THE ROLE OF FIELD INDEPENDENCE/DEPENDENCE, SPATIAL VISUALIZATION, AND CEREBRAL DOMINANCE IN MATHEMATICS ACHIEVEMENT OF TENTH GRADE STUDENTS

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Mathematics teachers encounter the widespread belief that the world is divided into two kinds of people, those who can do mathematics and those who cannot (Grow and Johnson, 1983). This belief is ingrained in students early in their school experience, and the typical high school teacher discovers the agonies of dealing with students who know they cannot learn mathematics. A search for an explanation of this belief motivates this study.

Cognitive style is a psychological construct that has been explored in an attempt to explain individual differences in learning. A great deal of the theoretical structure of the construct originated with Ketch and Crutchfield (1948). They proposed that cognitive style is a dimension that is different from general intelligence. Cognitive style had been defined in terms of the processes that determine the way a person relates perception to higher order thinking and includes the cognitive activities of selecting, sorting, and organizing that impose structure on information (Santostefano, Rutledge and Randall, 1965). Witkin, Moore, Goodenough, and Cox (1977) stressed the importance of cognitive style to learning and stated that knowing a child's cognitive style can be as useful to education as knowing a child's IQ. Three factors of cognitive style that have been linked to mathematics achievement were the foci of this study. They are field independence/dependence, spatial visualization, and cerebral dominance.

One factor of cognitive style that has been related to mathematics achievement by several researchers is field independence/dependence. Witkin et al. (1977) stated that this factor is relatively stable and influences the way an individual interacts with his surroundings. The influence of the prevailing field with individual performance on perceptual tasks determines field dependence. A person who perceptually cannot separate an item from its surrounding field is said to be field dependent. The person who can do this is said to be field independent. According to Adams and McLeod (1979):

> Individual differences in field dependence/independence are identified on a continuum determined by the extent a person perceives analytically. Students who are relatively field dependent find it difficult to restructure a situation in order to solve a problem or to impose structure on material when structure is lacking. On the other hand, field independent students are more capable of taking a critical element out of context in order to use that element in a different context (p. 347).

Spatial visualization is another factor of cognitive style that has been related to mathematics achievement. Researchers have described different subfactors or levels of spatial ability. McDaniel and Guay (1976) suggested a continuum for describing spatial ability that ranges from the ability to recognize and retain visual patterns to more complex mental manipulations of visual images. Two of these levels were included in this study--two dimensional and three dimensional spatial visualization.

Many references in popular literature concern differences in which the two hemispheres of the brain process information (Wonder and Donovan, 1984). In most right handed people, the brain's left hemisphere is the primary center for speech. The thinking style associated with the left hemisphere is described as verbal, sequential, analytical, propositional, and remembering in words. The right hemisphere's processing style is characterized as visual, synthetic, positional, relational, remembering in images (Wheatley, Frankland, Michel, and Kraft, 1978; Gray, 1980). It has been hypothesized that individuals have a tendency to prefer processing information in one hemisphere over the other or can integrate the processing styles to fit the given situation. This preference is called cerebral dominance.

A detailed study of these factors and their interactions may provide some insight for the student who believes he cannot do mathematics. Is the student who prefers a right brain thinking style doomed in mathematics? Is the student who prefers a left brain thinking style more likely to succeed in mathematics or does the student who can integrate both left and right brain thinking styles have the best chance of success? What level of achievement in mathematics can the student expect who is field dependent, has low spatial abilities, and is right brain dominant?

Statement of the Problem

The problem under investigation was a study of the relationships between and among the factors of field independence/dependence, two and three dimensional spatial visualization, and cerebral dominance on mathematics achievement of tenth grade students after the effects of race and gender had been removed. The population was composed of the tenth grade students in Muskogee, Oklahoma, enrolled during the 1986-87 school year. The sample (n= 240) for the study was randomly selected from the tenth grade class at Muskogee High School in Muskogee, Oklahoma, during the 1986-87 school year.

Hypotheses

The foci of this study were four main effects, six two-way interactions, four three-way interactions, and one four-way interaction once the effects of gender and race had been removed. To state the null and alternative hypotheses in symbolic form, the following representations will be used.

X1 represents the continuous variable of field independence/dependence.

X2 represents the continuous variable of three-dimensional spatial visualizattion.

X3 represents the continuous variable of two dimensional spatial visualization.

X4 represents the continuous variable of cerebral dominance.

X5 represents the dichotomous variable for gender.

X6 represents a race variable--whether the student is American Indian.

X7 represents another race variable--whether the student is black.

The hypothesis for the four way interaction were as follows:

1. H_0: X1 X2 X3 X4 = 0.

   There is no difference in mathematics achievement due to interaction of field independence/dependence, two dimensional and three dimensional spatial visualization, and cerebral dominance.

H_a: X1 X2 X3 X4 $\neq$ 0.

There is a difference in mathematics achievement due to the interaction of field independence/dependence, two dimensional and three dimensional spatial visualization, and cerebral dominance.

The hypotheses for the four three-way interactions were as follows:

2. H_o: X1 X2 X3 = 0.

There is no difference in mathematics achievement due to the interaction of field independence/dependence and two dimensional and three dimensional spatial visualization.

H_a: X1 X2 X3 $\neq$ 0.

