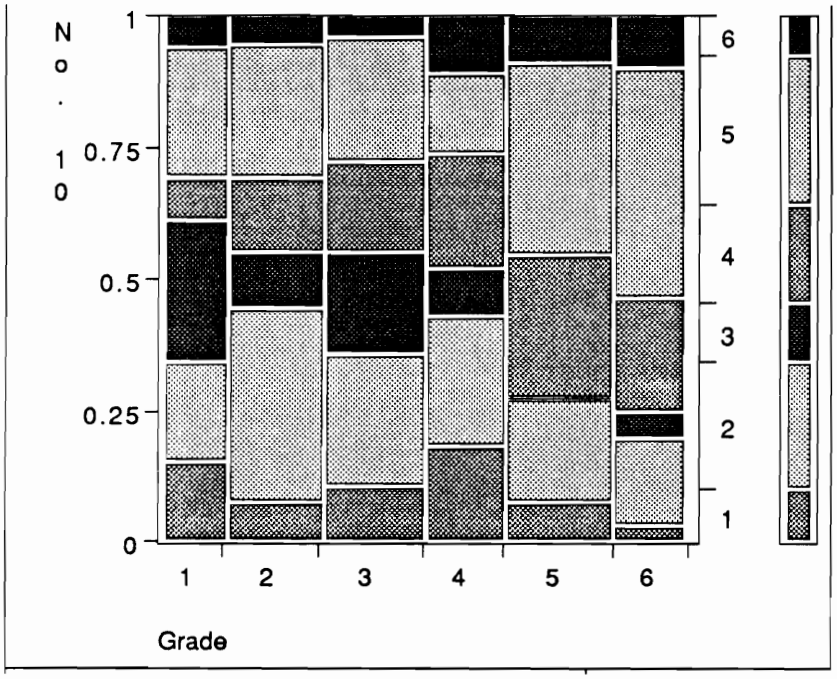
Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	59.027	0.0012
Pearson	62.060	0.0005

Response Counts

Scale 9	1	2	3	4	5	6	Total
0	0	0	1	0	0	0	1
1	5	7	8	13	14	4	51
2	7	27	18	18	21	12	103
3	16	10	17	3	4	4	54
4	8	9	11	11	14	9	62
5	9	20	20	16	19	16	100
6	7	5	8	4	16	15	55
	52	78	83	65	88	60	426

Response Profiles

Scale 9	1	2	3	4	5	6
0	0.0000	0.0000	0.0120	0.0000	0.0000	0.0000
1	0.0962	0.0897	0.0964	0.2000	0.1591	0.0667
2	0.1346	0.3462	0.2169	0.2769	0.2386	0.2000
3	0.3077	0.1282	0.2048	0.0462	0.0455	0.0667
4	0.1538	0.1154	0.1325	0.1692	0.1591	0.1500
5	0.1731	0.2564	0.2410	0.2462	0.2159	0.2667
6	0.1346	0.0641	0.0964	0.0615	0.1818	0.2500
	52	78	83	65	88	60



Summary of Fit

Rsquare (U)	.0537293
Observations (or Sum Wgts)	426

Analysis of LogLikelihood

Source	DF	-LogLikelihood
Model	25	38.52641
Error	448	678.52000
C Total	473	717.04640

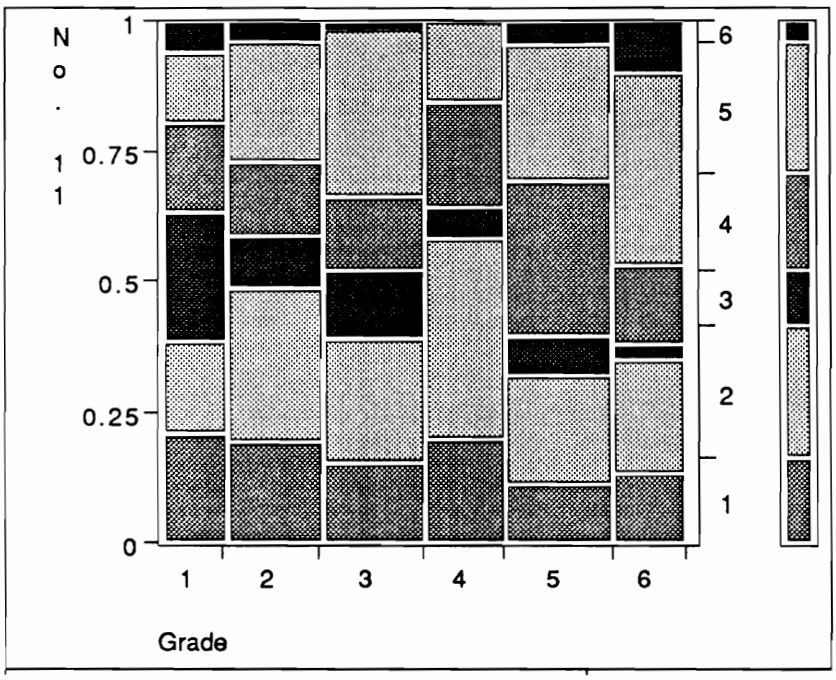
Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	77.053	0.0000
Pearson	70.726	0.0000

Response Counts

Scale 10	1	2	3	4	5	6	Total
1	8	6	9	12	7	2	44
2	10	29	21	16	17	10	103
3	14	8	16	6	0	3	47
4	4	11	14	14	24	13	80
5	13	20	20	10	32	26	121
6	3	4	3	7	8	6	31
	52	78	83	65	88	60	426

Response Profiles

Scale 10	1	2	3	4	5	6
1	0.1538	0.0769	0.1084	0.1846	0.0795	0.0333
2	0.1923	0.3718	0.2530	0.2462	0.1932	0.1667
3	0.2692	0.1026	0.1928	0.0923	0.0000	0.0500
4	0.0769	0.1410	0.1687	0.2154	0.2727	0.2167
5	0.2500	0.2564	0.2410	0.1538	0.3636	0.4333
6	0.0577	0.0513	0.0361	0.1077	0.0909	0.1000
	52	78	83	65	88	60



Summary of Fit

Rsquare (U)	.0379431
Observations (or Sum Wgts)	427

Analysis of LogLikelihood

Source	DF	-LogLikelihood
Model	25	27.05966
Error	448	686.10302
C Total	473	713.16268

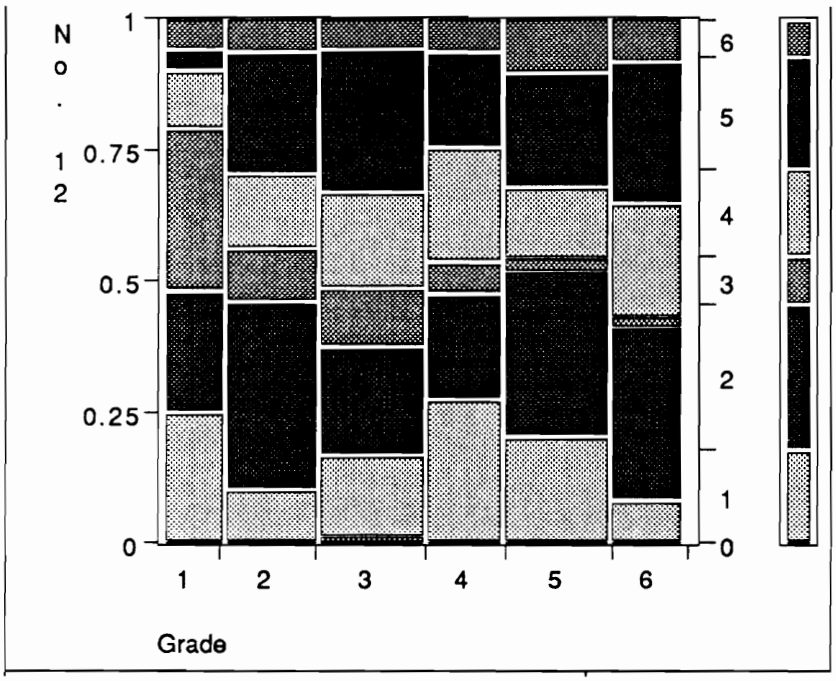
Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	54.119	0.0006
Pearson	54.717	0.0005

Response Counts

Scale 11	1	2	3	4	5	6	Total
1	11	15	13	13	10	8	70
2	9	23	20	25	18	13	108
3	13	8	11	4	7	2	45
4	9	11	12	13	26	9	80
5	7	18	27	10	23	22	107
6	3	3	1	0	4	6	17
	52	78	84	65	88	60	427

Response Profiles

Scale 11	1	2	3	4	5	6
1	0.2115	0.1923	0.1548	0.2000	0.1136	0.1333
2	0.1731	0.2949	0.2381	0.3846	0.2045	0.2167
3	0.2500	0.1026	0.1310	0.0615	0.0795	0.0333
4	0.1731	0.1410	0.1429	0.2000	0.2955	0.1500
5	0.1346	0.2308	0.3214	0.1538	0.2614	0.3667
6	0.0577	0.0385	0.0119	0.0000	0.0455	0.1000
	52	78	84	65	88	60



Summary of Fit

Rsquare (U)	.0474423
Observations (or Sum Wgts)	431

Analysis of LogLikelihood

Source	DF	-LogLikelihood
Model	30	35.08474
Error	442	704.43818
C Total	472	739.52292

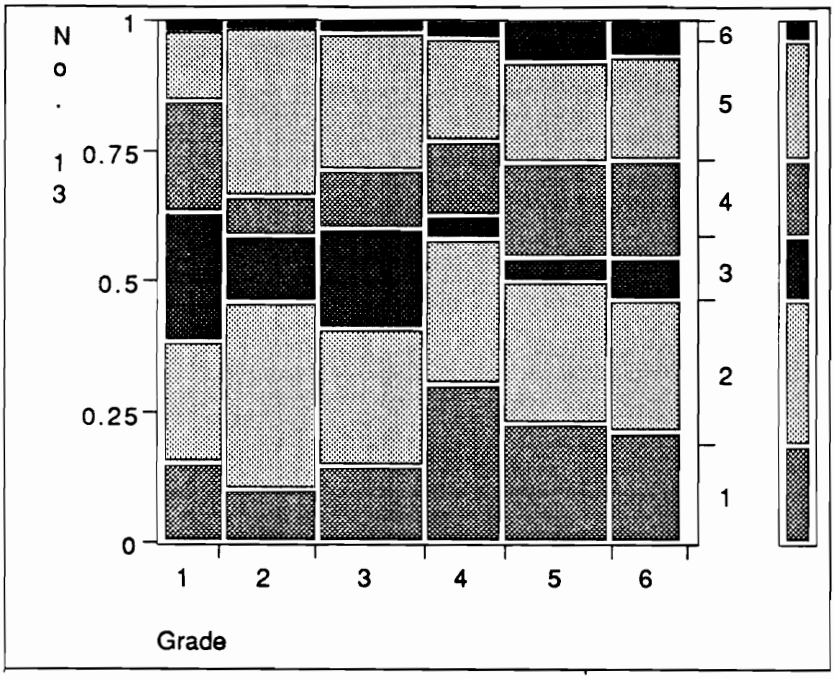
Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	70.169	0.0000
Pearson	71.832	0.0000

Response Counts

Scale 12	1	2	3	4	5	6	Total
0	0	0	1	0	0	0	1
1	13	8	14	18	18	5	76
2	12	28	18	13	28	20	119
3	16	8	10	4	2	1	41
4	6	11	16	14	12	13	72
5	2	18	24	12	19	16	91
6	3	5	5	4	9	5	31
	52	78	88	65	88	60	431

Response Profiles

Scale 12	1	2	3	4	5	6
0	0.0000	0.0000	0.0114	0.0000	0.0000	0.0000
1	0.2500	0.1026	0.1591	0.2769	0.2045	0.0833
2	0.2308	0.3590	0.2045	0.2000	0.3182	0.3333
3	0.3077	0.1026	0.1136	0.0615	0.0227	0.0167
4	0.1154	0.1410	0.1818	0.2154	0.1364	0.2167
5	0.0385	0.2308	0.2727	0.1846	0.2159	0.2667
6	0.0577	0.0641	0.0568	0.0615	0.1023	0.0833
	52	78	88	65	88	60



Summary of Fit

Rsquare (U)	.0353581
Observations (or Sum Wgts)	431

Analysis of LogLikelihood

Source	DF	-LogLikelihood
Model	25	25.46669
Error	448	694.78215
C Total	473	720.24885

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	50.933	0.0016
Pearson	51.114	0.0015

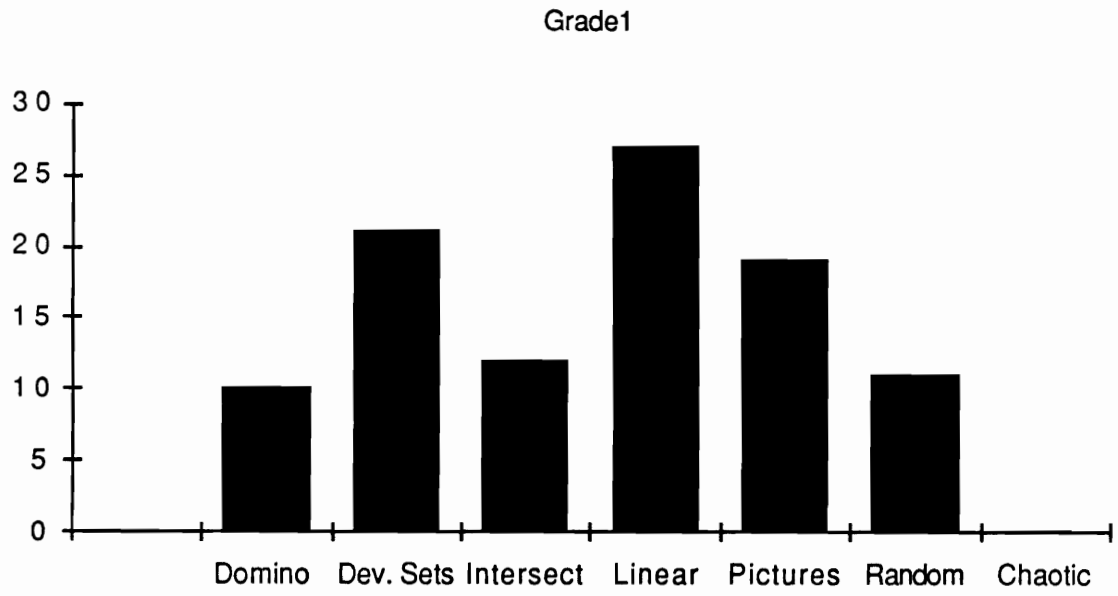
Response Counts

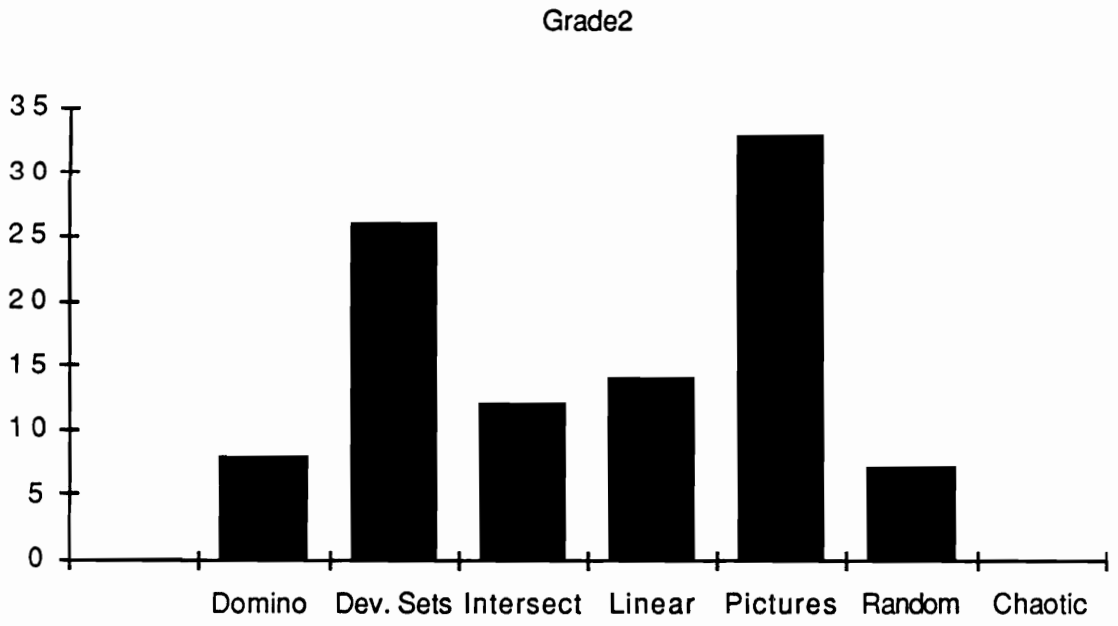
Scale 13	1	2	3	4	5	6	Total
1	8	8	13	20	20	13	82
2	12	28	23	18	24	15	120
3	13	10	17	3	4	5	52
4	11	6	10	9	16	11	63
5	7	25	23	13	17	12	97
6	1	1	2	2	7	4	17
	52	78	88	65	88	60	431

Response Profiles

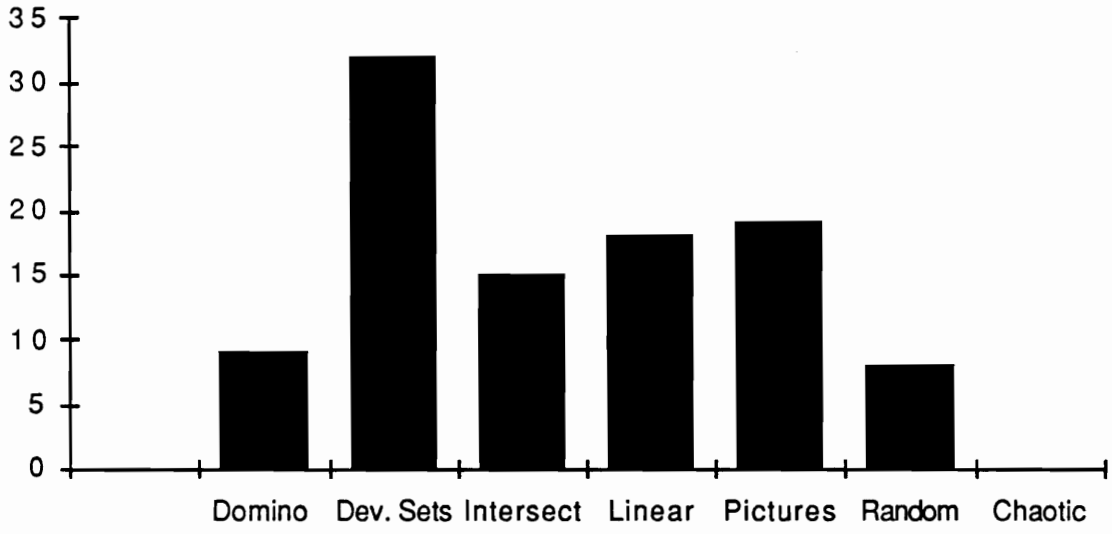
Scale 13	1	2	3	4	5	6
1	0.1538	0.1026	0.1477	0.3077	0.2273	0.2167
2	0.2308	0.3590	0.2614	0.2769	0.2727	0.2500
3	0.2500	0.1282	0.1932	0.0462	0.0455	0.0833
4	0.2115	0.0769	0.1136	0.1385	0.1818	0.1833
5	0.1346	0.3205	0.2614	0.2000	0.1932	0.2000
6	0.0192	0.0128	0.0227	0.0308	0.0795	0.0667
	52	78	88	65	88	60