There is a difference in mathematics achievement due to the interaction of field independence/dependence and two dimensional and three dimensional spatial visualization.

3. H_o: X1 X3 X4 = 0.

There is no difference in mathematics achievement due to the interaction of field independence/dependence, two dimensional spatial visualization, and cerebral dominance.

H_a: X1 X3 X4 $\neq$ 0.

There is a difference in mathematics achievement due to the interaction of field independence/dependence, two dimensional spatial visualization, and cerebral dominance.

4. H_o: X1 X2 X4 = 0.

There is no a difference in mathematics achievement due to the interaction of field independence/dependence, three dimensional spatial visualization, and cerebral dominance.

H_a: X1 X2 X4 $\neq$ 0.

There is a difference in mathematics achievement due to the interaction of field independence/dependence, three dimensional spatial visualization, and cerebral dominance.

5. H_o: X2 X3 X4 = 0.

There is no difference in mathematics achievement due to the interaction of three dimensional and two dimensional spatial visualization, and cerebral dominance.

H_a: X2 X3 X4 $\neq$ 0.

There is a difference in mathematics achievement due to the interaction of three dimensional and two dimensional spatial visualization, and cerebral dominance.

The hypotheses for the six two-way interactions were as follows:

6. H_o: X1 X2 = 0.

There is no difference in mathematics achievement due to the interaction of field independence/dependence and three dimensional spatial visualization.

H_a: X1 X2 $\neq$ 0.

There is a difference in mathematics achievement due to the interaction of field independence/dependence and three dimensional spatial visualization.

7. H_o: X1 X3 = 0.

There is no difference in mathematics achievement due to the interaction of field independence/dependence and two dimensional spatial visualization.

H_a: X1 X3 $\neq$ 0.

There is a difference in mathematics achievement due to the interaction of field independence/dependence and two dimensional spatial visualization.

8. H_o: X1 X4 = 0.

There is no difference in mathematics achievement due to the interaction of field independenc/dependence and cerebral dominance.

H_a: X1 X4 $\neq$ 0.

There is a difference in mathematics achievement due to the interaction of field independence/dependence and cerebral dominance.

9. H_o: X2 X3 = 0.

There is no difference in mathematics achievement due to the interaction of two dimensional and three dimensional spatial visualization.

H_a: X2 X3 $\neq$ 0.

There is a difference in mathematics achievement due to the interaction of two dimensional and three dimensional spatial visualization.

10. H_o: X2 X4 = 0.

There is no difference in mathematics achievement due to the interaction of three dimensional spatial visualization and cerebral dominance.

H_a: X2 X4 $\neq$ 0.

There is a difference in mathematics achievement due to the interaction of three dimensional spatial visualization and cerebral dominance.

11. H_o: X3 X4 = 0.

There is no difference in mathematics achievement due to the interaction of two dimensional spatial visualization and cerebral dominance.

H_a: X3 X4 $\neq$ 0.

There is a difference in mathematics achievement due to the interaction of two dimensional spatial visualization and cerebral dominance.

The hypotheses for the main effects were as follows:

12. H_o: X1 = 0.

There is no difference in mathematics achievement among students with differing degrees of field independence/dependence.

H_a: X1 $\neq$ 0.

There is a difference in mathematics achievement among students with degrees of field independence/dependence.

13. H_o: X2 = 0.

There is no difference in mathematics achievement among students with differing degrees of three dimensional spatial visualization ability.

H_a: $X2 \neq 0$.

There is a difference in mathematics achievement among students with differing degrees of three dimensional spatial visualization abiltiy.

14. H_o: $X3 = 0$.

There is no difference in mathematics achievement among students with differing degrees of two dimensional spatial visualization ability.

H_a: $X3 \neq 0$.

There is a difference in mathematics achievement among students with differing degrees of two dimensional spatial visualization ability.

15. H_o: $X4 = 0$.

There is no difference in mathematics achievement among students with differing degrees of cerebral dominance.

H_a: $X4 \neq 0$.

There is a difference in mathematics achievement among students with differing degrees of cerebral dominance.

Importance of the Study

Research has shown there is a relationship between spatial visualization and mathematics achievement for secondary students. Reviews by Fennema and Sherman (1977) and Maccoby and Jacklin (1974) established male superiority in spatial visualization and in mathematics ability with both appearing during early adolescence and continuing throughout adulthood. Research has shown there is a relationship between field independence/dependence and mathematics achievement. Field independent students show higher mathematics achievement than their field dependent peers (Vaidya and Chansky, 1980). In a study involving students evidencing dyscalculia and a control group of students not evidencing dyscalculia, significant differences were found in these two factors of cognitive style--field independence/dependence and spatial visualization (Tishler, 1981).

The mode of processing information differs for the left and right hemisphere. The right hemisphere is characterized as holistic or gestalt and the left is characterized as sequential or serial. These differences may shed new light on cognitive style (Wheatley et al., 1978). Recent brain research has revealed new knowledge about how the human brain is organized and how it functions. This medical research has contributed to the development of the theory of cerebral dominance.

A large percentage of children demonstrate dominance of one hemisphere of the brain. This asymmetry results in an individual cognitive style sufficient to affect school performance (Wheatley et al., 1978). Often the predominance of one hemisphere over another is related to heredity and, especially among boys, a strong dominant right hemisphere learning style may run in families (Bannatyne, 1971).