Percent of Responses by Category for each Grade

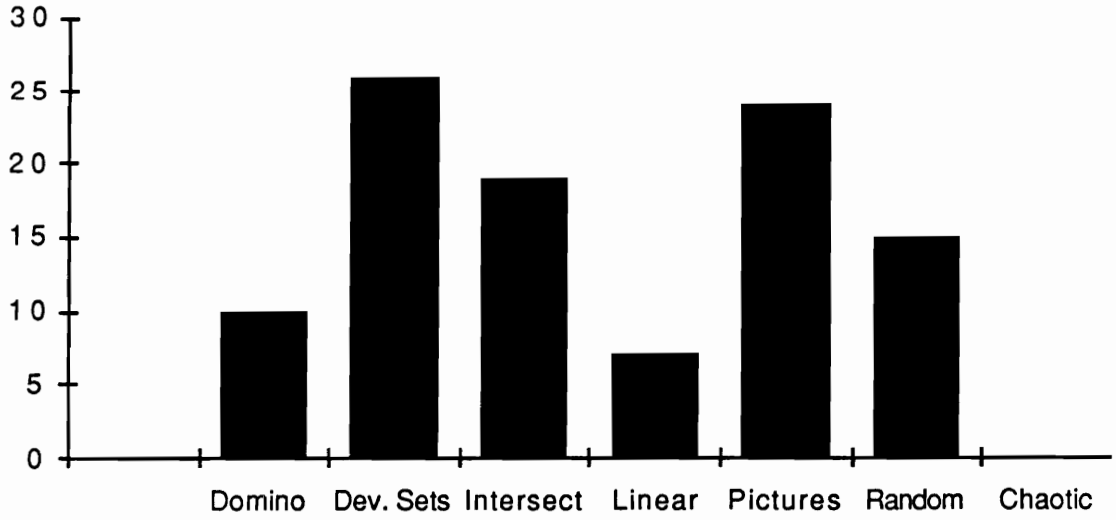




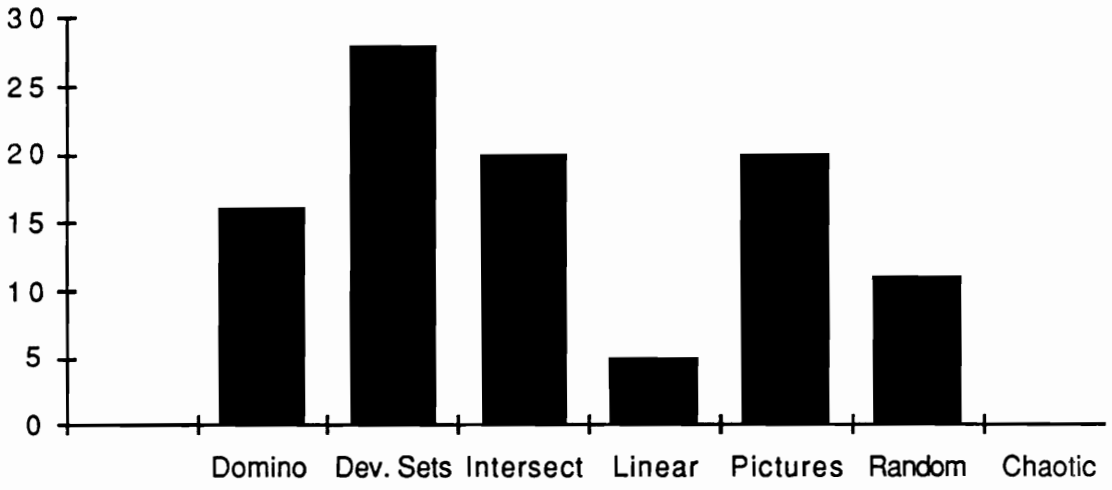
Grade 3



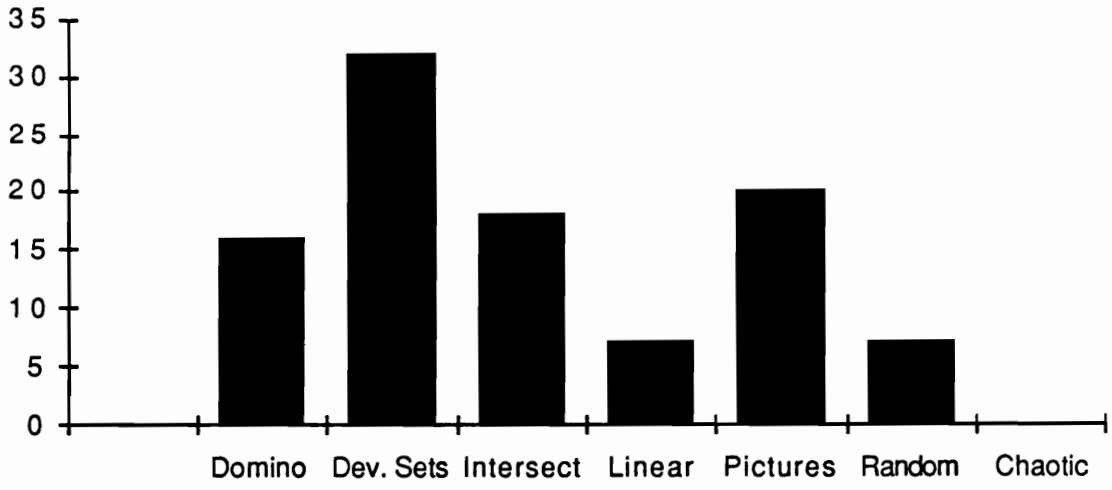
Grade 4

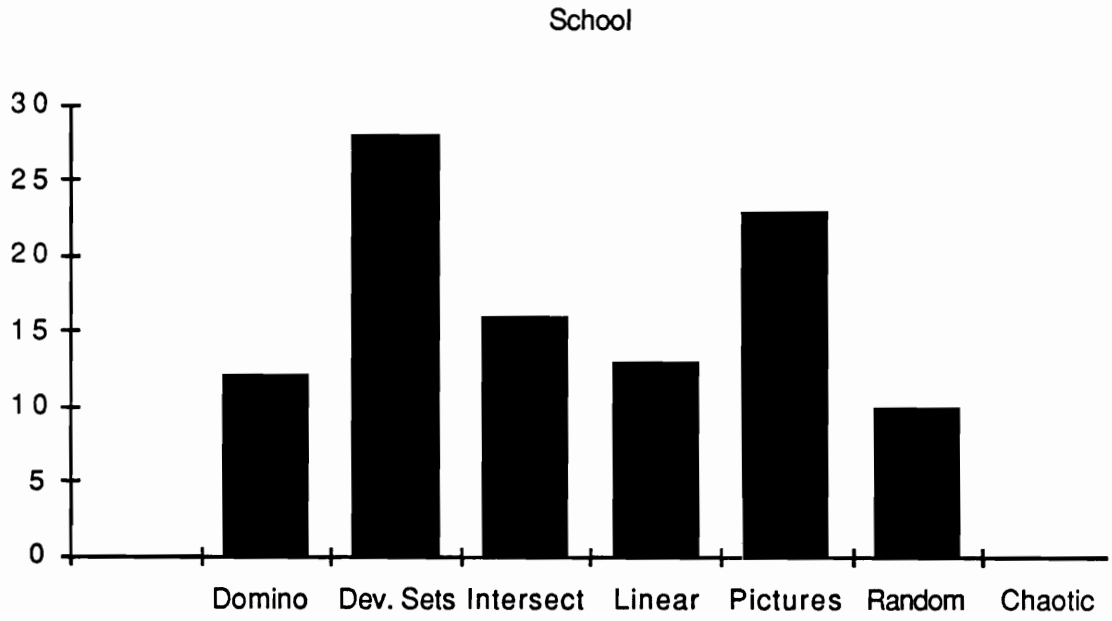


Grade 5

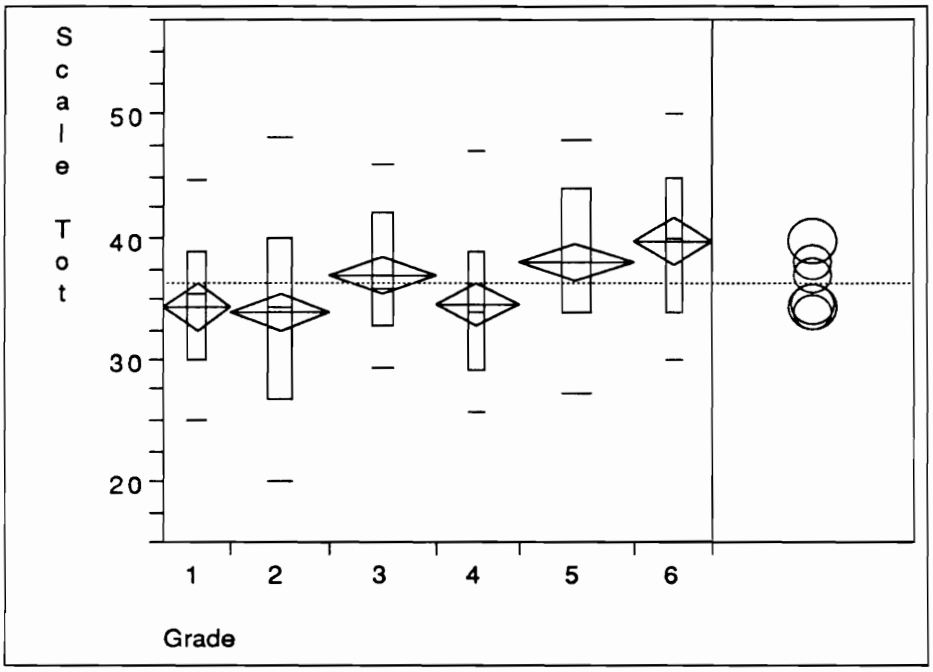


Grade 6




School
30
25
20
15
10
5
0
Domino
Dev. Sets
Intersect
Linear
Pictures
Random
Chaotic

ANOVA of Imagery Scores by Grade



Means with 95% confid.interval
Quantiles: 90%,75%,50%,25%,10%
Means Comparison Circles, 95%

Means

Summary of Fit

Rsquare	.0684394
Root Mean Square Error	7.678270
Mean of Response	36.39344
Observations (or Sum Wgts)	427

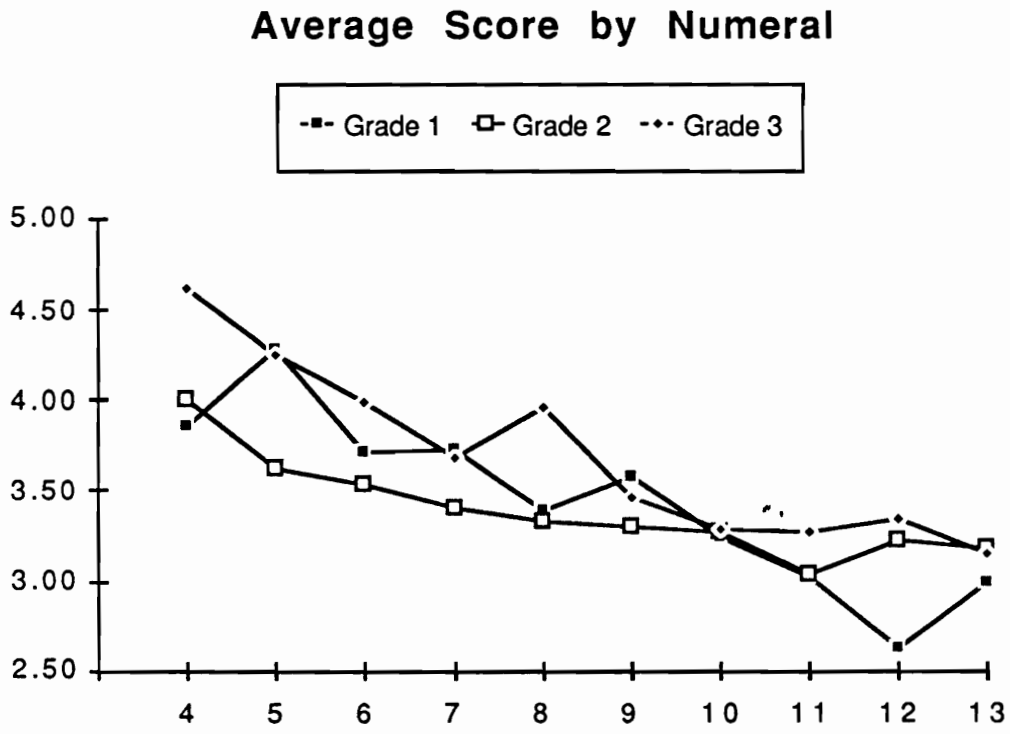
Analysis of Variance

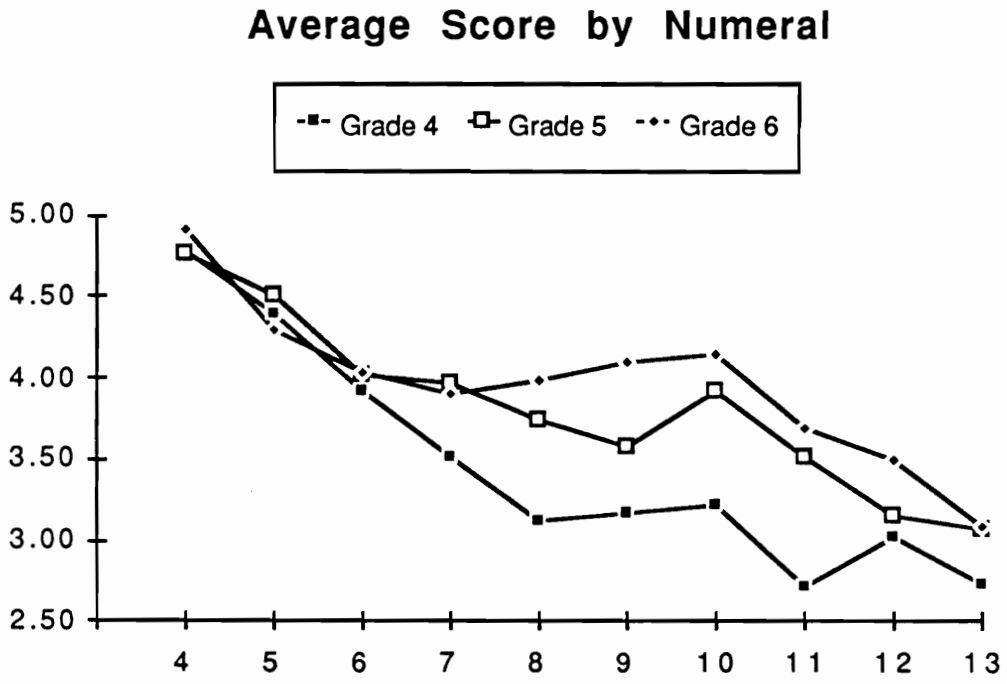
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	1823.493	364.699	6.1860
Error	421	24820.408	58.956	Prob > F
C Total	426	26643.902		0.0000

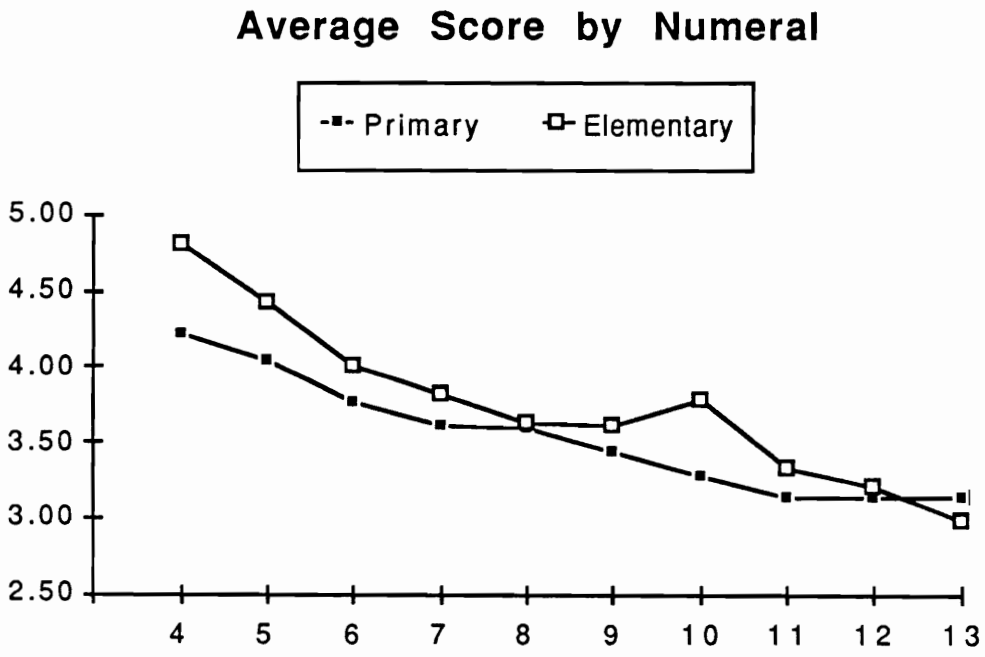
Mean Estimates

Level	number	Mean	Std Error
1	52	34.4615	1.0648
2	78	33.9487	0.8694
3	82	37.0244	0.8479
4	65	34.6154	0.9524
5	91	38.1538	0.8049
6	59	39.6949	0.9996

Average Imagery Score by Numeral




Average Score by Numeral
Grade 4
Grade 5
Grade 6
5.00
4.50
4.00
3.50
3.00
2.50
4
5
6
7
8
9
10
11
12
13


Average Score by Numeral
Primary
Elementary
5.00
4.50
4.00
3.50
3.00
2.50
4
5
6
7
8
9
10
11
12
13

Appendix D

Multiple Regression Models

School Regression Model for Response: Imagery Score

Summary of Fit

Rsquare	.1585418
Root Mean Square Error	7.350393
Mean of Response	36.32057
Observations (or Sum Wgts)	418

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	251	13333.395	53.1211	0.9577
Pure Error	158	8764.174	55.4695	Prob > F
Total Error	409	22097.568		0.6226

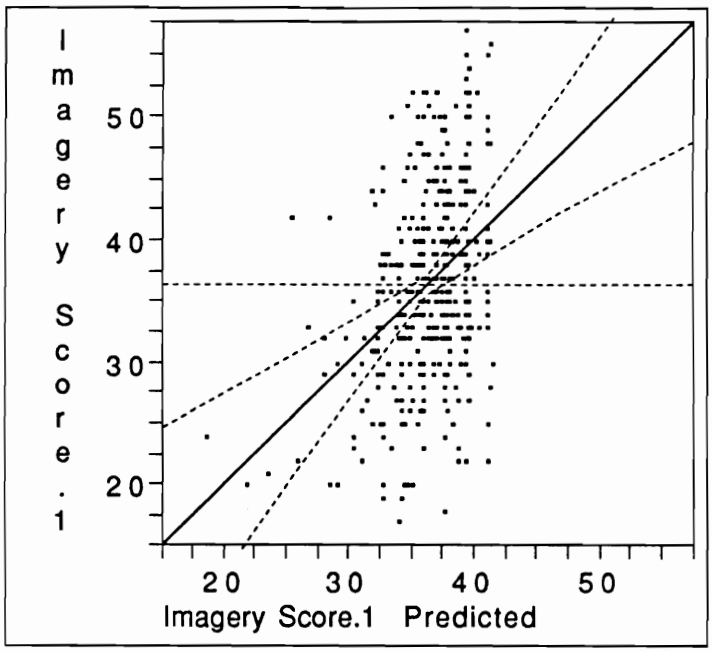
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	19.560171	2.94200	6.65	0.0000
Grade[2]	.98237256	1.63701	0.60	0.5488
Grade[3]	2.1331294	1.18964	1.79	0.0737
Grade[4]	-2.748110	1.32397	-2.08	0.0385
Grade[5]	3.5918935	1.21526	2.96	0.0033
Grade[6]	1.7003458	1.24318	1.37	0.1721
gender[0-1]	.85532700	.367070	2.33	0.0203
Adding	-.0387850	.025657	-1.51	0.1314
Accuracy	.37866550	.062968	6.01	0.0000

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Grade	5	5	1174.1696	4.3465	0.0007
gender	1	1	293.3502	5.4296	0.0203
Adding	1	1	123.4612	2.2851	0.1314
Accuracy	1	1	1953.8191	36.1629	0.0000

Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	4163.475	520.434	9.6326
Error	409	22097.568	54.028	Prob > F
C Total	417	26261.043		0.0000

Grades 1-3 Regression Model for Response: Imagery Score

Summary of Fit

Rsquare	.1985483
Root Mean Square Error	7.112452
Mean of Response	35.12621
Observations (or Sum Wgts)	206

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	171	9044.475	52.8917	1.4486
Pure Error	28	1022.333	36.5119	Prob > F
Total Error	199	10066.808		0.1239

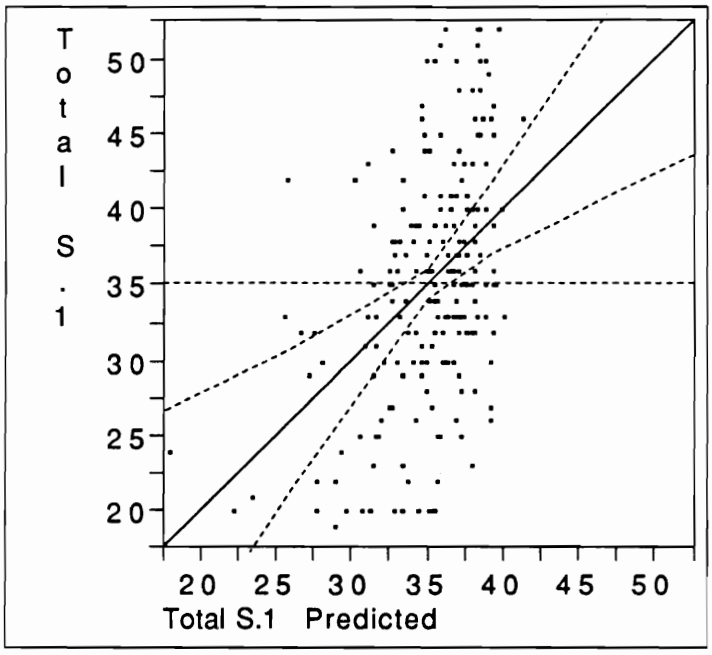
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	20.420989	3.09717	6.59	0.0000
gender[0-1]	.77808892	.519104	1.50	0.1355
Econ L[1]	-1.739947	1.12328	-1.55	0.1230
Econ L[2]	-2.467353	1.56210	-1.58	0.1158
Percentile	.04042083	.019226	2.10	0.0368
Handedne[0-1]	1.6435508	1.01661	1.62	0.1075
Accuracy	.35582592	.066676	5.34	0.0000

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
gender	1	1	113.6546	2.2467	0.1355
Econ L	2	2	321.3382	3.1761	0.0439
Percentile	1	1	223.5801	4.4197	0.0368
Handedness	1	1	132.2195	2.6137	0.1075
Accuracy	1	1	1440.6874	28.4794	0.0000

Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	2493.910	415.652	8.2166
Error	199	10066.808	50.587	Prob > F
C Total	205	12560.718		0.0000

Grades 4-6 Regression Model with Response: Imagery Score

Summary of Fit

Rsquare	.1187153
Root Mean Square Error	7.454466
Mean of Response	37.35885
Observations (or Sum Wgts)	209