The public school curriculum favors a strong left hemisphere learning style, with heavy emphasis on such language skills as reading and spelling (Bratt, 1981). Mathematics curricula often place heavy emphasis on computational skills, which require left brain processing skills. Clearly, the child who processes information in a holistic, visual-spatial, right hemisphere style is at a disadvantage (Bratt, 1981). It may well be that students who do not find school relevant are right brain oriented. To them, left brain tasks do not make sense and they would be more successful in a curriculum that stresses spatial presentations and multisensory learning. It is important to realize that complex thinking, especially of a problem solving nature is based on a smooth integration of these two modes of thinking (Wheatley et al., 1980).

Because the investigation of cognitive style has shown promise for explaining learning differences, this research study was designed to study not only the effects but also the interactions of three factors of cognitive style--field independence/dependence, spatial visualization, cerebral dominance--on achievement in mathematics. No previous research has simultaneously examined these effects on mathematics achievement.

Definitions

Cerebral Dominance is the extent to which one hemisphere of the brain dominates the other for control of behavior.

Cognitive Style is a characteristic approach an individual brings to a learning situation that encompasses both his perceptual and intellectual activities.

Field Independence is the ability to perceive an item as discrete from the surrounding field.

Field Dependence is the inability to separate perceptually an item from the surrounding field.

Psychological construct is an internal human process that cannot be observed, touched or measured directly.

Two dimensional spatial visualization is the ability to visualize two dimensional configurations and to mentally manipulate these configurations.

Three dimensional spatial visualization is the ability to visualize three dimensional configurations and to mentally manipulate these configurations.

Race, as used in this study, was the student's response to the question "What is your race?". The major categories found in this sample were Black, American Indian, and white.

Assumptions

The results of the Metropolitan Achievement Test (MAT) are assumed to be reliable indices of student achievement in mathematics. The scores of the Card Rotations Test and the Cube Comparison Test are assumed to reliably measure spatial visualization. The scores on the "Your Style of Learning" questionnaire are assumed to determine cerebral dominance and the Group Embedded Figures test is assumed to determine field independence.

It is assumed the variables race and gender are reliable, as they are self-report variables. Their use as covariates in this nonexperimental study is based upon their reliability being high.

It is also assumed that the students in the sample will answer the testing instruments with integrity.

Limitations

A limitation of the design of this study is common to most correlational studies. Although information was gathered on the existence and strength of the relationships between field independence/dependence, two dimensional and three dimensional spatial visualization, and cerebral dominance and mathematics achievement, the cause of the relationships will remain unclear. This study is also limited to the extent to which the assessed factors reflect the actual factors and assessed achievement represents true achievement for each student involved in the study.

This study is limited in scope as the sample will be randomly selected from the tenth grade class of Muskogee High School enrolled during the 1986-87 school year and the results of the study will generalize only to this population.

Overview

This study is divided into five chapters, the first presenting the statement of the problem under consideration. A review of literature pertaining to field independence/dependence, two dimensional and three dimensional spatial visualization, and cerebral dominance and the relation of these factors to mathematics achievement is the content of Chapter II. The experiment is discussed in Chapter III and includes the design and sample, the measuring instruments, the collection of data, and methods of analysis used in the treatment of data. The results of the experiment will be reported in Chapter IV and Chapter V will present the summary, conclusion, implications and suggestions for further study.

CHAPTER II

REVIEW OF LITERATURE

The literature about field independence/dependence will be reviewed first. Then, the literature concerning spatial visualization will be examined. Finally, the topic of cerebral dominance will be discussed.

Field Independence/Dependence

The cognitive style factor of field independence/dependence was chosen as a variable of interest in this study because it has been extensively researched and has wide applications to educational problems (Witkin et al., 1977). This variable has been linked to mathematics achievement in numerous studies (Buriel, 1978; Vaidya and Chansky, 1980; Mrosla, 1983).

Individual differences in field independence/dependence form a continuous distribution. These labels reflect a tendency of varying degrees of strength toward one mode of perception or the other. There is no implication that there are two distinct kinds of people, and in the following discussion the term field dependent will mean relatively more field dependent. Underlying these individual differences is the degree to which a person perceives a part of a field as discrete from the surrounding field as a whole, rather than embedded in the field, or more simply, the degree to which a person perceives analytically. The person who perceptually cannot keep an item separate from the surrounding field is field dependent. A person who can perceive an item separate from its background is field independent. Students who are field dependent have difficulty with the class of problems in which the solution depends on taking some critical element out of the context in which it is presented and restructuring the problem so that the item is now used in a different context (Witkin et. al., 1977). Field dependent students have a tendency to leave material "as is" if it is lacking in structure (Witkin et. al., 1962/1974). In a study by Stasz (1974), field dependent students made fewer distinctions among concepts. For field dependent students, concepts clustered in a large, loosely organized group that included most of the concepts. For field independent students, Stasz found that the concepts clustered in small, tights groups with less overlap. This kind of research has led to a concept of the field independence/dependence continuum as an articulated/global continuum. The articulated style involves perceiving items separate from the background and then imposing a structure on the field when it may have had little inherent structure. The person who perceives globally does not separate items from the field and accepts the inherent structure without analyzing it or restructuring it.

The field dependent person is more socially adept than the field independent person. It has been demonstrated that field dependent people literally look more at faces of other people, which are the primary sources of what others are feeling and thinking (Konstadt and Forman, 1965). Field dependent people are drawn to people and like to be with people. They are better liked and perceived as warm, tactful, considerate, socially outgoing, and affectionate with others (Crutchfield, Woodworth, and Albrecht, 1958). The field independent person is not as sensitive to the social undercurrent. He or she is more likely to be interested in the abstract and theoretical (Biggs, Fitzgerald and Atkison, 1971).

It is logical that field independence/dependence is likely to influence mathematics achievement. The analytic ability that is required on mathematics achievement tests involves embedding and developing problem solving strategies that depend on reorganizing and restructuring information. This skill is assumed to be the cognitive style factor of field independence/dependence. Researchers Bien (1974), Buriel (1978), and Vaidya and Chansky (1980) have found higher mathematics achievement among field independent subjects.

Gender differences have been linked to this factor of field independence/dependence. In Western societies, small but persistent differences have been found that begin in adolescence. The difference is small compared to the range of scores within each gender. There is considerable overlap for the two genders (Witkin et. al., 1977).

Spatial Visualization

The use of graphs, diagrams and charts in all branches of mathematics would suggest that having good visual spatial abilities would be a definite advantage in the study of mathematics. In a general sense, visual spatial ability is a cognitive skill that involves the ability to perceive spatial relationships and to mentally manipulate visual material. Several mathematicians have noted the importance of this skill. Hamley, a mathematician and a psychologist, states that "mathematical ability is probably a compound of general intelligence, visual imagery, ability to perceive number and space configurations and to retain such configurations as mental patterns" (Smith, 1964). Another mathematician, Merserve, notes the extensive use of geometric models in all areas of mathematics and states that ". . . geometrical thinking must retain some link . . . with spatial intuition" (Fennema and Sherman, 1976).

Visual spatial ability has been extensively researched. Julia Sherman has consistently included spatial variables in studies investigating influences on mathematics performance of girls (Fennema and Sherman, 1978; Sherman, 1979). Schonberger (1976) searched for gender-related differences in performance on tests of visual spatial abilities and mathematics problem solving of seventh grade students. McDaniel and Guay (1976) examined the relationship between spatial ability, mathematics achievement and gender for students in grades 2 - 7. They found scores on lower levels of spatial ability were independent of the subject's gender, while males performed significantly better on higher levels than females.

In search for an explanation of why some intellectually capable students were unable to achieve in mathematics, Tishler (1981) studied the cognitive factor of spatial visualization and its effect. Her results indicated that students evidencing dyscalculia were significantly different from their mathematically achieving peers on two factors of cognitive style: field independence/dependence and spatial visualization.

Fennema (1974) identified a key problem that hinders adequate synthesis of past work involving visual spatial abilities. Researchers have no uniform agreement as to the critical factors that specify "spatial visualization ability". The brief summary of the literature that follows will demonstrate this.

During World War II, two factors of visual spatial ability were identified by the Aviation Psychology Program. One was called visualization and the other was called spatial relations (Schonberger, 1976). Thurstone (1950) identified three factors dealing with visual orientation in space. The factor S1 was described as the ability to identify an object seen from different angles or to visualize a rigid configuration moved to different positions. Thurstone's Flags is a test of the S1 factor. In this test, the subject must decide which flags are only rotations of a given flag and which ones are reflections. The second factor S2 was thought to represent the ability to imagine movement within the figure or among parts of the figure. An example of a S2 test is Surface Development in which the subject has to choose which of a set of solids is the one that results from folding and pasting a paper pattern. The S3 factor involved body orientation of the observer as an essential part of the problem.

In 1957, previous research was synthesized by Michael, Guilford, Fruchter and Zimmerman. They labeled three factors, wrote sub-factor descriptions and selected tests for the Kit of Reference Test of Cognition Factors developed under the auspices of Educational Testing Service. The first factor was called spatial relations and orientation (SR-O) and was described as the ability to comprehend the arrangement of elements within a visual stimulus pattern with the subject's body as a frame of reference. In SR-O test the entire figure is moved into a different position with parts of the figure remaining related to each other in the same way. The second factor was essentially the same as

Thurstone's S2 and was called visualization (Vz). On Vz tests the subject is expected to manipulate mentally one or more objects or parts of a configuration according to relatively explicit directions and the new configuration must be recognized or drawn. The third factor, called kinesthetic imagery, involved right-left discrimination.

Maccoby and Jacklin (1974) reviewed studies related to spatial ability and gender differences. They divided the studies into two groups. Thirty studies seemed to involve nonanalytic spatial processes (e.g., mazes, form boards) and 47 studies involved analytic visual spatial processes (e.g., embedded figures). Maccoby and Jacklin tentatively viewed the analytic tasks as requiring "decontextualization", i.e., the process of disembedding the stimulus or figure from its surrounding context. They thought both types of spatial tasks showed a similar pattern in regard to gender differences, a male advantage appearing at adolescence.