Lack Of Fit

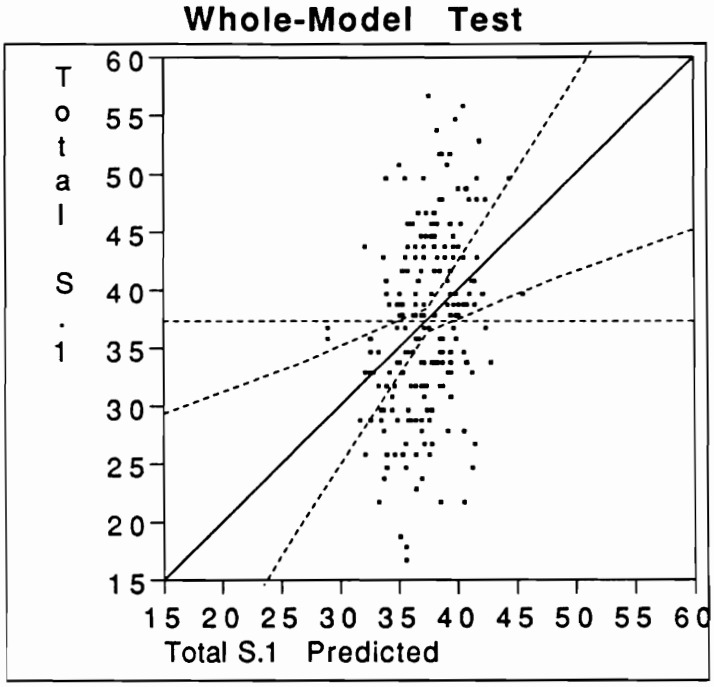
Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	177	9804.020	55.3899	0.9754
Pure Error	26	1476.500	56.7885	Prob > F
Total Error	203	11280.520		0.5627

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	10.543268	10.7331	0.98	0.3271
Gender[0-1]	1.3581236	.527604	2.57	0.0108
Age	.16223005	.045262	3.58	0.0004
Handedne[0-1]	-1.945576	.928413	-2.10	0.0374
Adding	-.1206605	.057910	-2.08	0.0385
Accuracy	.31598342	.172614	1.83	0.0686

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Gender	1	1	368.20958	6.6262	0.0108
Age	1	1	713.86480	12.8464	0.0004
Handedness	1	1	244.03194	4.3915	0.0374
Adding	1	1	241.23766	4.3412	0.0385
Accuracy	1	1	186.21118	3.3510	0.0686



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	1519.566	303.913	5.4691
Error	203	11280.520	55.569	Prob > F
C Total	208	12800.086		0.0001

First Grade Regression Model for Response: Imagery Score

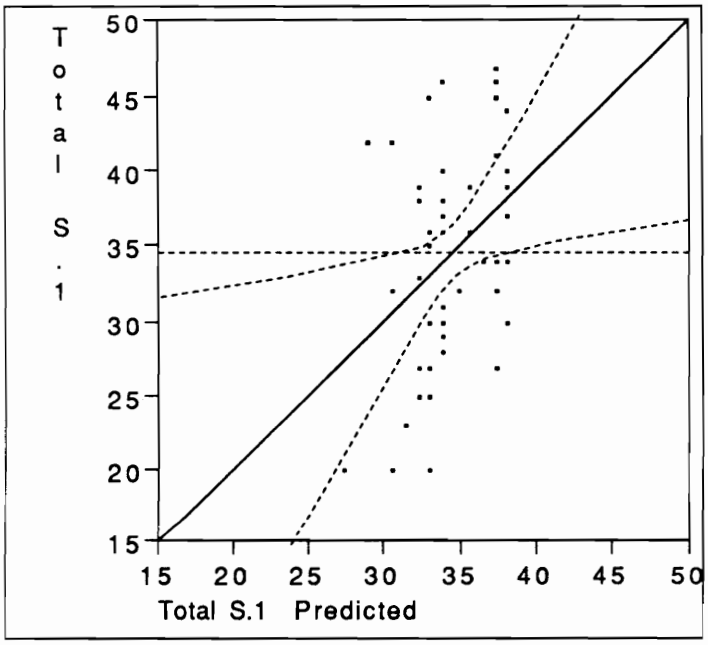
Summary of Fit

Rsquare	.1530910
Root Mean Square Error	6.465935
Mean of Response	34.46153
Observations (or Sum Wgts)	52

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
gender	1	1	222.06514	5.3115	0.0255
Accuracy	1	1	99.16124	2.3718	0.1300

Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	370.3156	185.158	4.4287
Error	49	2048.6075	41.808	Prob > F
C Total	51	2418.9231		0.0171

Second Grade Regression Model for Response: Imagery Score

Summary of Fit

Rsquare	.3521642
Root Mean Square Error	7.369524
Mean of Response	33.94871
Observations (or Sum Wgts)	78

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	58	2915.7887	50.2722	0.7190
Pure Error	15	1048.8333	69.9222	Prob > F
Total Error	73	3964.6220		0.8172

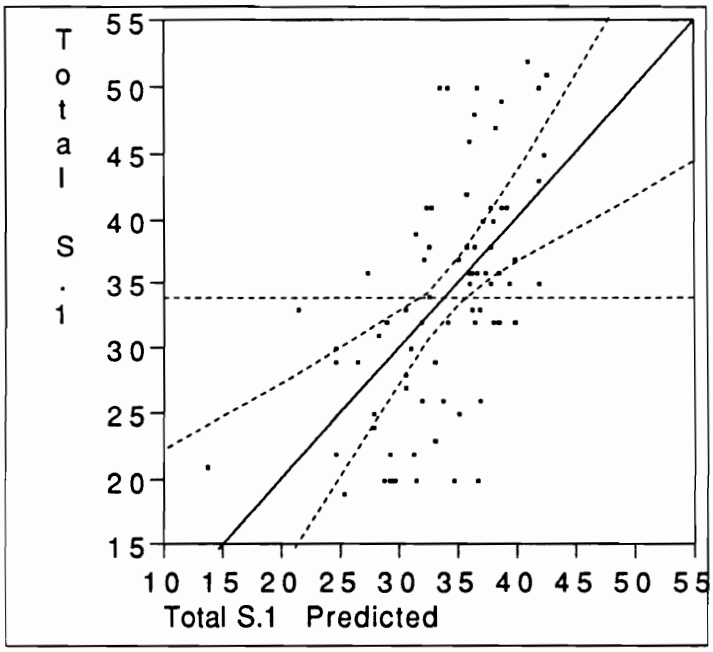
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	41.088963	13.9781	2.94	0.0044
Econ L[1]	-2.885317	1.85266	-1.56	0.1237
Econ L[2]	-5.044123	3.06007	-1.65	0.1036
Age	-.3197562	.131521	-2.43	0.0175
Accuracy	.60085749	.107545	5.59	0.0000

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Econ L	2	2	360.5849	3.3197	0.0417
Age	1	1	321.0163	5.9108	0.0175
Accuracy	1	1	1695.2562	31.2145	0.0000

Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	2155.1729	538.793	9.9207
Error	73	3964.6220	54.310	Prob > F
C Total	77	6119.7949		0.0000

Third Grade Regression Model for Response: Imagery Score

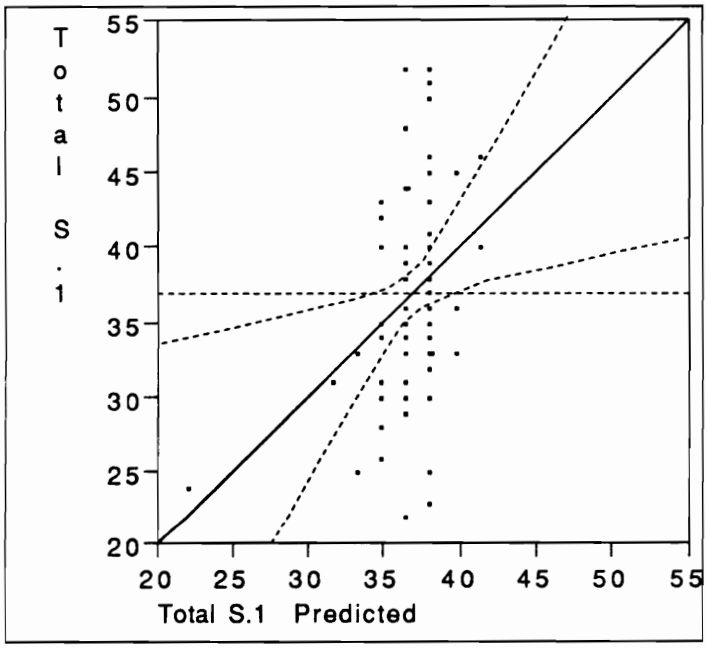
Summary of Fit

Rsquare	.1126973
Root Mean Square Error	6.603945
Mean of Response	36.95061
Observations (or Sum Wgts)	81

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Handedness	1	1	73.42851	1.6837	0.1983
Accuracy	1	1	379.43079	8.7001	0.0042

Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	432.0595	216.030	4.9534
Error	78	3401.7430	43.612	Prob > F
C Total	80	3833.8025		0.0094

Fourth Grade Regression Model for Response: Imagery Score

Summary of Fit

Rsquare	.1013802
Root Mean Square Error	7.183665
Mean of Response	34.35483
Observations (or Sum Wgts)	62

Lack Of Fit

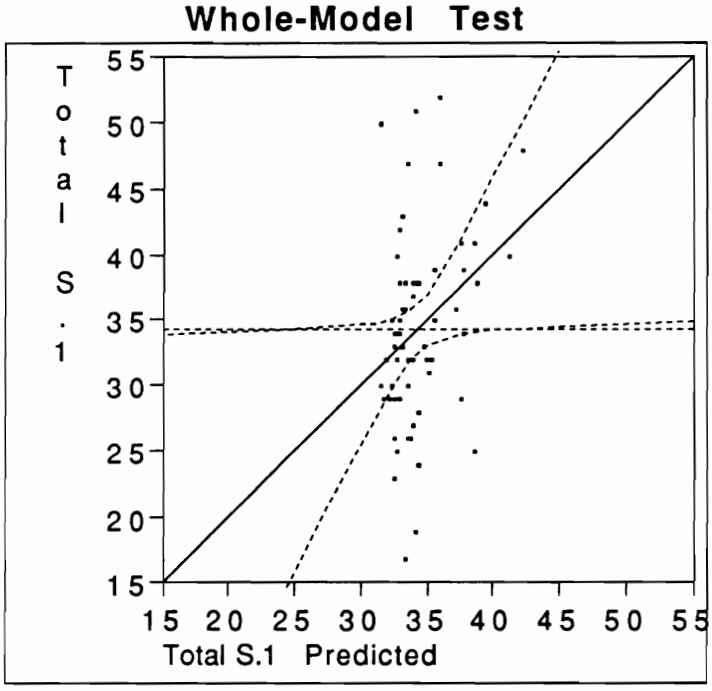
Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	47	2408.8642	51.2524	0.9673
Pure Error	12	635.8333	52.9861	Prob > F
Total Error	59	3044.6976		0.5648

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	25.644493	18.3354	1.40	0.1672
Age	.18706107	.129366	1.45	0.1535
Adding	-.1500898	.079129	-1.90	0.0628

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Age	1	1	107.89878	2.0909	0.1535
Adding	1	1	185.65946	3.5977	0.0628



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	343.4960	171.748	3.3281
Error	59	3044.6976	51.605	Prob > F
C Total	61	3388.1935		0.0427

Fifth Grade Regression Model for Response: Imagery Score

Summary of Fit

Rsquare	.1356450
Root Mean Square Error	7.191708
Mean of Response	38.15384
Observations (or Sum Wgts)	91

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	7	226.2873	32.3268	0.6052
Pure Error	80	4273.4114	53.4176	Prob > F
Total Error	87	4499.6987		0.7500

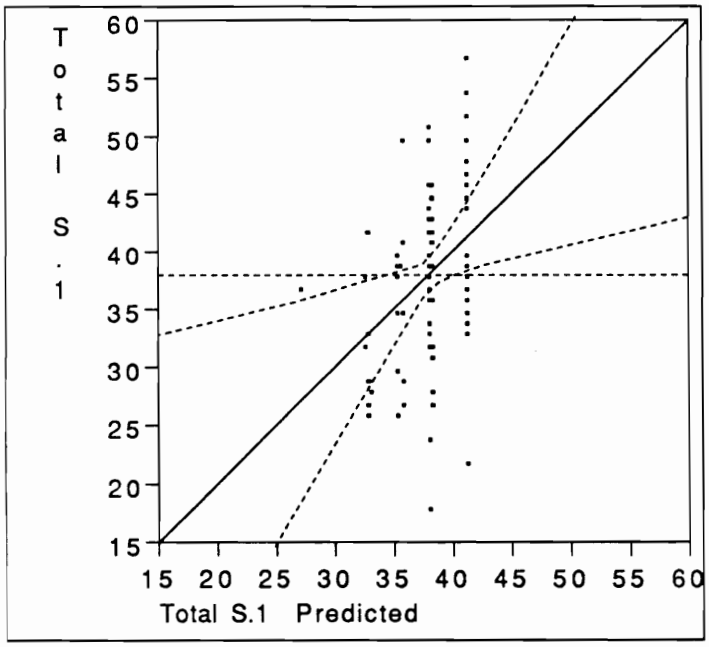
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	10.726532	11.9466	0.90	0.3717
Gender[1]	-3.018677	1.51063	-2.00	0.0488
Handedne[0-1]	-2.655843	1.15741	-2.29	0.0242
Accuracy	.55573048	.245369	2.26	0.0260

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Gender	1	1	206.52800	3.9931	0.0488
Handedness	1	1	272.32555	5.2653	0.0242
Accuracy	1	1	265.30895	5.1296	0.0260

Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	706.1475	235.382	4.5510
Error	87	4499.6987	51.721	Prob > F
C Total	90	5205.8462		0.0052

Sixth Grade Regression Model for Response: Imagery Score

Summary of Fit

Rsquare	.1006666
Root Mean Square Error	7.412473
Mean of Response	39.43103
Observations (or Sum Wgts)	58

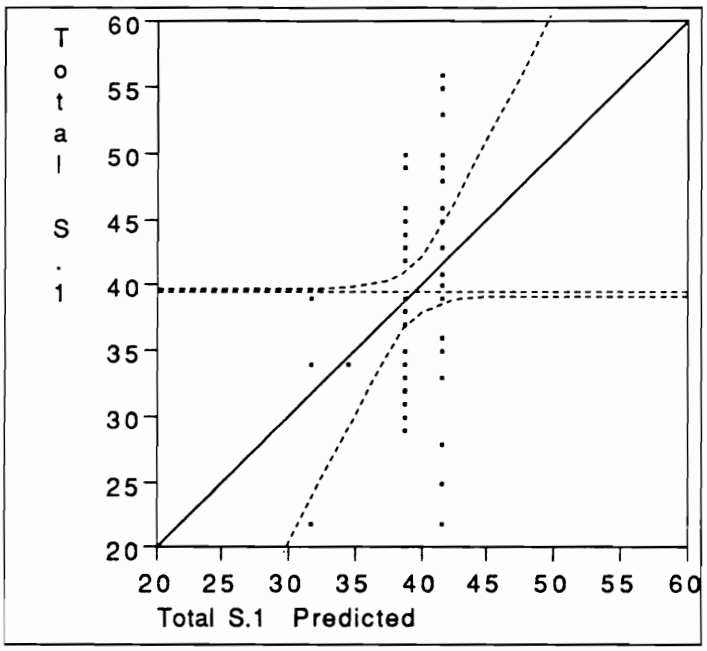
Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	1	0.2275	0.2275	0.0041
Pure Error	54	3021.7343	55.9580	Prob > F
Total Error	55	3021.9618		0.9494

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Gender	1	1	116.71414	2.1242	0.1507
Handedness	1	1	185.62234	3.3783	0.0715

Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	338.2623	169.131	3.0782
Error	55	3021.9618	54.945	**Prob > F**
C Total	57	3360.2241		0.0541

Imagery Score Regression Equations for:

School

$$19.5601715 + \left(\begin{cases} 5.65963120, & \text{if } Grade=6 \\ 3.95928535, & \text{if } Grade=5 \\ .367391761, & \text{if } Grade=4 \\ 3.11550198, & \text{if } Grade=3 \\ .982372568, & \text{if } Grade=2 \\ 0, & \text{if } Grade=1 \\ \bullet, & \text{otherwise} \end{cases} \right)$$

$$+ \left(\begin{cases} -.85532700, & \text{if } gender=1 \\ .855327002, & \text{if } gender=0 \\ \bullet, & \text{otherwise} \end{cases} \right) + -.03878507 \bullet Adding +$$

$$.378665505 \bullet Accuracy = Imagery\ Score.1$$

Grades 1-3

$$20.4209895 + \left(\begin{cases} -.77808892, & \text{if } gender=1 \\ .778088929, & \text{if } gender=0 \\ \bullet, & \text{otherwise} \end{cases} \right)$$

$$+ \left(\begin{cases} -4.2073016, & \text{if } Econ\ L=2 \\ -1.7399478, & \text{if } Econ\ L=1 \\ 0, & \text{if } Econ\ L=0 \\ \bullet, & \text{otherwise} \end{cases} \right) + .040420838 \bullet Math\ Percentile$$

$$+ \left(\begin{cases} -1.6435508, & \text{if } Handedness=1 \\ 1.64355089, & \text{if } Handedness=0 \\ \bullet, & \text{otherwise} \end{cases} \right) + .355825920 \bullet Accuracy = Imagery\ Score.1$$

Grades 4-6

$$35.3501933+\left(\begin{cases} 6.04085112, & \text{if } Grade=6 \\ 4.28708559, & \text{if } Grade=5 \\ 0, & \text{if } Grade=4 \\ \bullet, & \text{otherwise} \end{cases}\right) + -.16123416 \bullet Adding + .254563519 \bullet Accuracy + \left(\begin{cases} -1.2960121, & \text{if } Gender=1 \\ 1.29601217, & \text{if } Gender=0 \\ \bullet, & \text{otherwise} \end{cases}\right) + \left(\begin{cases} 2.05402510, & \text{if } Handedness=1 \\ -2.0540251, & \text{if } Handedness=0 \\ \bullet, & \text{otherwise} \end{cases}\right) = Imagery\ Score.1$$

First Grade

$$27.7162685+\left(\begin{cases} -2.1451806, & \text{if } gender=1 \\ 2.14518060, & \text{if } gender=0 \\ \bullet, & \text{otherwise} \end{cases}\right)+.165492836 \bullet Accuracy = Imagery\ Score.1$$

Sceond Grade

$$41.0889638+\left(\begin{cases} -7.9294417, & \text{if } Econ\ L=2 \\ -2.8853179, & \text{if } Econ\ L=1 \\ 0, & \text{if } Econ\ L=0 \\ \bullet, & \text{otherwise} \end{cases}\right) + -.31975627 \bullet Age + .600857493 \bullet Accuracy = Imagery\ Score.1$$

Third Grade

$$23.7961135+\left(\begin{cases} -1.6982315, & \text{if } Handedness=1 \\ 1.69823154, & \text{if } Handedness=0 \\ \bullet, & \text{otherwise} \end{cases}\right)+.317869627\bullet Accuracy$$

$$= Imagery\ Score.1$$

Fourth Grade

$$6.86397444+-.15918528\bullet Adding+.222059483\bullet Age+.323820949\bullet Accuracy$$

$$= Imagery\ Score.1$$

Fifth Grade

$$10.7265325+\left(\begin{cases} -3.0186777, & \text{if } Gender=1 \\ 0, & \text{if } Gender=0 \\ \bullet, & \text{otherwise} \end{cases}\right)+$$

$$\left(\begin{cases} 2.65584350, & \text{if } Handedness=1 \\ -2.6558435, & \text{if } Handedness=0 \\ \bullet, & \text{otherwise} \end{cases}\right)$$

$$+\ .555730485\bullet Accuracy = Imagery\ Score.1$$

Sixth Grade

$$36.5182887+\left(\begin{cases} -1.4346832, & \text{if } Gender=1 \\ 1.43468321, & \text{if } Gender=0 \\ \bullet, & \text{otherwise} \end{cases}\right)$$

$$+\left(\begin{cases} 3.55094709, & \text{if } Handedness=1 \\ -3.5509470, & \text{if } Handedness=0 \\ \bullet, & \text{otherwise} \end{cases}\right) = Imagery\ Score.1$$

Regression Models with Imagery Score as the Response Variable

Correlations for School Regression Model

Correlations

Variable	Grade	gender	Adding	Accuracy
Grade	1.0000	-0.0739	0.7088	0.3134
gender	-0.0739	1.0000	-0.1403	-0.0960
Adding	0.7088	-0.1403	1.0000	0.3124
Accuracy	0.3134	-0.0960	0.3124	1.0000

Inverse Corr

Variable	Grade	gender	Adding	Accuracy
Grade	2.0520	-0.0647	-1.3970	-0.2128
gender	-0.0647	1.0253	0.1691	0.0659
Adding	-1.3970	0.1691	2.0745	-0.1941
Accuracy	-0.2128	0.0659	-0.1941	1.1336

Correlations for Grades 1-3 Regression Model

Correlations

Variable	gender	Econ L	Math	Percentile	Handedness	Accuracy
gender	1.0000	-0.1510	-0.0016	-0.1408	-0.0622	
Econ L	-0.1510	1.0000	0.3341	0.1376	0.0551	
Math Percentile	-0.0016	0.3341	1.0000	0.1846	0.2686	
Handedness	-0.1408	0.1376	0.1846	1.0000	-0.0104	
Accuracy	-0.0622	0.0551	0.2686	-0.0104	1.0000	

Inverse Corr

Variable	gender	Econ L	Math	Percentile	Handedness	Accuracy
gender	1.0511	0.1689	-0.1045	0.1449	0.0856	
Econ L	0.1689	1.1616	-0.3896	-0.0637	0.0505	
Math Percentile	-0.1045	-0.3896	1.2530	-0.1957	-0.3236	
Handedness	0.1449	-0.0637	-0.1957	1.0661	0.0761	
Accuracy	0.0856	0.0505	-0.3236	0.0761	1.0903	

Correlations for Grades 4-6 Regression Model

Correlations

Variable	Gender	Age	Handedness	Adding	Accuracy
Gender	1.0000	0.1188	-0.0747	-0.1066	-0.1064
Age	0.1188	1.0000	-0.0602	0.0811	0.0272
Handedness	-0.0747	-0.0602	1.0000	0.1076	-0.0210
Adding	-0.1066	0.0811	0.1076	1.0000	0.1162
Accuracy	-0.1064	0.0272	-0.0210	0.1162	1.0000

Inverse Corr

Variable	Gender	Age	Handedness	Adding	Accuracy
Gender	1.0422	-0.1313	0.0610	0.1031	0.1037
Age	-0.1313	1.0283	0.0624	-0.1007	-0.0289
Handedness	0.0610	0.0624	1.0213	-0.1130	0.0393
Adding	0.1031	-0.1007	-0.1130	1.0441	-0.1100
Accuracy	0.1037	-0.0289	0.0393	-0.1100	1.0254

Correlations for First Grade Regression Model

Correlations

Variable	gender	Accuracy
gender	1.0000	-0.1407
Accuracy	-0.1407	1.0000

Inverse Corr

Variable	gender	Accuracy
gender	1.0202	0.1435
Accuracy	0.1435	1.0202

Correlation for Second Grade Regression Model

Correlations

Variable	Econ L	Age	Accuracy
Econ L	1.0000	-0.3051	0.0475
Age	-0.3051	1.0000	-0.0027
Accuracy	0.0475	-0.0027	1.0000

Inverse Corr

Variable	Econ L	Age	Accuracy
Econ L	1.1053	0.3371	-0.0516
Age	0.3371	1.1028	-0.0130
Accuracy	-0.0516	-0.0130	1.0024

Correlations for Third Grade Regression Model

Correlations

Variable	Handedness	Accuracy
Handedness	1.0000	0.0599
Accuracy	0.0599	1.0000

Inverse Corr

Variable	Handedness	Accuracy
Handedness	1.0036	-0.0601
Accuracy	-0.0601	1.0036

Correlations for Fourth Grade Regression Model

Correlations

Variable	Age	Adding
Age	1.0000	-0.1485
Adding	-0.1485	1.0000

Inverse Corr

Variable	Age	Adding
Age	1.0226	0.1519
Adding	0.1519	1.0226

Correlations for Fifth Grade Regression Model

Correlations

Variable	Gender	Handedness	Accuracy
Gender	1.0000	0.0134	0.0232
Handedness	0.0134	1.0000	-0.0409
Accuracy	0.0232	-0.0409	1.0000

Inverse Corr

Variable	Gender	Handedness	Accuracy
Gender	1.0007	-0.0143	-0.0238
Handedness	-0.0143	1.0019	0.0414
Accuracy	-0.0238	0.0414	1.0022

Correlations for Sixth Grade Regression Model

Correlations

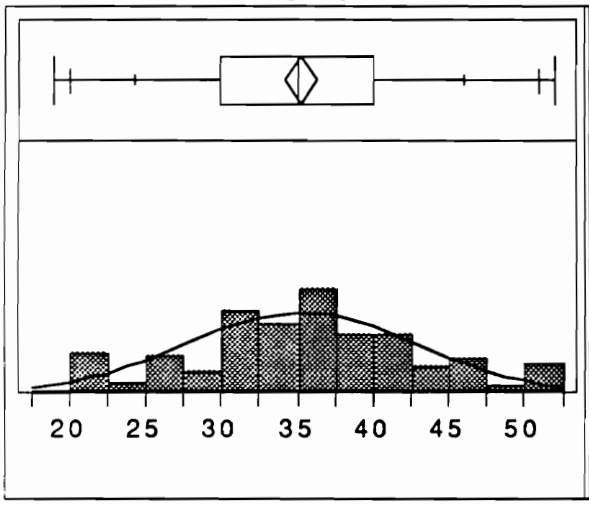
Variable	Gender	Handedness
Gender	1.0000	-0.1900
Handedness	-0.1900	1.0000

Inverse Corr

Variable	Gender	Handedness
Gender	1.0375	0.1972
Handedness	0.1972	1.0375

Distribution of Imagery Scores

School Imagery Scores



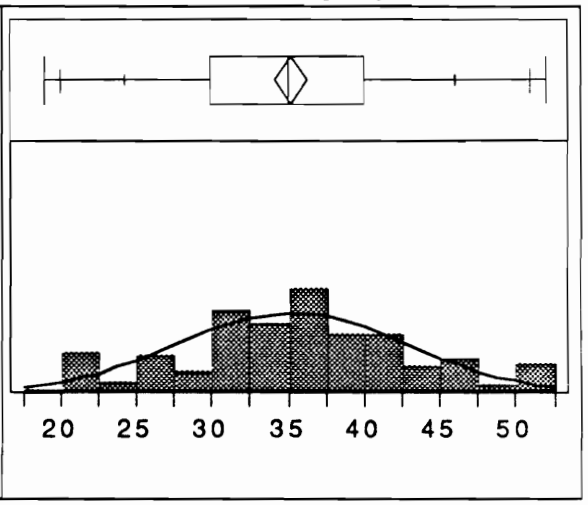
Quantiles

maximum	100.0%	57.000
	99.5%	55.860
	97.5%	52.000
	90.0%	47.000
quartile	75.0%	42.000
median	50.0%	36.000
quartile	25.0%	32.000
	10.0%	26.000
	2.5%	20.000
	0.5%	18.140
minimum	0.0%	17.000

Moments

Mean	36.3934
Std Dev	7.9085
Std Err Mean	0.3827
upper 95% Mean	37.1457
lower 95% Mean	35.6412
N	427.0000

Grade 1-3 Imagery Scores



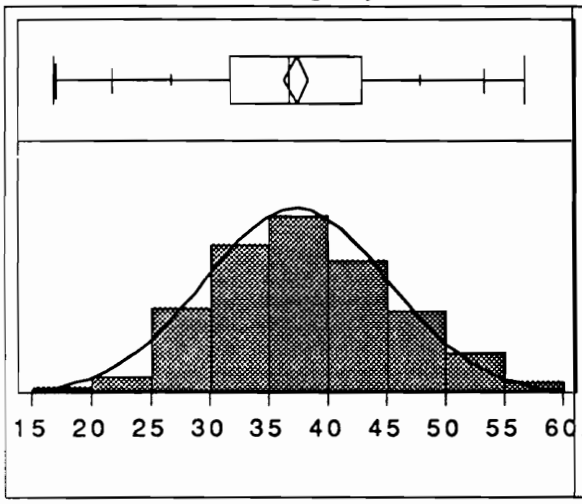
Quantiles

maximum	100.0%	52.000
	99.5%	52.000
	97.5%	51.000
	90.0%	46.000
quartile	75.0%	40.000
median	50.0%	35.000
quartile	25.0%	30.000
	10.0%	24.300
	2.5%	20.000
	0.5%	19.065
minimum	0.0%	19.000

Moments

Mean	35.2642
Std Dev	7.7982
Std Err Mean	0.5356
upper 95% Mean	36.3199
lower 95% Mean	34.2084
N	212.0000

Grade 4-6 Imagery Scores



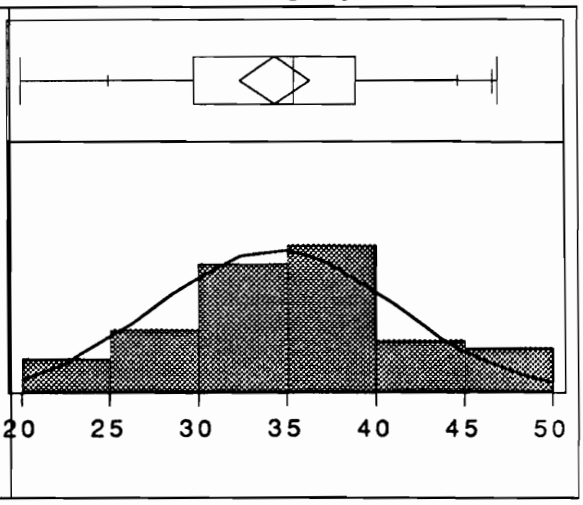
Quantiles

maximum	100.0%	57.000
	99.5%	56.920
	97.5%	53.600
	90.0%	48.000
quartile	75.0%	43.000
median	50.0%	37.000
quartile	25.0%	32.000
	10.0%	27.000
	2.5%	22.000
	0.5%	17.080
minimum	0.0%	17.000

Moments

Mean	37.5070
Std Dev	7.8763
Std Err Mean	0.5372
upper 95% Mean	38.5658
lower 95% Mean	36.4482
N	215.0000
Sum Wgts	215.0000

Grade 1 Imagery Scores



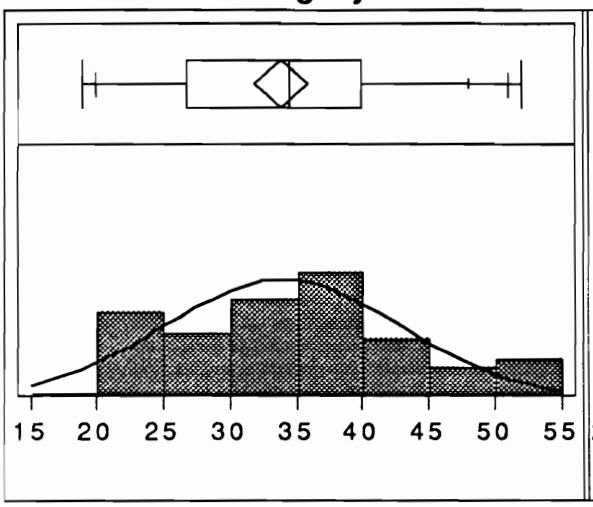
Quantiles

maximum	100.0%	47.000
	99.5%	47.000
	97.5%	46.675
	90.0%	44.700
quartile	75.0%	39.000
median	50.0%	35.500
quartile	25.0%	30.000
	10.0%	25.000
	2.5%	20.000
	0.5%	20.000
minimum	0.0%	20.000

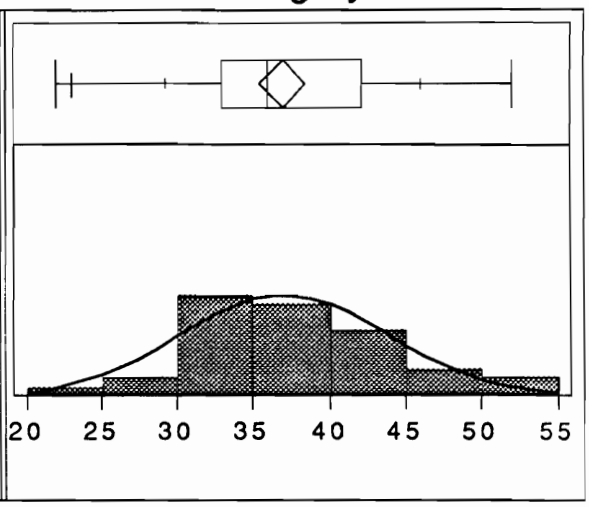
Moments

Mean	34.46154
Std Dev	6.88693
Std Err Mean	0.95505
upper 95% Mean	36.37887
lower 95% Mean	32.54421
N	52.00000
Sum Wgts	52.00000

Grade 2 Imagery Scores



Grade 3 Imagery Scores



Quantiles

maximum	100.0%	52.000
	99.5%	52.000
	97.5%	51.025
	90.0%	48.100
quartile	75.0%	40.000
median	50.0%	34.500
quartile	25.0%	26.750
	10.0%	20.000
	2.5%	19.975
	0.5%	19.000
minimum	0.0%	19.000

Quantiles

maximum	100.0%	52.000
	99.5%	52.000
	97.5%	52.000
	90.0%	46.000
quartile	75.0%	42.250
median	50.0%	36.000
quartile	25.0%	33.000
	10.0%	29.300
	2.5%	23.075
	0.5%	22.000
minimum	0.0%	22.000

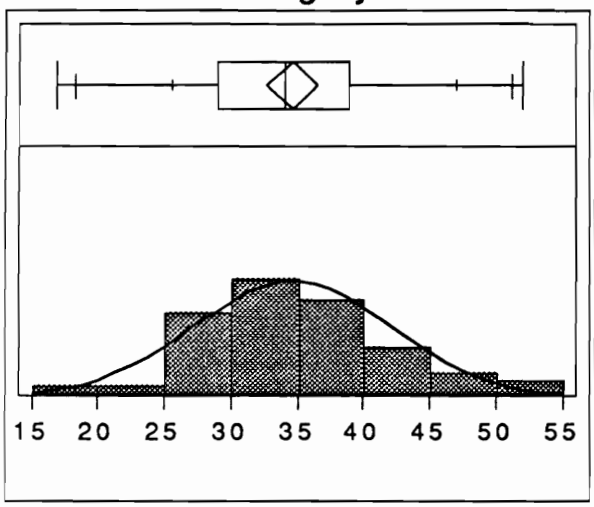
Moments

Mean	33.94872
Std Dev	8.91504
Std Err Mean	1.00943
upper 95% Mean	35.95875
lower 95% Mean	31.93868
N	78.00000
Sum Wgts	78.00000

Moments

Mean	37.02439
Std Dev	6.91210
Std Err Mean	0.76331
upper 95% Mean	38.54315
lower 95% Mean	35.50563
N	82.00000
Sum Wgts	82.00000

Grade 4 Imagery Scores



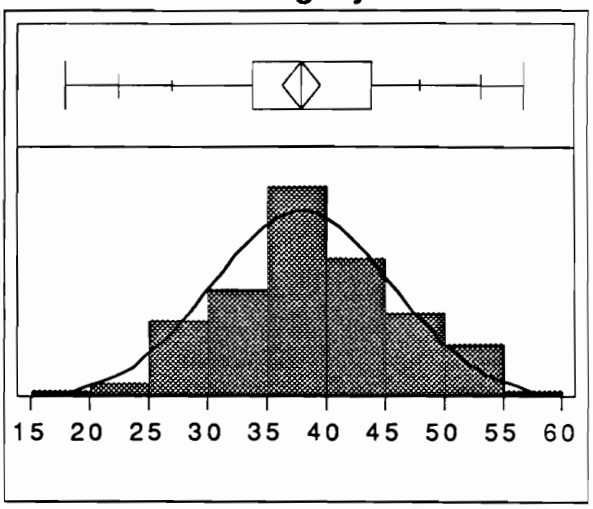
Quantiles

maximum	100.0%	52.000
	99.5%	52.000
	97.5%	51.350
	90.0%	47.000
quartile	75.0%	39.000
median	50.0%	34.000
quartile	25.0%	29.000
	10.0%	25.600
	2.5%	18.300
	0.5%	17.000
minimum	0.0%	17.000

Moments

Mean	34.61538
Std Dev	7.50769
Std Err Mean	0.93121
upper 95% Mean	36.47570
lower 95% Mean	32.75507
N	65.00000
Sum Wgts	65.00000

Grade 5 Imagery Scores



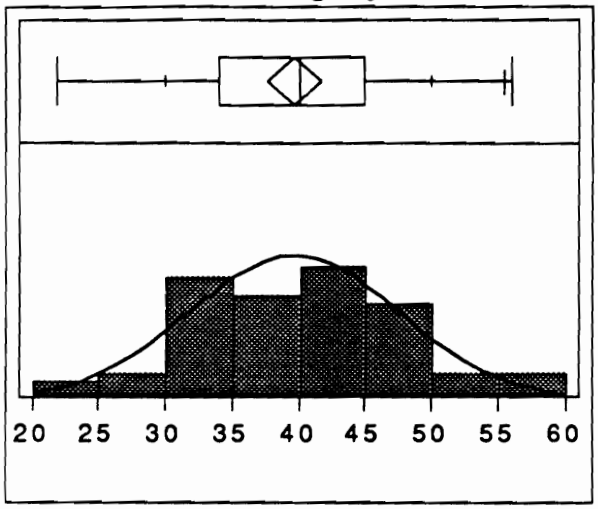
Quantiles

maximum	100.0%	57.000
	99.5%	57.000
	97.5%	53.400
	90.0%	48.000
quartile	75.0%	44.000
median	50.0%	38.000
quartile	25.0%	34.000
	10.0%	27.200
	2.5%	22.600
	0.5%	18.000
minimum	0.0%	18.000

Moments

Mean	38.15385
Std Dev	7.60544
Std Err Mean	0.79727
upper 95% Mean	39.73776
lower 95% Mean	36.56993
N	91.00000
Sum Wgts	91.00000

Grade 6 Imagery Scores



Quantiles

maximum	100.0%	56.000
	99.5%	56.000
	97.5%	55.500
	90.0%	50.000
quartile	75.0%	45.000
median	50.0%	40.000
quartile	25.0%	34.000
	10.0%	30.000
	2.5%	22.000
	0.5%	22.000
minimum	0.0%	22.000

Moments

Mean	39.69492
Std Dev	7.87675
Std Err Mean	1.02547
upper 95% Mean	41.74761
lower 95% Mean	37.64222
N	59.00000
Sum Wgts	59.00000

Nine Regression Models with Imagery Total Score as Response Variable

	Schoo l	Gr.1-3	Gr4-6	Gr 1	Gr 2	Gr 3	Gr 4	Gr 5	Gr 6
R square	.13	.20	.12	.15	.35	.11	.10	.14	.10
DF	8,409	6,199	5,203	2,49	4,73	2,78	2,59	3,87	2,55
F Ratio	9.63	8.22	5.47	4.43	9.92	4.95	3.33	4.55	3.08
MSe	54.028	50.587	55.569	41.808	54.310	43.612	51.605	51.721	54.945
Prob > F	.00	.00	.00	.02	.00	.01	.04	.01	.15
Variables:	**with corresponding P-values**								
Gender	.02	.14	.01	.03	•	•	•	.05	.15
IQ	•	•	•	•	•	•	•	•	•
Math L.	•	•	•	•	•	•	•	•	•
Econ. L.	•	.04	•	•	.04	•	•	•	•
Grade	•	•	•	•	•	•	•	•	•
Age	.00	•	.00	•	.01	•	.15	•	•
Math %tile	•	.04	•	•	•	•	•	•	•
Handedness	•	.11	.04	•	•	.20	•	.02	.07
Spec Ed	•	•	•	•	•	•	•	•	•
Adding	.06	•	.04	•	•	•	.06	•	•
Accuracy	.00	.00	.07	.13	.00	.00	•	.03	•

First Grade Regression Model for Response: Adding

Summary of Fit

Rsquare	.6489289
Root Mean Square Error	8.831173
Mean of Response	37.53061
Observations (or Sum Wgts)	49

Lack Of Fit

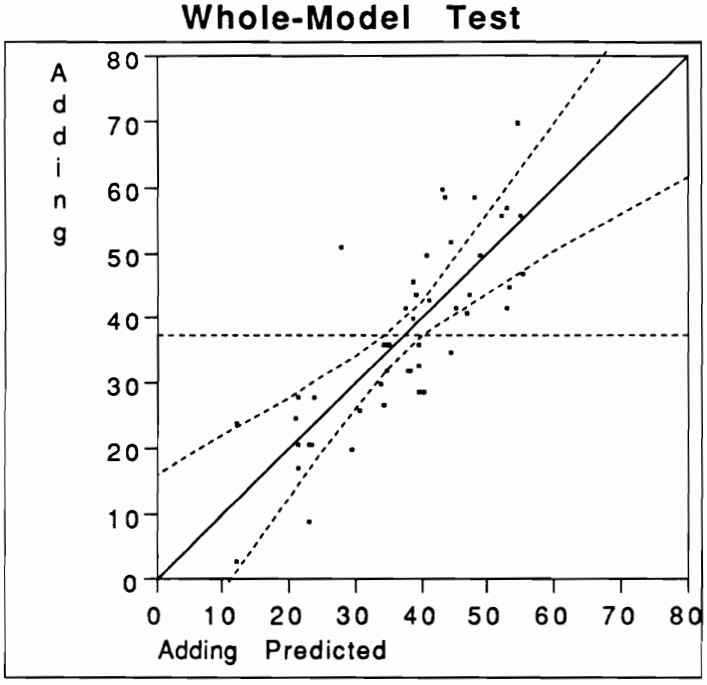
Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	35	2927.3977	83.6399	1.6816
Pure Error	7	348.1667	49.7381	Prob > F
Total Error	42	3275.5644		0.2442

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-7.831545	10.7637	-0.73	0.4709
IQ	.44543110	0.12603	3.53	0.0010
Math L[1]	11.780029	3.94408	2.99	0.0047
Math L[2]	9.8640927	3.21777	3.07	0.0038
Econ L[1]	-7.119050	3.19988	-2.22	0.0315
Econ L[2]	-2.241113	3.85754	-0.58	0.5644
Spec Ed[0-1]	6.4197727	3.49651	1.84	0.0734

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
IQ	1	1	974.2041	12.4915	0.0010
Math L	2	2	1679.3674	10.7666	0.0002
Econ L	2	2	523.8510	3.3585	0.0444
Spec Ed	1	1	262.9084	3.3711	0.0734



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	6054.6397	1009.11	12.9390
Error	42	3275.5644	77.99	Prob > F
C Total	48	9330.2041		0.0000

Adding Regression Equations for:

First Grade

$$-7.8315458+.445431108 \cdot IQ+\left(\begin{cases} 21.6441222, & \text{if } Math\ L=2 \\ 11.7800294, & \text{if } Math\ L=1 \\ 0, & \text{if } Math\ L=0 \\ \bullet, & \text{otherwise} \end{cases}\right)$$

$$+\left(\begin{cases} -9.3601647, & \text{if } Econ\ L=2 \\ -7.1190509, & \text{if } Econ\ L=1 \\ 0, & \text{if } Econ\ L=0 \\ \bullet, & \text{otherwise} \end{cases}\right)$$

$$+\left(\begin{cases} -6.4197727, & \text{if } Spec\ Ed=1 \\ 6.41977273, & \text{if } Spec\ Ed=0 \\ \bullet, & \text{otherwise} \end{cases}\right) = Adding$$