In 1979, McGee reviewed the work of factor analyses over the last 50 years and concluded that there has been "strong and consistent support for the existence of at least two distinct spatial abilities--visualization and orientation." McGee approved the following descriptions of spatial visualization (Vz) and orientation (S) factors provided by Elkstrom, French, Harman and Dermen (1976):

> Vz - An ability to manipulate or transform the image of spatial patterns in other arrangements; requires either the mental restructuring of a figure into components for manipulation or mental rotation of a spatial configuration in short term memory, and it requires performance of serial operations perhaps involving an analytic strategy.
>
> S - An ability to perceive spatial patterns or to maintain orientation with respect of objects in space--requires that a figure be perceived as a whole.

Clements (1981) criticized these descriptions as vague and self-contradictory. He claimed the contradiction can be avoided if it is allowed that orientation (S) involves both analysis of part of a figure and perception of the figure as a whole, but then the factor S would be very broad and it would have considerable overlap with factor Vz.

Linn and Petersen (1983) presented a meta-analysis of the findings of 172 studies of spatial abilities. Three subtypes of spatial ability were identified. About 75 percent of the total number of studies used measures requiring analytic ability for solution. Examples of tests used in these studies are Differential Aptitude Test, Space Relations sub-test, Embedded Figures Test, and Paper Folding. This construct was called spatial visualization and no significant gender effect was found for it. The second construct was called Horizontality/Verticality and it is measured by the Rod and Frame test. The third construct was called Mental Rotations and the test for it required rapid analog processing for achievement of high scores. Linn and Petersen (1983) found gender differences in the last two constructs.

McDaniel and Guay (1976) proposed a hierarchical structure of visual spatial abilities ranging from the ability to conceptualize patterns to the ability to mentally transform these patterns into different forms. They proposed four ascending steps or tasks in which the ability to visualize configurations and perform mental operations would be manifest. They constructed tests form each of these levels. The levels are listed as follows:

1. The ability to form a simple pattern from limited series of stimuli seen one at a time.
2. The ability to perceive a configuration and to retain that configuration in the mind despite distractions (Embedded Figures).

3. The ability to perceive a three dimensional object and conceptualize that object sufficiently well to describe portions not immediately shown.

4. The ability to conceptualize a three dimensional object and to mentally transform this object into two dimensional representation.

Factor analytic studies by Burt (1949) subdivided the space factor into two dimensional and three dimensional categories based on comments by teachers that success in plane geometry and solid geometry were not highly related. No empirical research was conducted and this division has not been thoroughly investigated (Schonberger, 1976).

After extensive discussion, Schonberger (1976) concluded that most factor analyses in which spatial tests split into two groups, the subgroups contain the same tests. So to summarize, many attempts have been made to study the sub-factors of spatial ability and agreement among the researchers is nonexistent. Some common ideas can be identified. Michael et al., Thurstone, and McGee each have a factor that involves transforming an image by reflection or rotation. The Card Rotation test is a timed, two dimensional test that involves recognizing if a planar figure has been rotated or reflected. In the study reported here, this factor was called the orientation factor. Petersen, McDaniel, and Thurstone identified a factor that involves manipulating an item mentally and recognizing its new configuration. In the study reported here, this factor was called the visualization factor, and the Cube Comparison test was a three dimensional test for this factor.

In reviewing the literature, an effort was made to isolate the spatial visual subfactors that have been linked by research to mathematics achievement. McDaniel and Guay (1976) found the low level as well as the high level of spatial ability correlated positively with mathematics achievement. In her study of students evidencing dyscalculia, Tishler (1981) applied McDaniel's low and high level theory but used the card Rotations test for the low level and the Mental Rotations test for the high level. She found that the dyscalculia group had significantly less low level and high level spatial visualization that the control group.

Moses (1980) in a study of the effects of spatial instruction on problem solving performance used four spatial tests to obtain a measure of spatial visualization. Two of these test were the Card Rotations test and the Mental Rotations test.

Next, the gender differences in visual spatial abilities will be examined. Clements (1981) concluded in an in-depth analysis of the literature on visual spatial abilities that adolescent males outperformed adolescent females on many spatial tasks that require three dimensional thinking and mental manipulations of images. Tasks which demand only two dimensional thinking and do not require mental manipulation of images are not likely to produce significant gender-related differences in the performance of mathematics.

The results of McDaniel and Guay (1976) showed that the scores on spatial tests requiring more lower levels of spatial abilities were independent of the subject's gender, while the male performance on higher level tests was significantly better than the females.

Cerebral Dominance

The third variable of cognitive style that was examined in this study is cerebral dominance. Researchers have gathered an abundance of evidence that the two hemispheres of the human brain are specialized to perform different cognitive functions. In most right-handed people, the left hemisphere treats stimuli serially whereas the right hemisphere processes stimuli many at a time as a gestalt. Because of this difference, the left hemisphere is better at such tasks as reading, speaking, analytic reasoning, and mathematical computations while the right hemisphere is better at spatial tasks, recognizing faces, and music (Wheatley et al., 1978).

The evidence for hemispheric specialization has come from many diverse investigations that include lesion studies, anatomical evidence, split brain research, dichotic listening, tachistoscopic studies, reaction time and sodium amytal tests, and electroencephalography (EEG). A brief summary of some of these investigations follows.

In 1960, Joseph Bogen, a neuro-surgeon, severed the corpus calloseum in ten patients to control severe epileptic seizures. The corpus callosum is the bundle of nerve fibers that connect the two hemispheres of the brain and acts as a communication channel between the hemispheres. The carefully designed studies performed on these "split-brain" patients made a significant contribution to the theory of cerebral dominance. Sperry (1964) was able to show that the right hemisphere of the "split-brain" patients could perform spatial tasks but had virtually no language capability. He found that the left hemisphere controlled speech, mathematics calculations, and reasoning, but separated as it was, the left brain could not perform spatial tasks.

The functional differences in the left and right hemisphere were first noted by observing people who suffered brain injury to one hemisphere. Damage to the right hemisphere resulted in loss of spatial ability and damage to the left hemisphere resulted in loss of speech and reasoning ability (Bogen, 1969).

Dichotic listening tests are performed by presenting balanced sounds to each ear simultaneously and then determining ear superiority for different types of tasks. Sounds presented to the right ear are processed by the left hemisphere (Geldard, 1972). These tests consistently have found a right ear advantage for linguistic stimuli and a left ear advantage for non-linguistic stimuli (Kimura, 1967). The reaction time of each hemisphere to different tasks revealed a similar pattern of specialization discovered in split brain patients. A single hemisphere can be anesthetized with sodium amytal, leaving the other hemisphere alert. Studies using the technique provide strong evidence of left hemisphere control of speech.

Electroencephalography (EEG) has been useful in the study of hemispheric processing. Using EEG, it is possible to measure hemispheric activity while a person is engaged in a task by using the ratio of alpha components of the two hemispheres. Using this ratio, Butler and Glass (1974) found the left hemisphere, but not the right, active in mental arithmetic. Galin and Ellis (1975) used EEG techniques to isolate hemispheric activity for logical and spatial tasks. Their findings are in line with the pattern of specialization presented earlier.

A word of caution seems necessary. The implications of research dealing with brain functions has often been over simplified. Some have claimed that Western society may be overly dependent on logical, linear left hemispheric processes while Eastern thought is more holistic in orientation. Rationality and logic are claimed to be the sole province of the left hemisphere while intuition and creativity are the sole province of the right hemisphere. Some claim that standard school curricula educate only the left side of the brain. Others claim that when engaged in any particular activity, people think with only one hemisphere are a time, either the left or the right depending on the activity. Some claim people think with only the left hemisphere, others with only the right. These assertions are either known to be false by neuropsychologist or totally lacking in any supportive scientific evidence (Levy, 1982).

The development of brain functioning has been explored by researchers and has been linked theoretically to Piaget's levels of cognition. A brief outline of this theory is presented as high school students have differing maturity rates and this theory may offer insights into differences of cerebral dominance. Studies suggest the right hemisphere to be dominant in most children where the left tends to be more dominant in most educated adults. The shift in the ratio of use from right to left occurs during childhood.

Much early learning is video-spatial and supports the idea that the right hemisphere is dominant. The pre-operational child still favors the right hemisphere's visual spatial nature. In a conservation task, a non-conserving child will tend to make his decision based on what he sees. The conserver is less interested in the visual display and bases his decision on more logical reasoning. The conserver (concrete operational) shows more left hemisphere processing. Gazzaniga (1970) suggested that at about the age of eight a specialization process begins and this process may be highly correlated with the onset of concrete operational thinking. Other changes may occur as children move into the formal operational stage. In a study by Dilling, Wheatley, and Mitchell (1976), formal operational students showed significantly more left hemisphere processing than concrete operational students with the greatest difference existing for a task in logic. This theory might explain why many high school students would prefer right hemisphere thinking processes. It has been shown by research that many high school students are in the concrete operational stage (Dilling et al., 1976).

The research on brain dominance in education in general and mathematics in particular will be reviewed. Kraft (1976) studied brain functioning as measured by EEG in normal right handed boys and girls aged 6-8 as they responded to a variety of tasks: science, mathematics, reading, spelling, Piagetian conservation, and problem solving. He found that each child has his own individual brain functioning pattern that the researchers likened to a fingerprint. Some right handed children showed dominant right hemispheric functioning, others dominant left hemispheric functioning, and still others had a high level of activity alternately in each hemisphere. Kraft observed that the natural brain functioning pattern of any child is remarkably consistent during his performance of various tasks, even at times when the nature of the tasks would cause the observers to expect a change in thinking style. Languis and Kraft (1977) state:

> It is possible that many children who drop out of school and . . . many more who 'turn off' to school do so because of serious mismatches between the individual's learning patterns and school expectations: right brained children taught by left brained teachers utilizing primarily left brained instructional strategies evaluated by left brain criteria (p. 6).

Dilling et al. (1976) conducted a study using EEG to investigate differences in hemispheric specialization of formal and concrete operational adults. Hemispheric asymmetry was determined by the ratios (left/right) of the alpha-powers from homologous leads. They found a trend toward greater left hemispheric activity compared to right for the formal operational subjects, especially for logic tasks.

Battista (1979) performed a study of the interrelationships between problem solving, right hemisphere processing facility, and success in mathematics instruction. His subjects were college students enrolled in college level mathematics courses. He used the Purdue Spatial Visualization test to measure right hemispheric processing ability. This test is designed to measure the ability to rotate mentally three dimensional objects depicted in drawings. The tasks required by the test was shown by EEG investigations to utilize right hemisphere processing (Wheatley et al., 1978). The correlation results of this study suggest a positive relationship exists between problem solving ability and right hemisphere processing facility and that both of these abilities are positively related to success in college level mathematics instruction.