Regression Model with Adding as the Response Variable

Correlations for First Grade Regression Model
Correlations

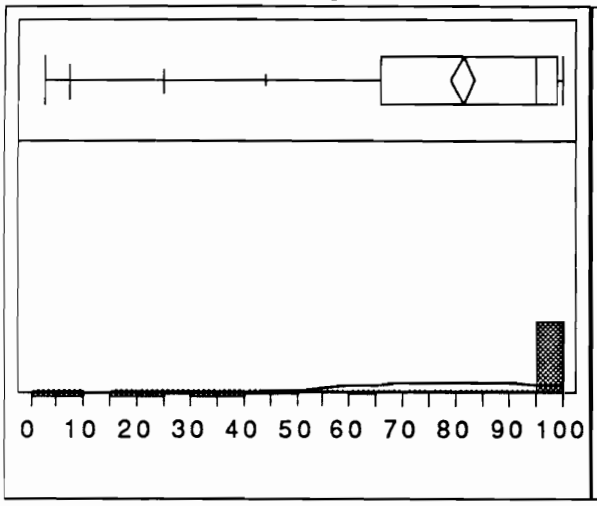
Variable	IQ	Math L	Econ L	Spec Ed
IQ	1.0000	0.6599	0.6061	0.2286
Math L	0.6599	1.0000	0.5820	0.2871
Econ L	0.6061	0.5820	1.0000	0.2112
Spec Ed	0.2286	0.2871	0.2112	1.0000

Inverse Corr

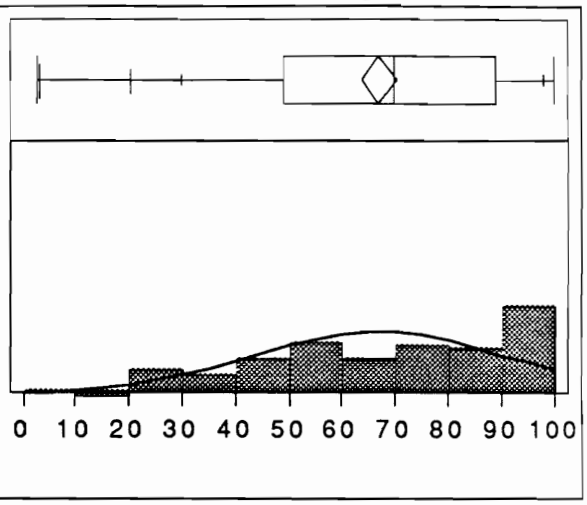
Variable	IQ	Math L	Econ L	Spec Ed
IQ	2.0435	-0.9355	-0.6827	-0.0542
Math L	-0.9355	2.0079	-0.5495	-0.2467
Econ L	-0.6827	-0.5495	1.7452	-0.0548
Spec Ed	-0.0542	-0.2467	-0.0548	1.0948

Distribution of Adding Scores

School Adding Scores



Grades 1-3 Adding Scores



Quantiles

maximum	100.0%	100.00
	99.5%	100.00
	97.5%	100.00
	90.0%	100.00
quartile	75.0%	99.00
median	50.0%	95.00
quartile	25.0%	65.75
	10.0%	44.10
	2.5%	24.78
	0.5%	7.31
minimum	0.0%	3.00

Quantiles

maximum	100.0%	100.00
	99.5%	100.00
	97.5%	100.00
	90.0%	98.00
quartile	75.0%	89.00
median	50.0%	70.00
quartile	25.0%	49.00
	10.0%	30.00
	2.5%	20.40
	0.5%	3.32
minimum	0.0%	3.00

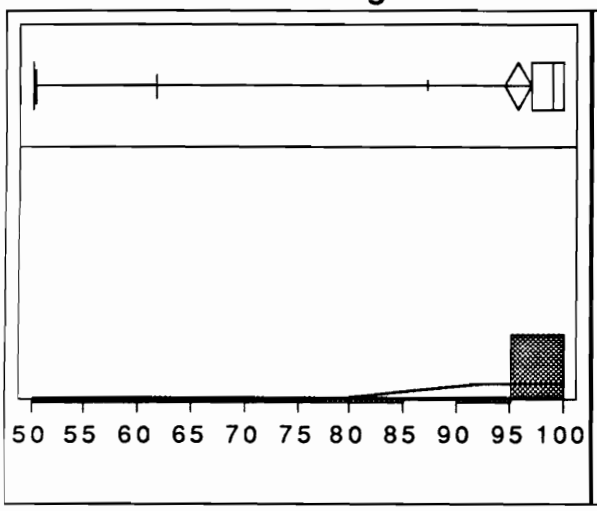
Moments

Mean	81.4140
Std Dev	23.4612
Std Err Mean	1.1314
upper 95% Mean	83.6378
lower 95% Mean	79.1901
N	430.0000

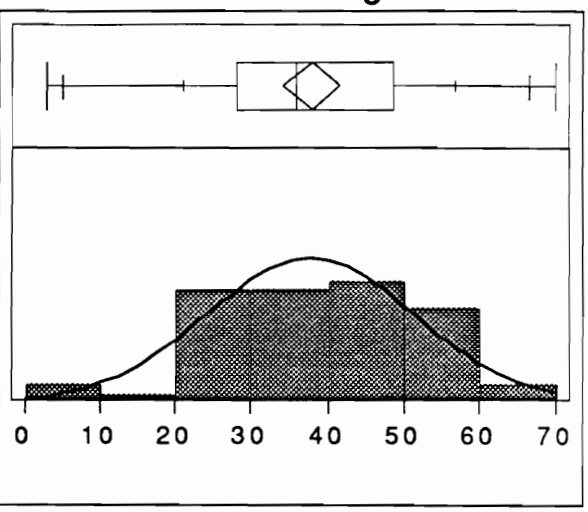
Moments

Mean	66.9395
Std Dev	24.5237
Std Err Mean	1.6725
upper 95% Mean	70.2363
lower 95% Mean	63.6428
N	215.0000

Grades 4-6 Adding Scores



First Grade Adding Scores



Quantiles

maximum	100.0%	100.00
	99.5%	100.00
	97.5%	100.00
	90.0%	100.00
quartile	75.0%	100.00
median	50.0%	99.00
quartile	25.0%	97.00
	10.0%	87.20
	2.5%	61.80
	0.5%	50.32
minimum	0.0%	50.00

Quantiles

maximum	100.0%	70.000
	99.5%	70.000
	97.5%	66.750
	90.0%	56.700
quartile	75.0%	48.500
median	50.0%	36.000
quartile	25.0%	28.250
	10.0%	21.000
	2.5%	4.950
	0.5%	3.000
minimum	0.0%	3.000

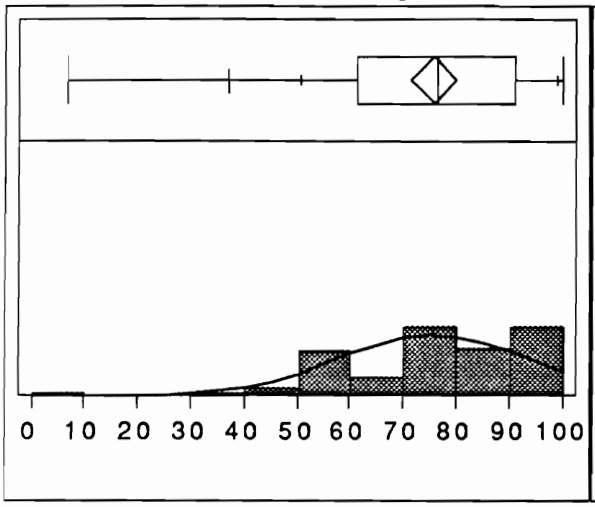
Moments

Mean	95.8884
Std Dev	9.0024
Std Err Mean	0.6140
upper 95% Mean	97.0986
lower 95% Mean	94.6782
N	215.0000

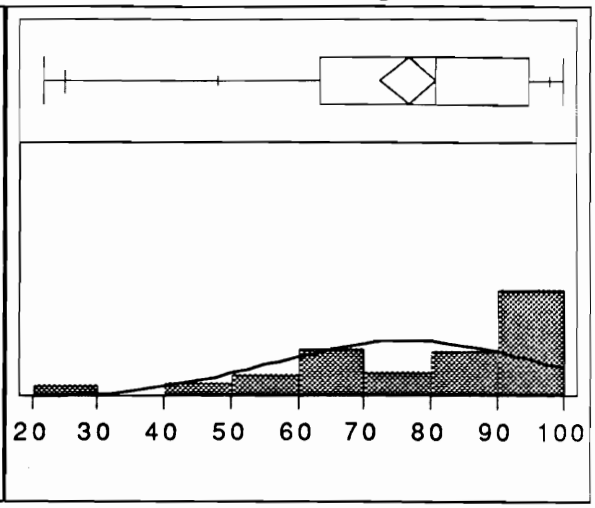
Moments

Mean	37.84615
Std Dev	13.76894
Std Err Mean	1.90941
upper 95% Mean	41.67944
lower 95% Mean	34.01286
N	52.00000

Second Grade Adding Scores



Third Grade Adding Scores



Quantiles

maximum	100.0%	100.00
	99.5%	100.00
	97.5%	100.00
	90.0%	99.00
quartile	75.0%	91.00
median	50.0%	76.50
quartile	25.0%	61.50
	10.0%	50.90
	2.5%	37.22
	0.5%	7.00
minimum	0.0%	7.00

Quantiles

maximum	100.0%	100.00
	99.5%	100.00
	97.5%	100.00
	90.0%	98.00
quartile	75.0%	95.00
median	50.0%	81.00
quartile	25.0%	63.50
	10.0%	48.20
	2.5%	25.00
	0.5%	22.00
minimum	0.0%	22.00

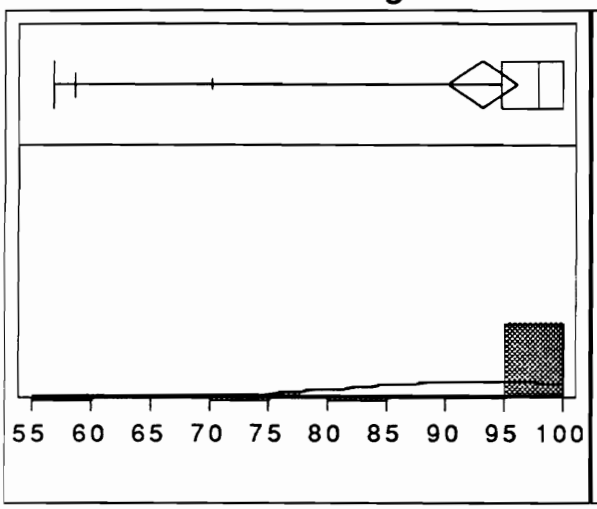
Moments

Mean	75.78205
Std Dev	18.55819
Std Err Mean	2.10130
upper 95% Mean	79.96629
lower 95% Mean	71.59781
N	78.00000

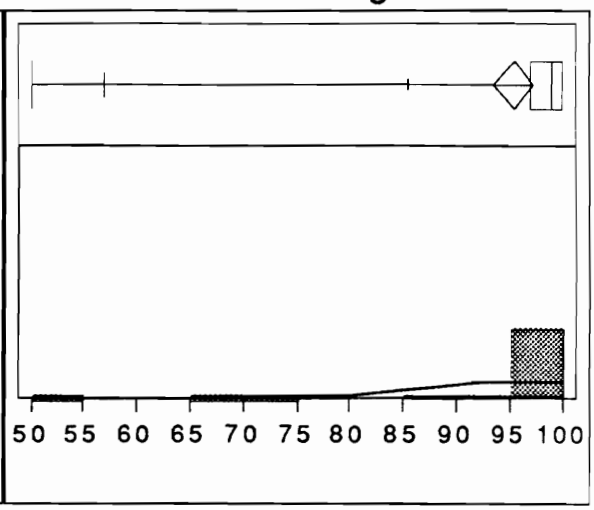
Moments

Mean	76.62353
Std Dev	20.24550
Std Err Mean	2.19593
upper 95% Mean	80.99040
lower 95% Mean	72.25666
N	85.00000

Fourth Grade Adding Scores



Fifth Grade Adding Scores



Quantiles

maximum	100.0%	100.00
	99.5%	100.00
	97.5%	100.00
	90.0%	100.00
quartile	75.0%	100.00
median	50.0%	98.00
quartile	25.0%	95.00
	10.0%	70.40
	2.5%	58.80
	0.5%	57.00
minimum	0.0%	57.00

Quantiles

maximum	100.0%	100.00
	99.5%	100.00
	97.5%	100.00
	90.0%	100.00
quartile	75.0%	100.00
median	50.0%	99.00
quartile	25.0%	97.00
	10.0%	85.40
	2.5%	57.03
	0.5%	50.00
minimum	0.0%	50.00

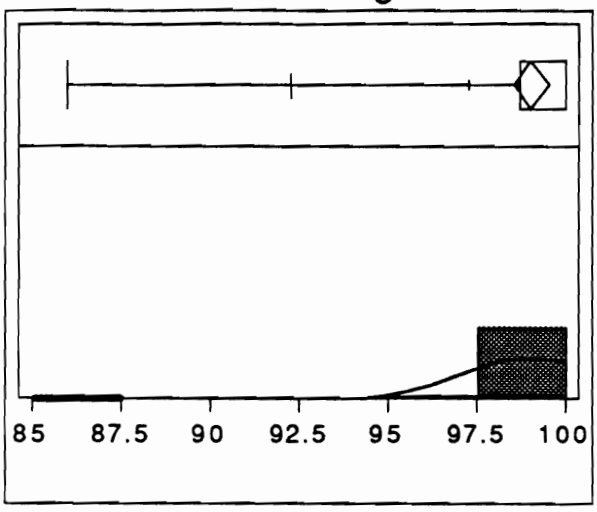
Moments

Mean	93.26984
Std Dev	11.67601
Std Err Mean	1.47104
upper 95% Mean	96.21041
lower 95% Mean	90.32927
N	63.00000

Moments

Mean	95.53333
Std Dev	9.23379
Std Err Mean	0.97333
upper 95% Mean	97.46732
lower 95% Mean	93.59934
N	90.00000

Sixth Grade Adding Scores



Quantiles

maximum	100.0%	100.00
	99.5%	100.00
	97.5%	100.00
	90.0%	100.00
quartile	75.0%	100.00
median	50.0%	100.00
quartile	25.0%	98.75
	10.0%	97.30
	2.5%	92.32
	0.5%	86.00
minimum	0.0%	86.00

Moments

Mean	99.06452
Std Dev	1.95751
Std Err Mean	0.24860
upper 95% Mean	99.56163
lower 95% Mean	98.56740
N	62.00000

School Regression Model for Response: N-Quantile Math Percentile

Summary of Fit

Rsquare	.5912672
Root Mean Square Error	.6441654
Mean of Response	.0419909
Observations (or Sum Wgts)	395

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	376	157.22768	0.418159	1.7240
Pure Error	7	1.69785	0.242550	Prob > F
Total Error	383	158.92553		0.2278

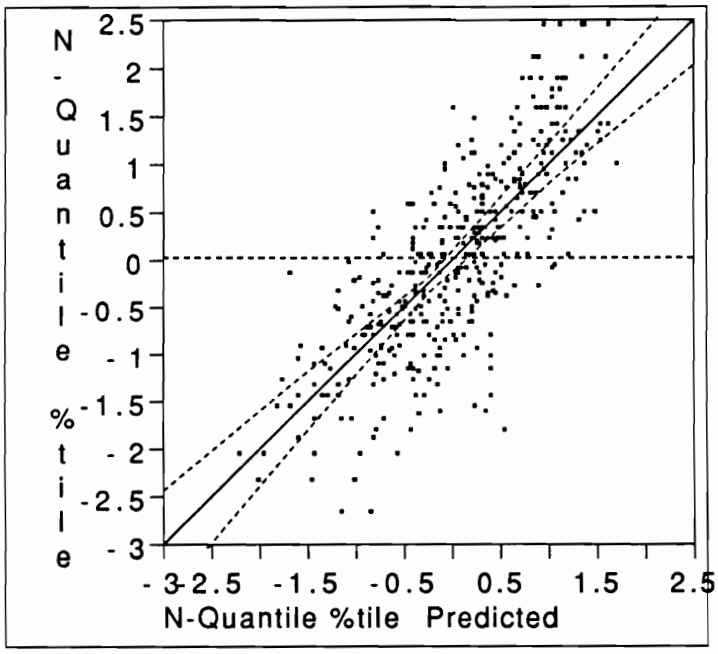
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-4.205937	.244354	-17.21	0.0000
Grade[2]	.04189374	.152763	0.27	0.7840
Grade[3]	.18356837	.106252	1.73	0.0849
Grade[4]	-.0567157	.122739	-0.46	0.6443
Grade[5]	-.4270600	.111419	-3.83	0.0001
Grade[6]	.09772630	.114080	0.86	0.3922
gender[0-1]	-.0922556	.033358	-2.77	0.0060
IQ	.02998571	.002441	12.28	0.0000
Math L[1]	.34753621	.093648	3.71	0.0002
Math L[2]	.47084139	.081328	5.79	0.0000
Handedne[0-1]	-.1186625	.059580	-1.99	0.0471
Adding	.00743231	.002549	2.92	0.0038

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Grade	5	5	10.685248	5.1501	0.0001
gender	1	1	3.173677	7.6484	0.0060
IQ	1	1	62.615797	150.8999	0.0000
Math L	2	2	24.617478	29.6632	0.0000
Handedness	1	1	1.645920	3.9666	0.0471
Adding	1	1	3.526855	8.4995	0.0038

Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	11	229.89949	20.9000	50.3675
Error	383	158.92553	0.4149	Prob > F
C Total	394	388.82503		0.0000

Grade 1-3 Regression Model for Response: N-Quantile Math Percentile

Summary of Fit

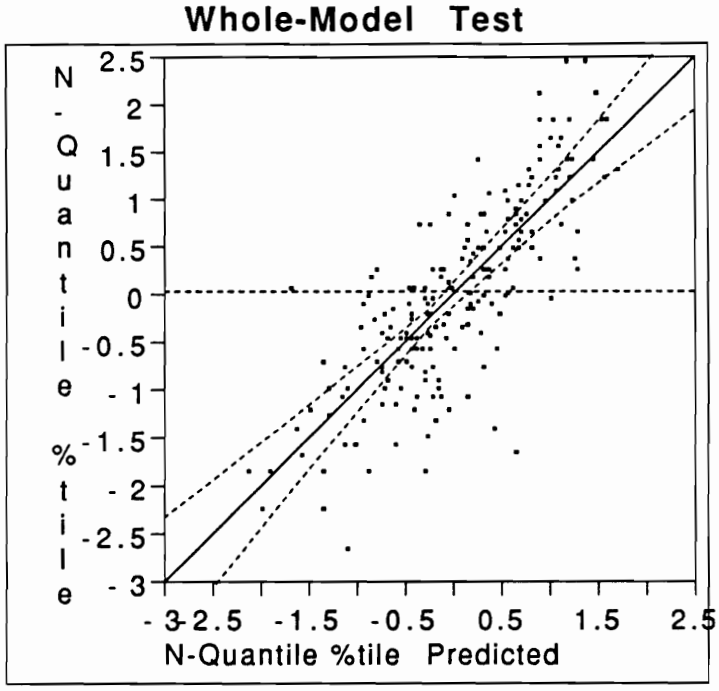
Rsquare	.6408478
Root Mean Square Error	.6075368
Mean of Response	.0290845
Observations (or Sum Wgts)	193

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-5.591157	.595781	-9.38	0.0000
Imagery Score	.01403226	.005778	2.43	0.0161
gender[0-1]	-.0941596	.047097	-2.00	0.0471
IQ	.03483591	.003531	9.86	0.0000
Math L[1]	.26851811	.125203	2.14	0.0333
Math L[2]	.37277594	.108210	3.44	0.0007
Handedne[0-1]	-.1833183	.090085	-2.03	0.0433
Adding	.00595935	.002394	2.49	0.0137
Age	.00803772	.004665	1.72	0.0866

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Imagery Score	1	1	2.176400	5.8965	0.0161
gender	1	1	1.475317	3.9971	0.0471
IQ	1	1	35.914459	97.3025	0.0000
Math L	2	2	8.367160	11.3345	0.0000
Handedness	1	1	1.528420	4.1409	0.0433
Adding	1	1	2.286400	6.1945	0.0137
Age	1	1	1.095566	2.9682	0.0866



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	121.18240	15.1478	41.0397
Error	184	67.91460	0.3691	Prob > F
C Total	192	189.09699		0.0000

Grades 4-6 Regression Model for Response: N-Quantile Math Percentile

Summary of Fit

Rsquare	.5344252
Root Mean Square Error	.6668982
Mean of Response	.0759267
Observations (or Sum Wgts)	198

Lack Of Fit

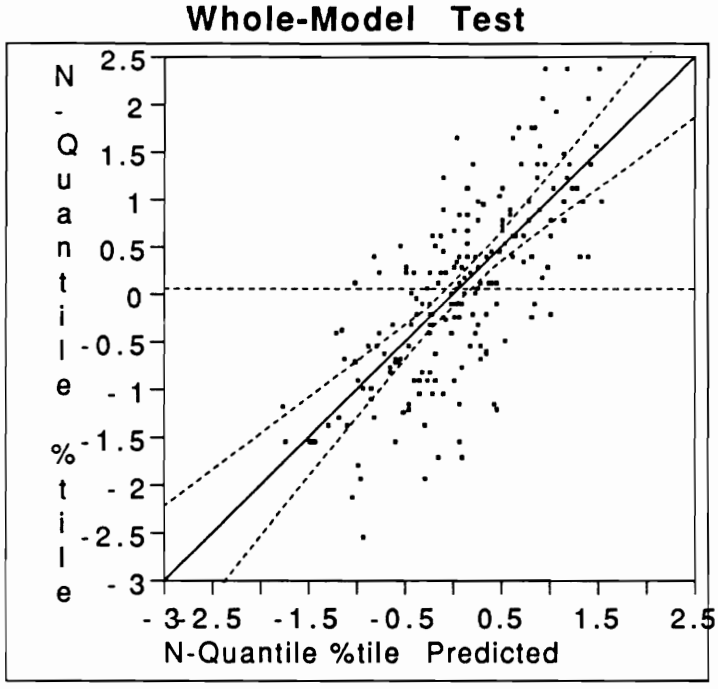
Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	181	82.097577	0.453578	1.6970
Pure Error	9	2.405546	0.267283	Prob > F
Total Error	190	84.503123		0.1951

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-3.869180	.664175	-5.83	0.0000
Grade[5]	-.4995626	.117421	-4.25	0.0000
Grade[6]	.11303582	.119484	0.95	0.3453
Adding	.00990323	.006127	1.62	0.1077
Gender[0-1]	-.1004011	.047817	-2.10	0.0371
IQ	.02541124	.003516	7.23	0.0000
Math L[1]	.48085371	.138365	3.48	0.0006
Math L[2]	.53286070	.121033	4.40	0.0000

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Grade	2	2	8.316028	9.3490	0.0001
Adding	1	1	1.161812	2.6123	0.1077
Gender	1	1	1.960761	4.4086	0.0371
IQ	1	1	23.222695	52.2148	0.0000
Math L	2	2	16.725677	18.8033	0.0000



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	7	96.99968	13.8571	31.1568
Error	190	84.50312	0.4448	Prob > F
C Total	197	181.50280		0.0000

First Grade Regression Model

Response: N-Quantile %tile

Summary of Fit

Rsquare	.9426898
Root Mean Square Error	.2267969
Mean of Response	.0448789
Observations (or Sum Wgts)	49

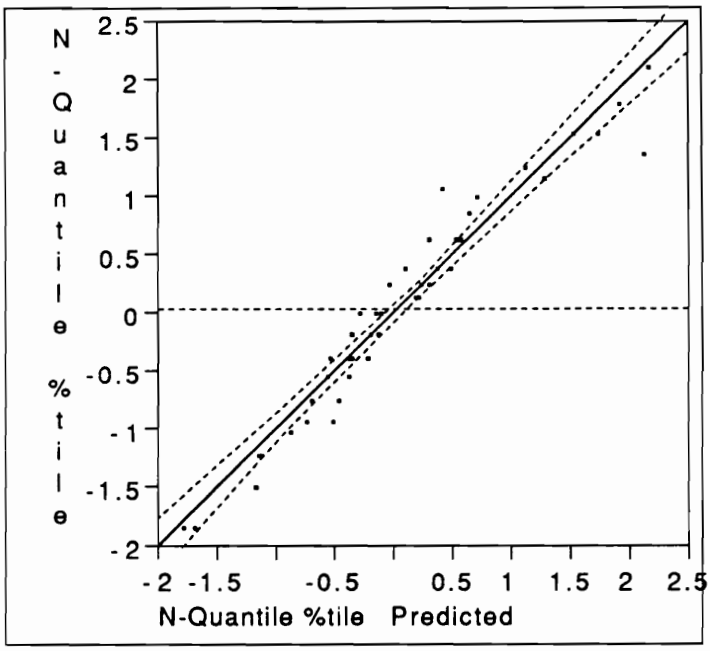
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-12.17880	.703909	-17.30	0.0000
Age	.07485356	.006729	11.12	0.0000
IQ	.05780663	.003151	18.34	0.0000
Adding	.00921880	.003174	2.90	0.0057

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Age	1	1	6.364884	123.7417	0.0000
IQ	1	1	17.305138	336.4345	0.0000
Adding	1	1	0.433697	8.4316	0.0057

Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	38.073623	12.6912	246.7337
Error	45	2.314659	0.0514	**Prob > F**
C Total	48	40.388282		0.0000

Second Grade Regression Model

Response: N-Quantile %tile

Summary of Fit

Rsquare	.5532913
Root Mean Square Error	.6702073
Mean of Response	.0023809
Observations (or Sum Wgts)	76

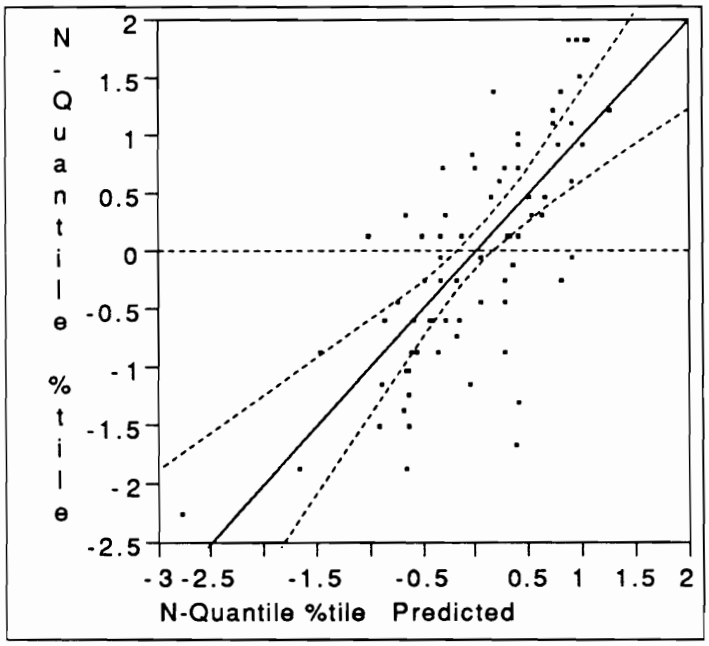
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-1.550546	1.66522	-0.93	0.3550
Age	-.0255344	.013547	-1.88	0.0636
IQ	.02363965	.005705	4.14	0.0001
Math L[1]	.37708950	.211145	1.79	0.0784
Math L[2]	.29175846	.185167	1.58	0.1196
Accuracy	.02995671	.010978	2.73	0.0080

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Age	1	1	1.5957520	3.5526	0.0636
IQ	1	1	7.7112881	17.1676	0.0001
Math L	2	2	3.7865418	4.2150	0.0187
Accuracy	1	1	3.3443894	7.4456	0.0080

Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	38.944485	7.78890	17.3403
Error	70	31.442454	0.44918	Prob > F
C Total	75	70.386939		0.0000

Third Grade Regression Model

Response: N-Quantile %tile

Summary of Fit

Rsquare	.7630185
Root Mean Square Error	.5182304
Mean of Response	.0091509
Observations (or Sum Wgts)	73

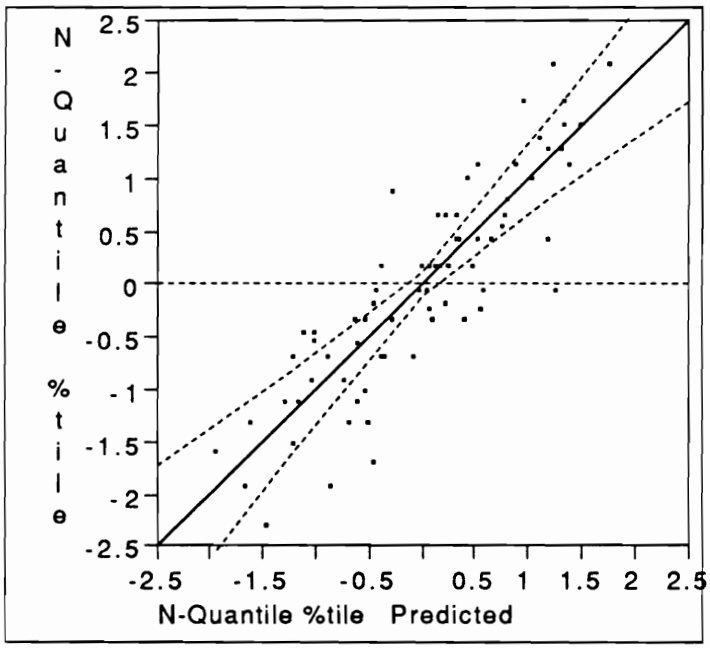
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-5.538366	.859249	-6.45	0.0000
age	.00887613	.004791	1.85	0.0686
Gender[0-1]	-.2371850	.066182	-3.58	0.0007
IQ	.03237904	.006430	5.04	0.0000
Math L[1]	.22557311	.181771	1.24	0.2192
Math L[2]	.47221123	.172094	2.74	0.0079
Econ L.[1]	.23533669	.160688	1.46	0.1480
Econ L.[2]	.26253074	.220021	1.19	0.2373
Adding	.00835892	.003464	2.41	0.0187
Handedne[0-1]	-.1978509	.104676	-1.89	0.0633

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
age	1	1	0.9216120	3.4316	0.0686
Gender	1	1	3.4493150	12.8436	0.0007
IQ	1	1	6.8096853	25.3560	0.0000
Math L	2	2	3.0197864	5.6221	0.0057
Econ L.	2	2	1.1233877	2.0915	0.1320
Adding	1	1	1.5636061	5.8221	0.0187
Handedness	1	1	0.9594593	3.5726	0.0633

Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	54.476244	6.05292	22.5382
Error	63	16.919458	0.26856	Prob > F
C Total	72	71.395702		0.0000

Fourth Grade Regression Model

Response: N-Quantile %tile

Summary of Fit

Rsquare	.4636862
Root Mean Square Error	.7553140
Mean of Response	.0101608
Observations (or Sum Wgts)	61

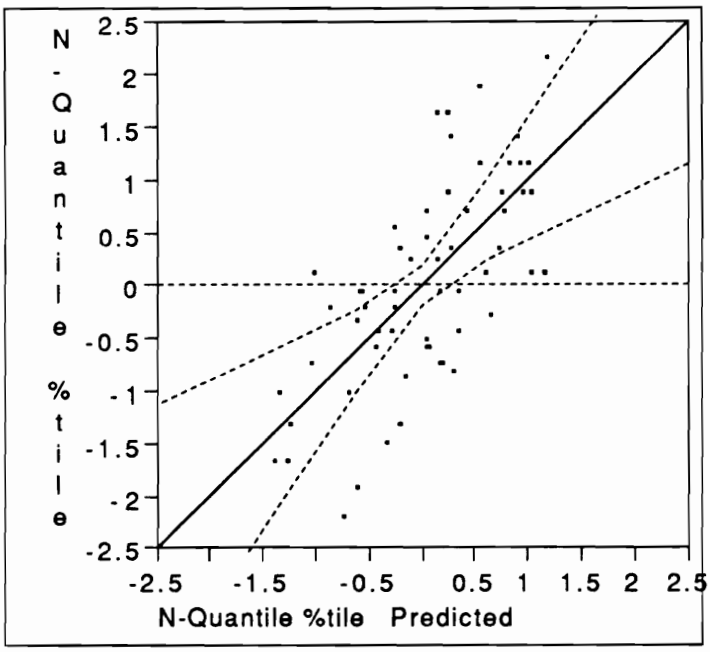
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-3.802544	.952416	-3.99	0.0002
Gender[0-1]	-.3481085	.107382	-3.24	0.0020
IQ	.02006079	.007138	2.81	0.0069
Math L[1]	.90214752	.257814	3.50	0.0009
Math L[2]	.08096122	.241685	0.33	0.7389
Handedne[0-1]	-.3463671	.237301	-1.46	0.1502
Imagery	.02096764	.013893	1.51	0.1371

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Gender	1	1	5.9953743	10.5090	0.0020
IQ	1	1	4.5052431	7.8970	0.0069
Math L	2	2	9.3014094	8.1520	0.0008
Handedness	1	1	1.2154246	2.1305	0.1502
Imagery	1	1	1.2994083	2.2777	0.1371

Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	26.635093	4.43918	7.7812
Error	54	30.806964	0.57050	Prob > F
C Total	60	57.442057		0.0000

Fifth Grade Regression Model

Response: N-Quantile %tile

Summary of Fit

Rsquare	.5979022
Root Mean Square Error	.6059721
Mean of Response	.0796223
Observations (or Sum Wgts)	85

Lack Of Fit

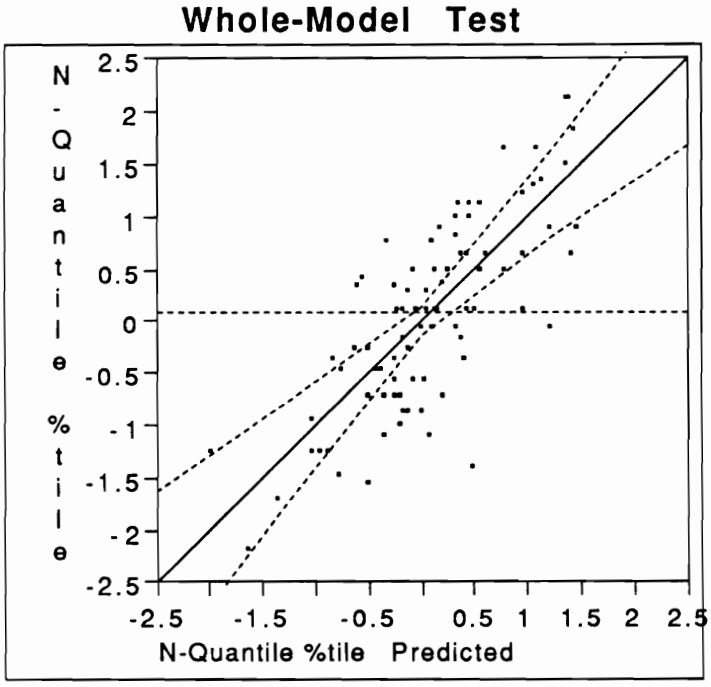
Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	76	28.277800	0.372076	2.0445
Pure Error	2	0.363976	0.181988	Prob > F
Total Error	78	28.641776		0.3849

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-2.608596	.577814	-4.51	0.0000
IQ	.02222024	.004919	4.52	0.0000
Math L[1]	.28829747	.219216	1.32	0.1923
Math L[2]	.86556251	.180980	4.78	0.0000
Handedne[0-1]	-.1644975	.100707	-1.63	0.1064
Spec Ed[0-1]	-.4174848	.192353	-2.17	0.0330
Imagery	-.0177648	.009216	-1.93	0.0576

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
IQ	1	1	7.4916353	20.4019	0.0000
Math L	2	2	9.1439946	12.4509	0.0000
Handedness	1	1	0.9797142	2.6681	0.1064
Spec Ed	1	1	1.7297714	4.7107	0.0330
Imagery	1	1	1.3642971	3.7154	0.0576



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	42.589104	7.09818	19.3304
Error	78	28.641776	0.36720	Prob > F
C Total	84	71.230880		0.0000

Sixth Grade Regression Model

Response: N-Quantile %tile

Summary of Fit

Rsquare	.7011187
Root Mean Square Error	.5257859
Mean of Response	.1272835
Observations (or Sum Wgts)	54

Lack Of Fit

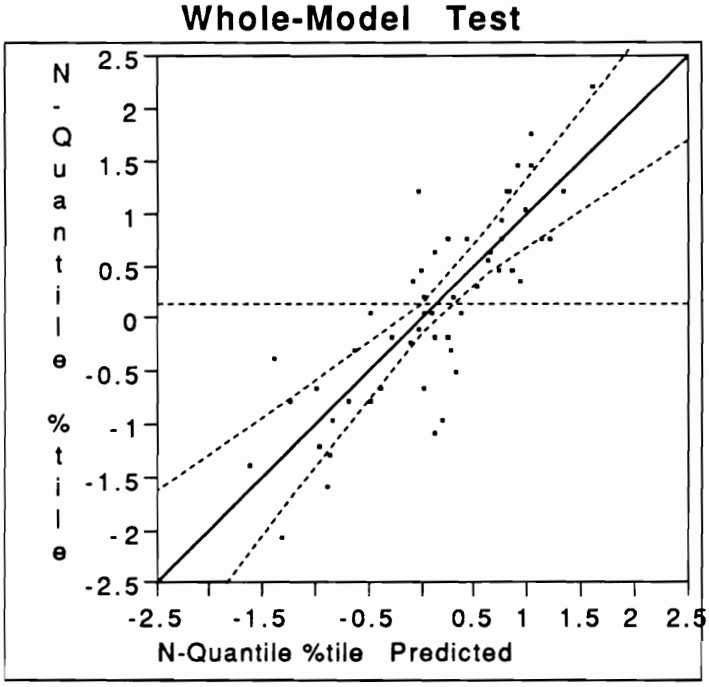
Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	44	11.420166	0.259549	0.5613
Pure Error	4	1.849477	0.462369	Prob > F
Total Error	48	13.269643		0.8503

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-15.02278	7.47614	-2.01	0.0501
IQ	.02696429	.005974	4.51	0.0000
Math L[1]	.66357177	.223007	2.98	0.0046
Math L[2]	.59151905	.180931	3.27	0.0020
Adding	.13474051	.074999	1.80	0.0787
Accuracy	-.0416570	.025299	-1.65	0.1062

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
IQ	1	1	5.6319340	20.3723	0.0000
Math L	2	2	5.8426099	10.5672	0.0002
Adding	1	1	0.8922822	3.2276	0.0787
Accuracy	1	1	0.7495226	2.7112	0.1062



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	31.128071	6.22561	22.5198
Error	48	13.269643	0.27645	Prob > F
C Total	53	44.397714		0.0000

N-Quantile Math Percentile Regression Equations for:

School

$$
\begin{aligned}
\text{-4.2059379+}\Bigg(\Bigg\{ & \begin{array}{ll} \text{-.16058732,} & \text{if } \textit{Grade}\text{=6} \\ \text{-.25831363,} & \text{if } \textit{Grade}\text{=5} \\ \text{.168746412,} & \text{if } \textit{Grade}\text{=4} \\ \text{.225462126,} & \text{if } \textit{Grade}\text{=3} \\ \text{.041893746,} & \text{if } \textit{Grade}\text{=2} \\ \text{0,} & \text{if } \textit{Grade}\text{=1} \\ \text{•,} & \text{otherwise} \end{array} \Bigg) \\
+\Bigg(\Bigg\{ & \begin{array}{ll} \text{.092255632,} & \text{if } \textit{gender}\text{=1} \\ \text{-.09225563,} & \text{if } \textit{gender}\text{=0} \\ \text{•,} & \text{otherwise} \end{array} \Bigg) \\
+\text{ .029985719•}\textit{IQ} & + \Bigg(\Bigg\{ \begin{array}{ll} \text{.818377604,} & \text{if } \textit{Math L}\text{=2} \\ \text{.347536209,} & \text{if } \textit{Math L}\text{=1} \\ \text{0,} & \text{if } \textit{Math L}\text{=0} \\ \text{•,} & \text{otherwise} \end{array} \Bigg) + \\
& \Bigg(\Bigg\{ \begin{array}{ll} \text{.118662596,} & \text{if } \textit{Handedness}\text{=1} \\ \text{-.11866259,} & \text{if } \textit{Handedness}\text{=0} \\ \text{•,} & \text{otherwise} \end{array} \Bigg) \\
+\text{ .007432319•}\textit{Adding} & = \textit{N-Quantile Math Percentile}
\end{aligned}
$$

Grades 1-3

$$-5.5911575+.014032263\bullet \textit{Imagery Score.1} + \begin{cases} .094159693, & \text{if } \textit{gender}=1 \\ -.09415969, & \text{if } \textit{gender}=0 \\ \bullet, & \text{otherwise} \end{cases}$$

$$+ .034835912\bullet \textit{IQ} + \begin{cases} .641294057, & \text{if } \textit{Math L}=2 \\ .268518114, & \text{if } \textit{Math L}=1 \\ 0, & \text{if } \textit{Math L}=0 \\ \bullet, & \text{otherwise} \end{cases}$$

$$+ \begin{cases} .183318356, & \text{if } \textit{Handedness}=1 \\ -.18331835, & \text{if } \textit{Handedness}=0 \\ \bullet, & \text{otherwise} \end{cases} + .005959353\bullet \textit{Adding} +$$

$$.008037725\bullet \textit{Age}$$

$$= \textit{N-Quantile Math Percentile}$$

Grades 4-6

$$-3.8691804+ \begin{cases} -.38652683, & \text{if } \textit{Grade}=6 \\ -.49956266, & \text{if } \textit{Grade}=5 \\ 0, & \text{if } \textit{Grade}=4 \\ \bullet, & \text{otherwise} \end{cases} + .009903230\bullet \textit{Adding}$$

$$+ \begin{cases} .100401149, & \text{if } \textit{Gender}=1 \\ -.10040114, & \text{if } \textit{Gender}=0 \\ \bullet, & \text{otherwise} \end{cases} + .025411248\bullet \textit{IQ}$$

$$+ \begin{cases} 1.01371442, & \text{if } \textit{Math L}=2 \\ .480853718, & \text{if } \textit{Math L}=1 \\ 0, & \text{if } \textit{Math L}=0 \\ \bullet, & \text{otherwise} \end{cases} = \textit{N-Quantile Math Percentile}$$