Several studies using students with learning disabilities and gifted students as subjects yielded results relevant to this study. Weinstein (1978) studied learning disabilities in mathematics in fifth and seventh graders. She suggested that students with dyscalculia may be delayed in their development of cerebral hemisphericity. This lag produces an over-reliance upon spatial/holistic processing under circumstances in which analytic reasoning is better suited. Research on learning disabled students consistently reveals a high prevalence of right brain processing styles. The characteristic processing difficulties encountered by the learning disabled child such as language and sequencing disorders (reading/writing difficulties, letter reversals, inversions) are indicative of the right brain's nonverbal random information style (Rubenzer, 1982). Olsen (1977) found gifted students used both hemispheres in contrast to normal students who choose one and only one processing style.

There has been very little research that has examined any of the two way interactions of field independence/dependence, spatial visualization, or cerebral dominance, although comments about these relationships can be found in the literature.

Brennan (1982) suggested that left brain preference people learn analytically and right preference people learn globally. Literature on analytic/global (field independent/dependent) learners describes left brain preference persons and field independents similarly. They both learn sequentially, emphasize the importance of language and verbal ability, and tend to be reflective. In a similar fashion, the right brained and global (field dependent) literature describes holistic learners who emphasize spatial relationships and emotions as characteristic and tend to be impulsive. Teachers traditionally present all the parts of a given lesson and expect students to be able to integrate the parts and "get the picture." Global learners thrive on "getting the picture" and then discovering the elements necessary to make up the picture. She states:

> The next time someone says to you 'I hate math. I've always hated math.', ask them if they liked geometry. About 75 percent will say they like geometry but hated math. The reason? In geometry you can 'get the picture' (p. 213).

There are several methods of assessing cerebral dominance. An informal way that a classroom teacher may assess cerebral dominance is through observation. The left dominant child respects the culture's social values, is time and sequence oriented, can identify with places that are both specific and general, shows verbal ability in describing events, and uses logic. The right dominant person loses track of time, lacks organization and responsibility, has unconventional values, is imaginative and creative, solves problems in unconventional ways, tends toward self-indulgence, and has an unbounded desire for exploration. The integrated person has characteristics of both the left and right dominant thinking styles (Matthews, 1982).

There are paper and pencil, self-report, forced choice questionnaires that are designed to determine preferred hemispheric processing styles. The one that appears most often in the literature is "Your Style of Learning and Thinking (Form C)" developed by Torrance, Reynolds, Riegel, and Ball in 1977. It is based on an extensive review of the literature on hemispheric functioning as it related to education. The questions on this group test correspond to associations between preferred cognitive styles and predominant hemispheric processing modes. The results are expressed in terms of left, integrated and right brain preference.

To briefly summarize, there has been research that has examined the individual factors of field independence/dependence, spatial visualization, gender, and to a lesser extent, cerebral dominance in relation to mathematics achievement. Very little research has examined the interactions of any two or three of these factors and none has examined all four.

CHAPTER III

THE EXPERIMENT

The Experimental Design and Sample

This study involved four independent variables--field independence/dependence (X1), three dimensional spatial visualization (X2), two dimensional spatial visualization (X3), and cerebral dominance (X4)--that cannot be manipulated. Also, the variables of gender (X5) and race (X6, X7) were used as covariates as the review of literature suggested some differences in the other variables when race and gender are considered. The use of race and gender as covariates enabled the researcher to determine the effect of the four continuous independent variables and their interactions upon mathematics achievement after the effects of race and gender had been statistically eliminated.

The research design was a correlational study using multiple regression techniques to determine the amount of variability in mathematics achievement related to the four independent variables and their interactions. A hierarchical multiple regression was chosen to analyse the data over an ANCOVA for two reasons. One major factor was the unequal cell size that would result had the independent variables been categorized into several levels. In ANCOVA analysis, when the cells have unequal number of scores per cell, the hypothesis tested for main effects and interactions are no longer independent and the design is no longer orthogonal and ambiguity is seen in the results

(Tabachnick, 1983). If handled in the ANCOVA framework, the continuous independent variables would have to be rendered discrete which might impose arbitrary cuts that weaken real relationships. In regression, the full range of the independent variable can be maintained (Tabachnick, 1983).

The sample size of 240 was chosen so the study would have statistical power. Ideally, regression analysis requires 20 times more cases than variables. The minimum reguirement is a ratio of five times more cases than variables. The higher the case to variable ratio, the less important it becomes that the residuals be normally distributed. The review of literature suggested that the effects of the independent variables chosen are not large. More cases are needed to demonstrate a small effect than a large one. Also, if substantial measurement error is expected from somewhat unreliable variables, more cases are needed. It was expected that the actual sample would be smaller than the targetted sample size as the absentee rate for high school students averages from 10 to 12 percent on any given day.

The sample was chosen from tenth grade students attending Muskogee High School in Muskogee, Oklahoma in the school year 1986-87. The tenth grade was chosen for the study because the State of Oklahoma requires schools to administer the Metropolitan Achievement Test (MAT) to all tenth grade students. The mathematics subscore on the MAT was used for the dependent variable in the study. Muskogee High School was chosen because the student body is large enough, over 300 tenth grade students, and the student body is diverse in socio-economic background and racial make-up.