First Grade

$$-12.178808+.057806639 \bullet IQ+.074853561 \bullet Age+.009218805 \bullet Adding$$

$$= \textit{N-Quantile Math Percentile}$$

Second Grade

$$-1.5505469+.023639656 \bullet IQ+\left(\begin{cases} .668847974, & \text{if } Math\ L=2 \\ .377089508, & \text{if } Math\ L=1 \\ 0, & \text{if } Math\ L=0 \\ \bullet, & \text{otherwise} \end{cases} \right) + .029956711 \bullet Accuracy$$

$$+ \ -.02553440 \bullet Age = \textit{N-Quantile Math Percentile}$$

Third Grade

$$-5.5383666+.008876131 \bullet age+\left(\begin{cases} .237185039, & \text{if } Gender=1 \\ -.23718503, & \text{if } Gender=0 \\ \bullet, & \text{otherwise} \end{cases} \right)+.032379049 \bullet IQ$$

$$+ \left(\begin{cases} .697784350, & \text{if } Math\ L=2 \\ .225573115, & \text{if } Math\ L=1 \\ 0, & \text{if } Math\ L=0 \\ \bullet, & \text{otherwise} \end{cases} \right) + \left(\begin{cases} .497867436, & \text{if } Econ\ L.=2 \\ .235336692, & \text{if } Econ\ L.=1 \\ 0, & \text{if } Econ\ L.=0 \\ \bullet, & \text{otherwise} \end{cases} \right)$$

$$+ .008358920 \bullet Adding + \left(\begin{cases} .197850922, & \text{if } Handedness=1 \\ -.19785092, & \text{if } Handedness=0 \\ \bullet, & \text{otherwise} \end{cases} \right)$$

$$= \textit{N-Quantile Math Percentile}$$

Fourth Grade

$$-3.8025441+\left(\begin{cases} .348108521, & \text{if } Gender=1 \\ -.34810852, & \text{if } Gender=0 \\ \bullet, & \text{otherwise} \end{cases}\right) + .020060791 \bullet IQ$$

$$+\left(\begin{cases} .983108758, & \text{if } Math\ L=2 \\ .902147529, & \text{if } Math\ L=1 \\ 0, & \text{if } Math\ L=0 \\ \bullet, & \text{otherwise} \end{cases}\right) + \left(\begin{cases} .346367198, & \text{if } Handedness=1 \\ -.34636719, & \text{if } Handedness=0 \\ \bullet, & \text{otherwise} \end{cases}\right)$$

$$+ .020967642 \bullet Imagery\ Score.1 = N\text{-}Quantile\ Math\ Percentile$$

Fifth Grade

$$-2.6085962+.022220242 \bullet IQ+\left(\begin{cases} 1.15385998, & \text{if } Math\ L=2 \\ .288297471, & \text{if } Math\ L=1 \\ 0, & \text{if } Math\ L=0 \\ \bullet, & \text{otherwise} \end{cases}\right)$$

$$+\left(\begin{cases} .164497552, & \text{if } Handedness=1 \\ -.16449755, & \text{if } Handedness=0 \\ \bullet, & \text{otherwise} \end{cases}\right)$$

$$+\left(\begin{cases} .417484800, & \text{if } Spec\ Ed=1 \\ -.41748480, & \text{if } Spec\ Ed=0 \\ \bullet, & \text{otherwise} \end{cases}\right) + -.01776482 \bullet Imagery\ Score.1$$

$$= N\text{-}Quantile\ Math\ Percentile$$

Sixth Grade

$$-15.022789+.026964296 \bullet IQ+\left(\begin{cases} 1.25509083, & \text{if } Math\ L=2 \\ .663571775, & \text{if } Math\ L=1 \\ 0, & \text{if } Math\ L=0 \\ \bullet, & \text{otherwise} \end{cases}\right)$$

$$+ .134740516 \bullet Adding$$

$$+ -.04165706 \bullet Accuracy = N\text{-}Quantile\ Math\ Percentile$$

Regression Models
with Normal Quantile as the Response Variable

Correlations for School Regression Model

Correlations

Variable	Grade	gender	IQ	Math L	Handedness	Adding
Grade	1.0000	-0.0970	0.3330	-0.0155	-0.0470	0.7172
gender	-0.0970	1.0000	-0.0614	-0.0725	-0.1107	-0.1524
IQ	0.3330	-0.0614	1.0000	0.4710	0.0188	0.3633
Math L	-0.0155	-0.0725	0.4710	1.0000	0.0493	0.2044
Handedness	-0.0470	-0.1107	0.0188	0.0493	1.0000	0.0303
Adding	0.7172	-0.1524	0.3633	0.2044	0.0303	1.0000

Inverse Corr

Variable	Grade	gender	IQ	Math L	Handedness	Adding
Grade	2.3422	0.0073	-0.4625	0.5816	0.1404	-1.6339
gender	0.0073	1.0374	-0.0162	0.0478	0.1088	0.1457
IQ	-0.4625	-0.0162	1.5126	-0.7045	-0.0149	-0.0758
Math L	0.5816	0.0478	-0.7045	1.4362	-0.0114	-0.4471
Handedness	0.1404	0.1088	-0.0149	-0.0114	1.0227	-0.1074
Adding	-1.6339	0.1457	-0.0758	-0.4471	-0.1074	2.3162

Correlations for Grades 1-3 Regression Model

Correlations

Variable	Imagery	gender	IQ	Math L	Hand	Adding	Age
Imagery Sc.	.1.0000	-0.0660	0.0833	0.1604	-0.0973	0.0861	0.0652
gender	-0.0660	1.0000	-0.0944	-0.0834	-0.1331	-0.1344	0.1293
IQ	0.0833	-0.0944	1.0000	0.5074	0.1577	0.2724	-0.2543
Math L	0.1604	-0.0834	0.5074	1.0000	0.0905	0.3363	-0.1535
Handedness	-0.0973	-0.1331	0.1577	0.0905	1.0000	0.0856	-0.0974
Adding	0.0861	-0.1344	0.2724	0.3363	0.0856	1.0000	0.4376
Age	0.0652	0.1293	-0.2543	-0.1535	-0.0974	0.4376	1.0000

Inverse Corr

Variable	Imagery	gender	IQ	Math L	Hand	Adding	Age
Imagery Sc	1.0557	0.0880	-0.0505	-0.1804	0.1230	0.0402	-0.1264
gender	0.0880	1.0855	-0.0442	-0.0464	0.1139	0.2763	-0.2743
IQ	-0.0505	-0.0442	1.5434	-0.5386	-0.1175	-0.4519	0.5051
Math L	-0.1804	-0.0464	-0.5386	1.5175	-0.0010	-0.4996	0.3322
Handedness	0.1230	0.1139	-0.1175	-0.0010	1.0628	-0.0942	0.0919
Adding	0.0402	0.2763	-0.4519	-0.4996	-0.0942	1.7779	-1.0171
Age	-0.1264	-0.2743	0.5051	0.3322	0.0919	-1.0171	1.6772

Correlations for Grades 4-6 Regression Model

Correlations

Variable	Grade	Adding	Gender	IQ	Math
Grade	1.0000	0.2599	0.0254	0.1148	0.0722
Adding	0.2599	1.0000	-0.0601	0.1224	0.2413
Gender	0.0254	-0.0601	1.0000	0.0505	-0.0637
IQ	0.1148	0.1224	0.0505	1.0000	0.5117
Math L	0.0722	0.2413	-0.0637	0.5117	1.0000

Inverse Corr

Variable	Grade	Adding	Gender	IQ	Math L
Grade	1.0834	-0.2808	-0.0361	-0.1106	0.0438
Adding	-0.2808	1.1369	0.0574	0.0248	-0.2631
Gender	-0.0361	0.0574	1.0170	-0.1106	0.1102
IQ	-0.1106	0.0248	-0.1106	1.3788	-0.7105
Math L	0.0438	-0.2631	0.1102	-0.7105	1.4309

Correlations for First Grade Regression Model

Correlations

Variable	Age	IQ	Adding
Age	1.0000	-0.4109	-0.1614
IQ	-0.4109	1.0000	0.6621
Adding	-0.1614	0.6621	1.0000

Inverse Corr

Variable	Age	IQ	Adding
Age	1.2356	0.6689	-0.2435
IQ	0.6689	2.1425	-1.3105
Adding	-0.2435	-1.3105	1.8283

Correlations for Second Grade Regression Models

Correlations

Variable	Age	IQ	Math L	Accuracy
Age	1.0000	-0.4584	-0.0016	-0.0052
IQ	-0.4584	1.0000	0.3286	0.1975
Math L	-0.0016	0.3286	1.0000	0.4276
Accuracy	-0.0052	0.1975	0.4276	1.0000

Inverse Corr

Variable	Age	IQ	Math L	Accuracy
Age	1.3086	0.6742	-0.2024	-0.0399
IQ	0.6742	1.4735	-0.4407	-0.0991
Math L	-0.2024	-0.4407	1.3556	-0.4937
Accuracy	-0.0399	-0.0991	-0.4937	1.2305

Correlations for Third Grade Regression Model

Correlations

Variable	age	Gender	IQ	Math L	Econ L	Adding	Hand
age	1.0000	-0.0170	-0.3203	-0.1372	-0.2521	-0.0843	-0.1151
Gender	-0.0170	1.0000	-0.0335	-0.0091	-0.0725	-0.1915	-0.1609
IQ	-0.3203	-0.0335	1.0000	0.6451	0.3298	0.3789	0.1569
Math L	-0.1372	-0.0091	0.6451	1.0000	0.4569	0.3209	0.0806
Econ L.	-0.2521	-0.0725	0.3298	0.4569	1.0000	0.2536	0.2095
Adding	-0.0843	-0.1915	0.3789	0.3209	0.2536	1.0000	0.0560
Handedness	-0.1151	-0.1609	0.1569	0.0806	0.2095	0.0560	1.0000

Inverse Corr

Variable	age	Gender	IQ	Math L	Econ L	Adding	Hand
age	1.1833	0.0476	0.4667	-0.2440	0.2664	-0.0594	0.0378
Gender	0.0476	1.0716	-0.0283	-0.0681	0.0386	0.2226	0.1673
IQ	0.4667	-0.0283	2.0347	-1.1620	0.1096	-0.3820	-0.1780
Math L	-0.2440	-0.0681	-1.1620	2.0112	-0.6023	-0.0922	0.1126
Econ L.	0.2664	0.0386	0.1096	-0.6023	1.3946	-0.1601	-0.2150
Adding	-0.0594	0.2226	-0.3820	-0.0922	-0.1601	1.2492	0.0599
Handedness	0.0378	0.1673	-0.1780	0.1126	-0.2150	0.0599	1.0918

Correlations for Fourth Grade Regression Model

Correlations

Variable	Gender	IQ	Math L	Handedness	Imagery
Gender	1.0000	0.1231	-0.0417	-0.2469	-0.1884
IQ	0.1231	1.0000	0.3559	-0.0319	-0.1079
Math L	-0.0417	0.3559	1.0000	0.0961	-0.1700
Handedness	-0.2469	-0.0319	0.0961	1.0000	-0.1467
Imagery	-0.1884	-0.1079	-0.1700	-0.1467	1.0000

Inverse Corr

Variable	Gender	IQ	Math L	Handedness	Imagery
Gender	1.1482	-0.1437	0.1146	0.3068	0.2653
IQ	-0.1437	1.1732	-0.4222	0.0475	0.0347
Math L	0.1146	-0.4222	1.1907	-0.0749	0.1674
Handedness	0.3068	0.0475	-0.0749	1.1159	0.2139
Imagery	0.2653	0.0347	0.1674	0.2139	1.1136

Correlations for Fifth Grade Regression Model

Correlations

Variable	IQ	Math L	Handedness	Spec Ed	Imagery
IQ	1.0000	0.5705	-0.0443	0.2938	0.0332
Math L	0.5705	1.0000	-0.0368	0.2303	0.0563
Handedness	-0.0443	-0.0368	1.0000	-0.0737	0.2078
Spec Ed	0.2938	0.2303	-0.0737	1.0000	-0.1693
Imagery	0.0332	0.0563	0.2078	-0.1693	1.0000

Inverse Corr

Variable	IQ	Math L	Handedness	Spec Ed	Imagery
IQ	1.5499	-0.8165	0.0305	-0.2750	-0.0585
Math L	-0.8165	1.4985	0.0275	-0.1172	-0.0828
Handedness	0.0305	0.0275	1.0492	0.0254	-0.2163
Spec Ed	-0.2750	-0.1172	0.0254	1.1443	0.2042
Imagery	-0.0585	-0.0828	-0.2163	0.2042	1.0862

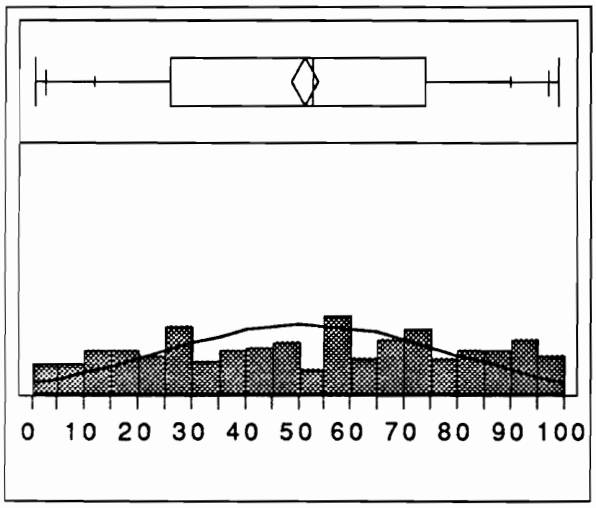
Correlations for Sixth Grade Regression Model

		Correlations		
Variable	IQ	Math L	Adding	Accuracy
IQ	1.0000	0.6291	-0.0308	0.1005
Math L	0.6291	1.0000	-0.1206	0.0864
Adding	-0.0308	-0.1206	1.0000	0.0434
Accuracy	0.1005	0.0864	0.0434	1.0000

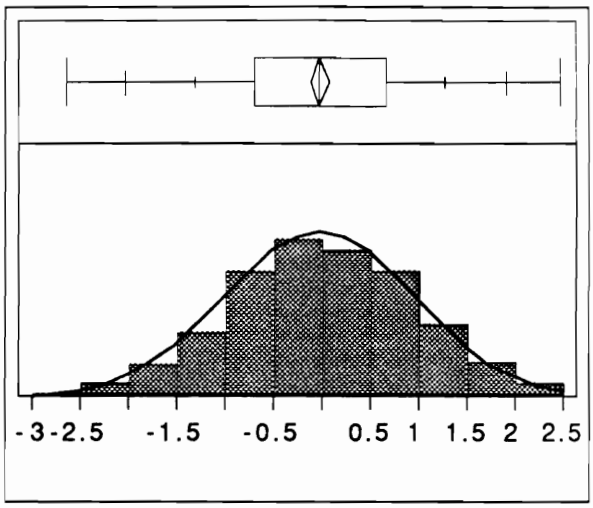
		Inverse Corr		
Variable	IQ	Math L	Adding	Accuracy
IQ	1.6660	-1.0504	-0.0722	-0.0736
Math L	-1.0504	1.6858	0.1731	-0.0476
Adding	-0.0722	0.1731	1.0209	-0.0520
Accuracy	-0.0736	-0.0476	-0.0520	1.0138

Distribution of Math Percentiles and Normal Quantile Percentile Scores

School Math Percentile



School N-Quantile %tile



Quantiles

maximum	100.0%	99.000
	99.5%	99.000
	97.5%	97.000
	90.0%	90.000
quartile	75.0%	74.000
median	50.0%	53.000
quartile	25.0%	26.000
	10.0%	12.000
	2.5%	3.000
	0.5%	1.000
minimum	0.0%	1.000

Quantiles

maximum	100.0%	2.4872
	99.5%	2.4872
	97.5%	1.9297
	90.0%	1.3014
quartile	75.0%	0.6779
median	50.0%	-0.0027
quartile	25.0%	-0.6881
	10.0%	-1.3014
	2.5%	-2.0245
	0.5%	-2.6282
minimum	0.0%	-2.6282

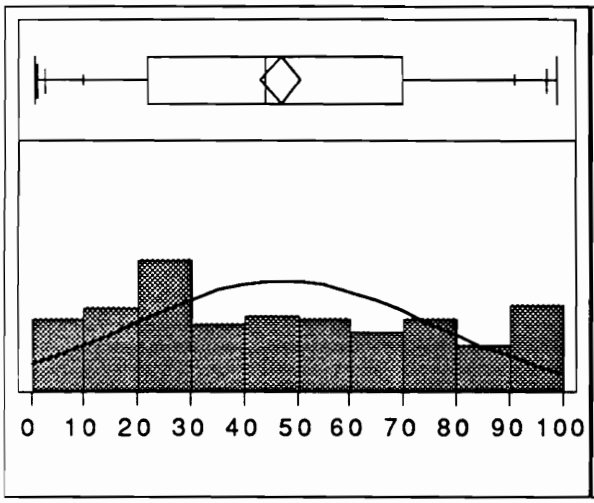
Moments

Mean	51.2581
Std Dev	27.8652
Std Err Mean	1.2922
upper 95% Mean	53.7974
lower 95% Mean	48.7187
N	465.0000

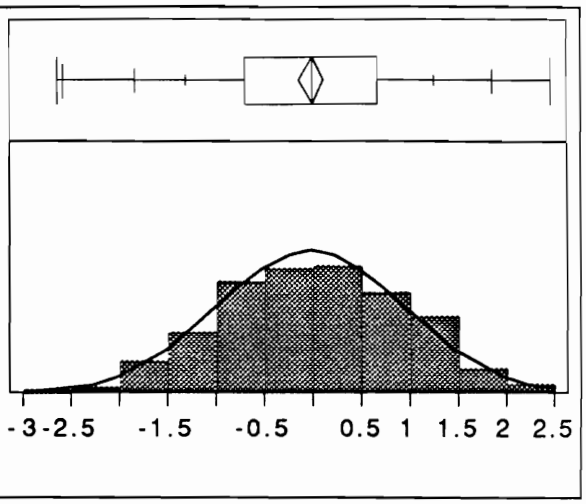
Moments

Mean	-0.0002
Std Dev	0.9867
Std Err Mean	0.0458
upper 95% Mean	0.0897
lower 95% Mean	-0.0902
N	465.0000

Grades 1-3 Math Percentile



Grades 1-3 N-Quantile %tile



Quantiles

maximum	100.0%	99.000
	99.5%	99.000
	97.5%	97.000
	90.0%	91.000
quartile	75.0%	70.000
median	50.0%	44.000
quartile	25.0%	22.000
	10.0%	10.000
	2.5%	3.000
	0.5%	1.120
minimum	0.0%	1.000

Quantiles

maximum	100.0%	2.4731
	99.5%	2.4731
	97.5%	1.8627
	90.0%	1.2541
quartile	75.0%	0.6675
median	50.0%	0.0112
quartile	25.0%	-0.6675
	10.0%	-1.2790
	2.5%	-1.8319
	0.5%	-2.5668
minimum	0.0%	-2.6148

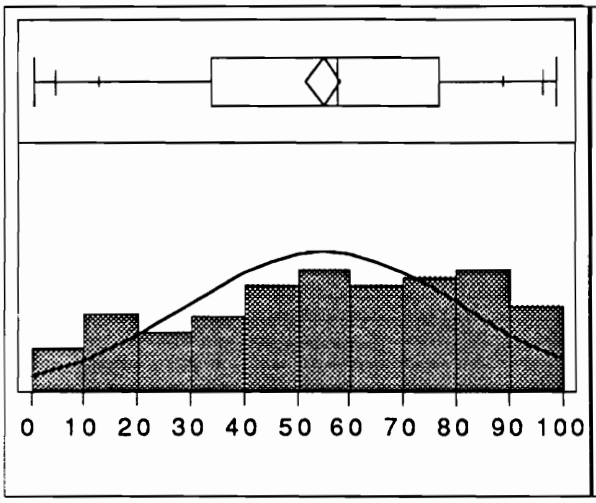
Moments

Mean	47.0852
Std Dev	28.7558
Std Err Mean	1.9256
upper 95% Mean	50.8801
lower 95% Mean	43.2903
N	223.0000

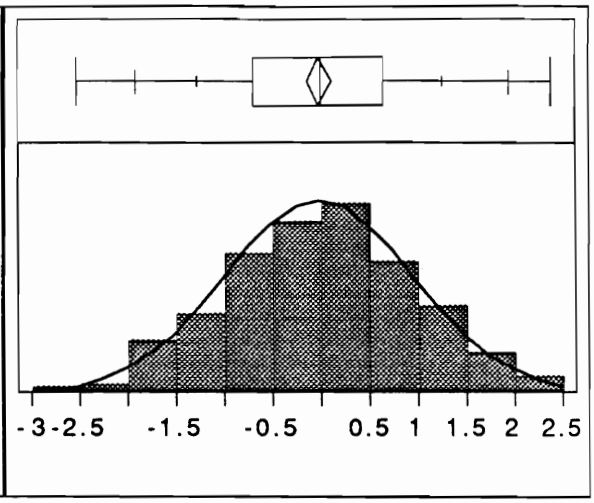
Moments

Mean	0.0001
Std Dev	0.9787
Std Err Mean	0.0655
upper 95% Mean	0.1292
lower 95% Mean	-0.1291
N	223.0000

Grades 4-6 Math Percentile



Grades 4-6 N-Quantile %tile



Quantiles

maximum	100.0%	99.000
	99.5%	99.000
	97.5%	96.850
	90.0%	89.000
quartile	75.0%	77.000
median	50.0%	58.000
quartile	25.0%	34.000
	10.0%	13.000
	2.5%	5.000
	0.5%	1.000
minimum	0.0%	1.000

Moments

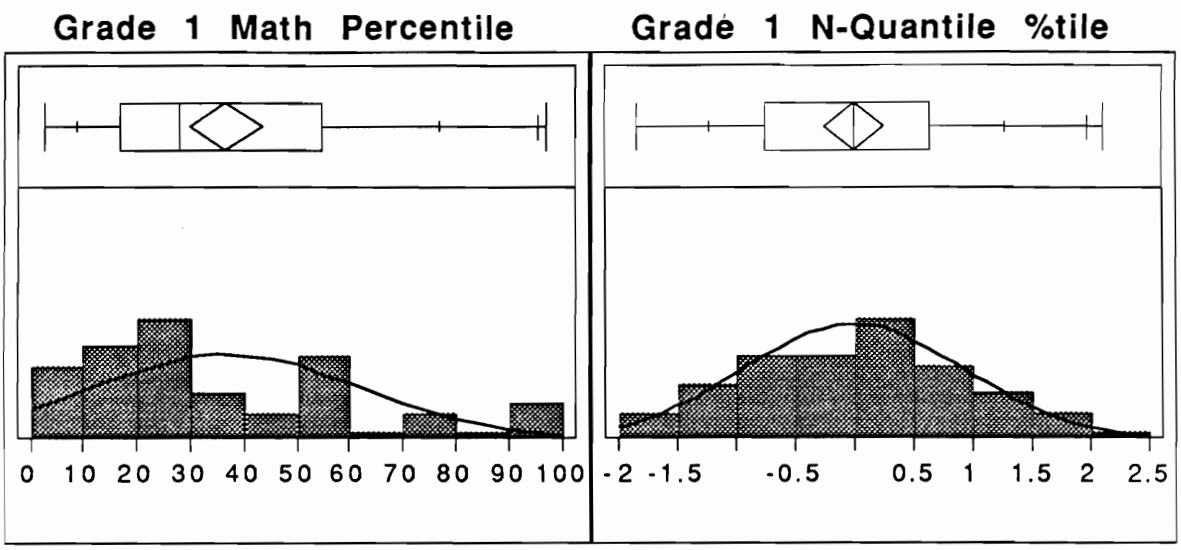
Mean	55.1033
Std Dev	26.5005
Std Err Mean	1.7035
upper 95% Mean	58.4590
lower 95% Mean	51.7476
N	242.0000

Quantiles

maximum	100.0%	2.3985
	99.5%	2.3985
	97.5%	1.9603
	90.0%	1.2539
quartile	75.0%	0.6393
median	50.0%	0.0000
quartile	25.0%	-0.6842
	10.0%	-1.2653
	2.5%	-1.8986
	0.5%	-2.5021
minimum	0.0%	-2.5021

Moments

Mean	-0.0002
Std Dev	0.9801
Std Err Mean	0.0630
upper 95% Mean	0.1239
lower 95% Mean	-0.1243
N	242.0000



Quantiles

maximum	100.0%	97.000
	99.5%	97.000
	97.5%	95.650
	90.0%	76.800
quartile	75.0%	55.000
median	50.0%	28.000
quartile	25.0%	17.000
	10.0%	9.000
	2.5%	3.000
	0.5%	3.000
minimum	0.0%	3.000

Quantiles

maximum	100.0%	2.1144
	99.5%	2.1144
	97.5%	1.9813
	90.0%	1.2826
quartile	75.0%	0.6476
median	50.0%	0.0216
quartile	25.0%	-0.7298
	10.0%	-1.2156
	2.5%	-1.8186
	0.5%	-1.8186
minimum	0.0%	-1.8186

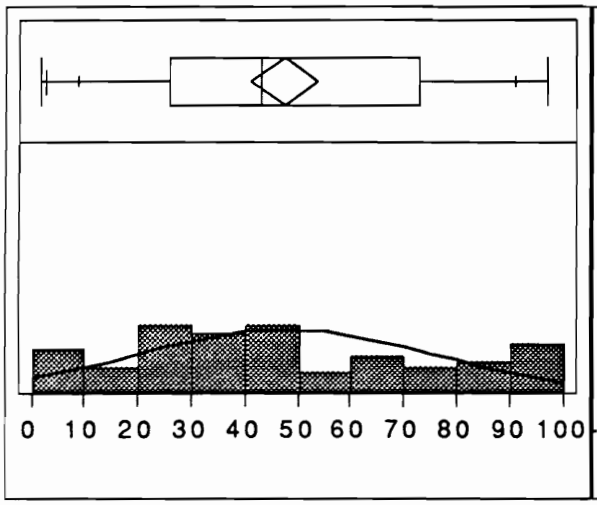
Moments

Mean	36.71930
Std Dev	25.47180
Std Err Mean	3.37382
upper 95% Mean	43.47787
lower 95% Mean	29.96072
N	57.00000

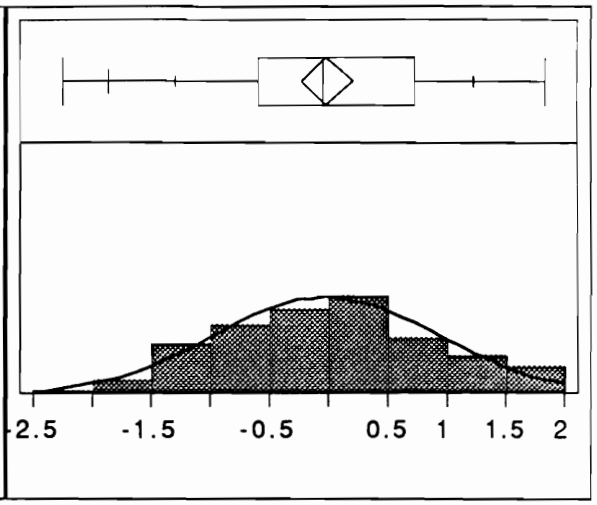
Moments

Mean	0.00211
Std Dev	0.94010
Std Err Mean	0.12452
upper 95% Mean	0.25155
lower 95% Mean	-0.24733
N	57.00000

Grade 2 Math Percentile



Grade 2 N-Quantile %tile



Quantiles

maximum	100.0%	97.000
	99.5%	97.000
	97.5%	97.000
	90.0%	91.000
quartile	75.0%	73.000
median	50.0%	43.000
quartile	25.0%	26.000
	10.0%	9.000
	2.5%	3.000
	0.5%	2.000
minimum	0.0%	2.000

Quantiles

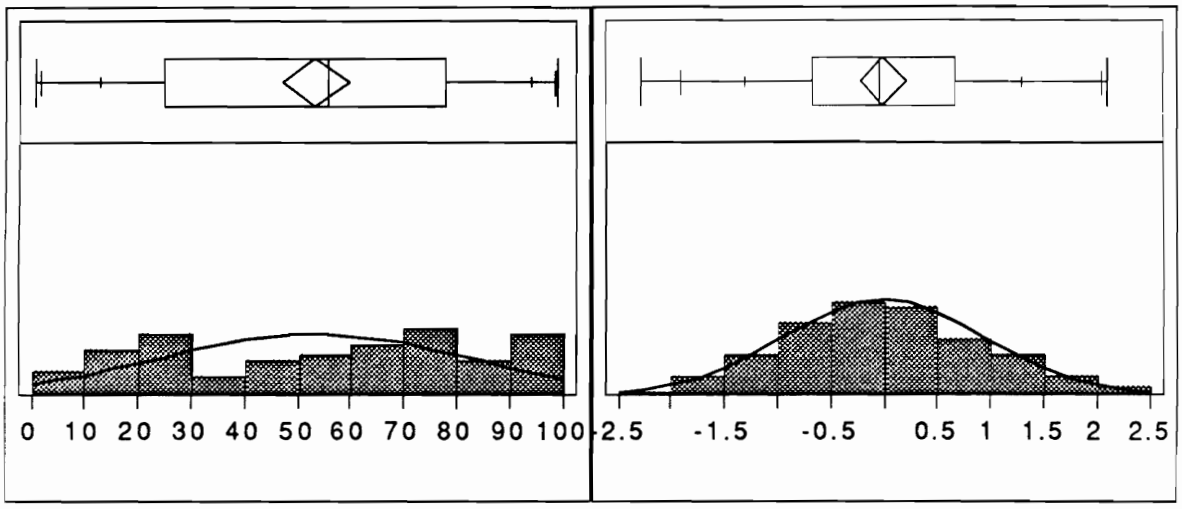
maximum	100.0%	1.8627
	99.5%	1.8627
	97.5%	1.8627
	90.0%	1.2467
quartile	75.0%	0.7347
median	50.0%	-0.0313
quartile	25.0%	-0.5791
	10.0%	-1.2816
	2.5%	-1.8627
	0.5%	-2.2414
minimum	0.0%	-2.2414

Moments

Mean	47.60759
Std Dev	28.31436
Std Err Mean	3.18561
upper 95% Mean	53.94969
lower 95% Mean	41.26550
N	79.00000

Moments

Mean	-0.00192
Std Dev	0.95084
Std Err Mean	0.10698
upper 95% Mean	0.21105
lower 95% Mean	-0.21490
N	79.00000



Quantiles

maximum	100.0%	99.000
	99.5%	99.000
	97.5%	98.800
	90.0%	94.000
quartile	75.0%	78.000
median	50.0%	56.000
quartile	25.0%	25.000
	10.0%	13.000
	2.5%	2.000
	0.5%	1.000
minimum	0.0%	1.000

Moments

Mean	53.40230
Std Dev	29.54833
Std Err Mean	3.16791
upper 95% Mean	59.69993
lower 95% Mean	47.10467
N	87.00000

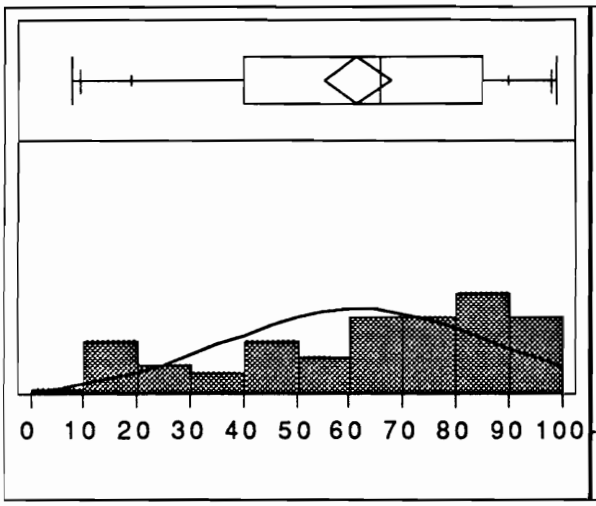
Quantiles

maximum	100.0%	2.1190
	99.5%	2.1190
	97.5%	2.0459
	90.0%	1.3012
quartile	75.0%	0.6745
median	50.0%	-0.0427
quartile	25.0%	-0.6745
	10.0%	-1.3012
	2.5%	-1.9047
	0.5%	-2.2780
minimum	0.0%	-2.2780

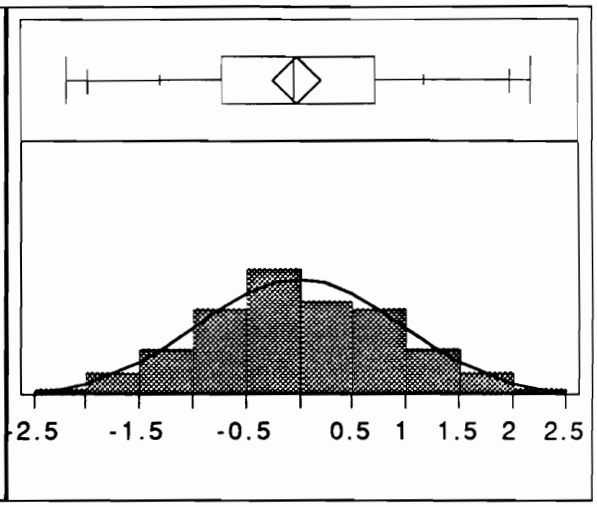
Moments

Mean	-0.00027
Std Dev	0.95779
Std Err Mean	0.10269
upper 95% Mean	0.20387
lower 95% Mean	-0.20440
N	87.00000

Grade 4 Math Percentile



Grade 4 N-Quantile %tile



Quantiles

maximum	100.0%	99.000
	99.5%	99.000
	97.5%	98.225
	90.0%	90.000
quartile	75.0%	85.000
median	50.0%	66.000
quartile	25.0%	40.000
	10.0%	19.000
	2.5%	9.550
	0.5%	8.000
minimum	0.0%	8.000

Quantiles

maximum	100.0%	2.1949
	99.5%	2.1949
	97.5%	1.9729
	90.0%	1.1764
quartile	75.0%	0.7081
median	50.0%	-0.0353
quartile	25.0%	-0.7081
	10.0%	-1.2896
	2.5%	-1.9729
	0.5%	-2.1949
minimum	0.0%	-2.1949

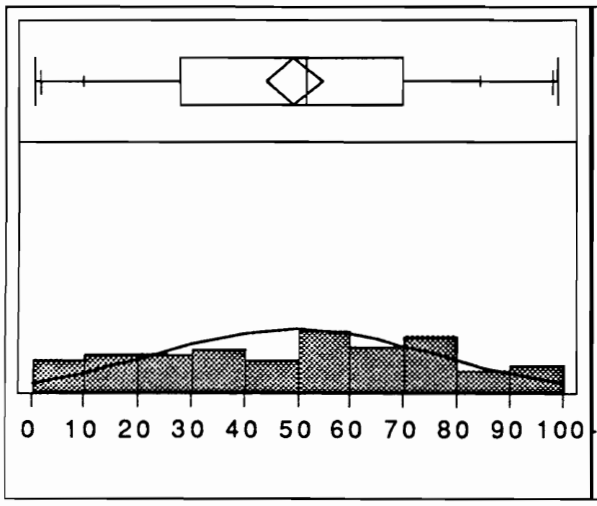
Moments

Mean	61.55714
Std Dev	25.91493
Std Err Mean	3.09743
upper 95% Mean	67.73635
lower 95% Mean	55.37793
N	70.00000

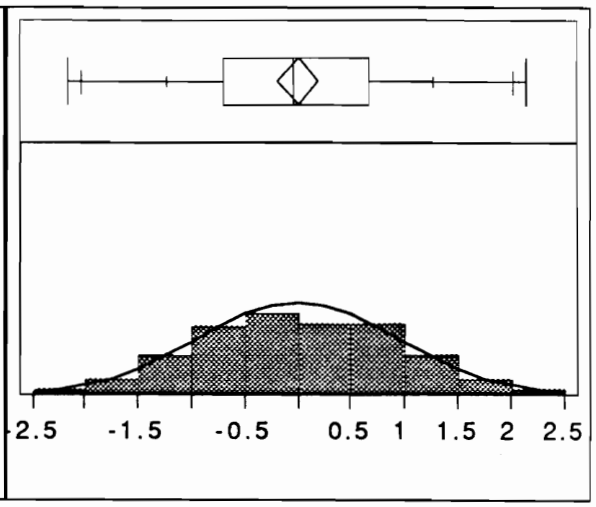
Moments

Mean	-0.00031
Std Dev	0.95261
Std Err Mean	0.11386
upper 95% Mean	0.22683
lower 95% Mean	-0.22745
N	70.00000

Grade 5 Math Percentile



Grade 5 N-Quantile %tile



Quantiles

maximum	100.0%	99.000
	99.5%	99.000
	97.5%	98.200
	90.0%	84.800
quartile	75.0%	70.000
median	50.0%	52.000
quartile	25.0%	28.000
	10.0%	10.000
	2.5%	1.800
	0.5%	1.000
minimum	0.0%	1.000

Quantiles

maximum	100.0%	2.1539
	99.5%	2.1539
	97.5%	2.0374
	90.0%	1.2821
quartile	75.0%	0.6745
median	50.0%	-0.0392
quartile	25.0%	-0.6910
	10.0%	-1.2299
	2.5%	-2.0374
	0.5%	-2.1539
minimum	0.0%	-2.1539

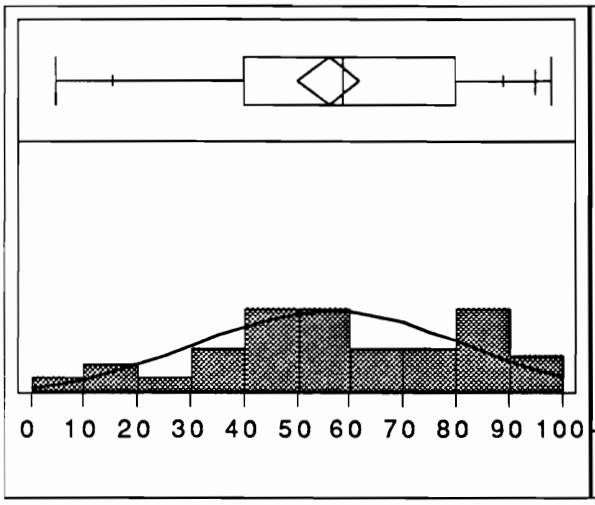
Moments

Mean	49.47368
Std Dev	27.07352
Std Err Mean	2.77768
upper 95% Mean	54.98887
lower 95% Mean	43.95850
N	95.00000

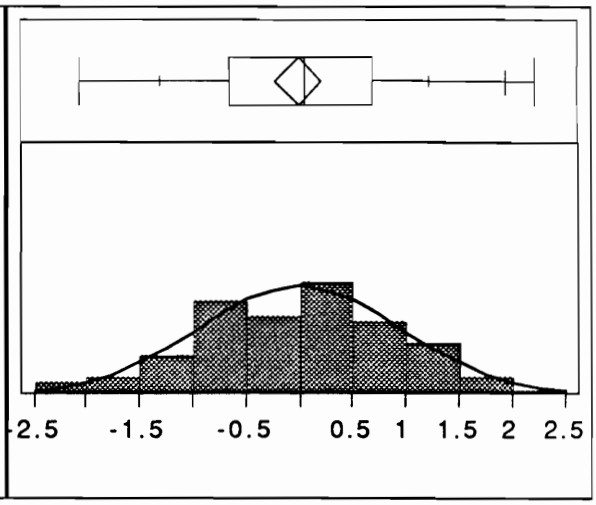
Moments

Mean	0.00005
Std Dev	0.96040
Std Err Mean	0.09853
upper 95% Mean	0.19570
lower 95% Mean	-0.19559
N	95.00000

Grade 6 Math Percentile



Grade 6 N-Quantile %tile



Quantiles

maximum	100.0%	98.000
	99.5%	98.000
	97.5%	95.150
	90.0%	89.000
quartile	75.0%	80.000
median	50.0%	59.000
quartile	25.0%	40.000
	10.0%	15.200
	2.5%	5.000
	0.5%	5.000
minimum	0.0%	5.000

Quantiles

maximum	100.0%	2.2316
	99.5%	2.2316
	97.5%	1.9632
	90.0%	1.2320
quartile	75.0%	0.7069
median	50.0%	0.0643
quartile	25.0%	-0.6347
	10.0%	-1.2903
	2.5%	-2.0699
	0.5%	-2.0699
minimum	0.0%	-2.0699

Moments

Mean	56.18182
Std Dev	25.12952
Std Err Mean	2.86377
upper 95% Mean	61.88554
lower 95% Mean	50.47810
N	77.00000

Moments

Mean	0.00039
Std Dev	0.95494
Std Err Mean	0.10883
upper 95% Mean	0.21714
lower 95% Mean	-0.21635
N	77.00000

Nine Regression Models with Normal Quantile Percentile as Response Variable

	School	Gr.1-3	Gr 4-6	Gr 1	Gr 2	Gr 3	Gr 4	Gr 5	Gr 6
R square	.59	.64	.53	.94	.55	.76	.46	.60	.70
DF	11,383	8,184	7,190	3,45	5,70	9,63	6,54	6,78	5,48
F Ratio	50.37	41.04	31.16	246.73	17.34	22.54	7.78	19.33	22.52
MSe	.4149	.3691	.4448	.0514	.44918	.26856	.57050	.36720	.27645
Prob > F	.00	.00	.00	.00	.00	.00	.00	.00	.00

Variables: with corresponding Probabilities of F

Gender	.01	.05	.04	•	•	.00	.00	•	•
IQ	.00	.00	.00	.00	.00	.00	.01	.00	.00
Math L.	.00	.00	.00	•	.02	.01	.00	.00	.00
Econ L.	•	•	•	•	•	.13	•	•	•
Grade	.00	•	.00	•	•	•	•	•	•
Age	•	.09	•	.00	.06	.07	•	•	•
Handedness	.05	.04	•	•	•	.06	.15	.11	•
Spec Ed	•	•	•	•	•	•	•	.03	•
Adding	.00	.01	.11	.01	•	.02	•	•	.08
Accuracy	•	•	•	•	.01	•	•	•	.11
Imagery	•	.02	•	•	•	•	.14	.06	•

Vita

Anita Short VanBrackle was born on August 17, 1947 in Alexandria, Virginia. She attended Radford University, receiving a Bachelor of Science Degree in Education with a major in Elementary Education in 1969. While employed as an elementary teacher, she began working toward a Master of Arts degree in Curriculum and Instruction with a concentration in Learning Disabilities at Virginia Polytechnic Institute and State University. The Master of Arts degree was conferred in 1977. She has worked in public schools as a classroom teacher in grades K-3 and as a special education teacher of students in grades K-7 in Virginia, Georgia and New Jersey. From 1982 to 1985, sixty hours of graduate work in Supervision and Instruction were completed at Emory University. In 1988 she began advanced graduate studies leading toward a Doctor of Education degree in Curriculum and Instruction at Virginia Polytechnic Institute and State University. Professional associations include: National Council of Teachers of Mathematics, Virginia Council of Teachers of Mathematics, American Educational Research Association, and Association for Supervision and Curriculum Development. She has presented math workshops in Virginia and Georgia. Honors include induction to The Honor Society of Phi Kappa Phi and selection as Teacher of the Year at High Point Elementary School in Fulton County, Georgia.

She is married to Lewis N. VanBrackle and they have one son, Robert. She currently resides in Dallas, Georgia.