All tenth grade students attending this school are required to take a mathematics course. It was arranged that the tenth grade students in four teachers' classes for the last three hours of the school day be used for the sample. The classes selected included Algebra 1/2, Algebra I, Algebra II, and Geometry and included students of all abilities. There were 238 tenth grade students in these classes. Of these 238 subjects selected, 32 were American Indians and 42 were Black. In the 196 data points used by the computer, 25 were American Indian and 37 were Black.

The Measuring Instruments

The following tests were administered under normal school conditions:

1. The Group Embedded Figures Test (GEFT) was used to measure field independence/dependence. Students were asked to locate a geometric shape hidden within a more complex design. Eighteen items were presented and the test was limited to 20 minutes. Validity reports are available. A reliability estimate of 0.82 for the GEFT was reported by Witkin on a college student population. The raw score ranged from 0 to 18 and was used as continuous data in regression analysis.
2. The Card Rotations Test (CRT) was used to measure two dimensional spatial visualization ability. This test, from the Kit of Factor-Referenced Cognitive Tests, was developed by the Educational Testing Service from Thurstone's cards to measure the factor "spatial orientation" (Ekstrom, French, and Harman, 1976). The CRT presents two dimensional objects in rotation. A reliability of 0.92 was reported by Tishler. A

reliability of .86 for males and .89 for females was reported by Elkstrom et al. (1976). The test was scored by subtracting the number of wrong answers from the number of right answers so negative scores are possible. The maximum score is 160.

3. The Cube Comparison Test (CCT), a group test of three dimensional spatial visualization, was used to measure high level spatial visualizations, the ability to visualize three dimensional configurations and to mentally rotate these configurations. This test also comes from the Kit of Factor-Referenced Cognitive Tests. A reliability of 0.87 was reported by Tishler. A reliability of .77 for both females and males was reported by Elkstom, French, and Harman (1976). This test was scored by right minus wrong and negative scores are possible. The highest possible score is 40.
4. Your Styles of Learning, Form C, (YSLC) was developed by Torrance et al. (1976) and was used to measure Cerebral Dominance. It is a 36 item multiple choice inventory derived from research and theory concerning the specialized functions of the right and left hemispheres of the brain. It is easier to use than most of the performance tests that have been devised for this purpose and has useful feedback properties (Matthews, 1982). The answers are separated into three categories, right brained, left brained or integrated. A score of 1 was assigned to the right brained answers, a score of 2 for integrated, and a score of 3 for left brained responses. These were added and the possible scores ranged for 36 to 108. The lower the score the score the more the student prefers a right brained style of

thinking and the higher the score the more the student favors a left brain thinking pattern. The standardization sample for this test consisted of over 1000 students. A test-retest reliability estimate over a 10 week period was found to be 0.78.

5. Metropolitan Achievement Tests (MAT). Measures of mathematics achievement were taken from the Total Mathematics Sub-test of the MAT which was administered to all tenth graders near the end of the school year as a part of the school's regularly scheduled testing. The mathematics subtest has a K-20 reliability score of 0.92.

Collection of the Data

Preliminary meetings were arranged with the Muskogee High School principal, Ron Wolfe, and the head of the Mathematics Department, Danny Allen, to agree on testing procedures. The timed tests, GEFT, CRT and the CCT were administered to the selected students on April 14, 1987 by the regular classroom teachers. The YSLC questionnaire was administered on a different day of the teachers' choice. The results of the MAT were made available to the researcher in May, 1987. There were 42 students that did not have a score on the mathematics subtest of the MAT. These students were dropped from the sample.

The tests were scored by the researcher during May, 1987. A complete set of data was tabulated for 186 students. There were ten students had no scores on the YSLC questionnaire. These students were included in the sample and their scores were used when the variable of cerebral dominance was not being examined.

The regression analysis was done at the Computer Center of Oklahoma State University during August and September of 1987. The statistical package used to run the regressions was SPSS-X, the Statistical Package for Social Sciences, Version X.

Testing of the Hypotheses

The execution of the hierarchical multiple regression program provided for testing the 15 null hypotheses. The hypotheses numbered 12 through 15 were tested during step two of the REGRESSION program when the main effects are entered. The hypotheses numbered 6 through 11 were tested in step three of the REGRESSION in which the two-way interactions were entered. The hypotheses numbered 2 through 5 were tested in step four of the REGRESSION program in which the three-way interactions are entered. Hypothesis 1 was tested in step 5 of the REGRESSION program when the four-way interaction is entered.

CHAPTER IV

RESULTS

Method of Analysis

A hierarchical multiple regression was performed on the data. The dependent variable was mathematics achievement (Y). The four independent variables consisted of field independence/dependence (X1), three dimensional spatial visualization (X2), two dimensional spatial visualization (X3) and cerebral dominance (X4). Gender (X5) and race (X6 and X7) were used as covariates so a more precise look at the independent-dependent variable relationships could be achieved after the effects of race and gender were removed.

The analysis was done using the SPSS-X REGRESSION program entering the covariates on the first step. On the second step, the main effects were entered. The partial tests using full model residual are equivalent to the ANCOVA main effect. The six two-way interactions were entered on the third step, followed on the fourth and fifth step by the entry of the four three-way interactions and the single four-way interaction.

The variables race and gender were recorded as dummy variables. The dummy variable X5 was coded 0 for female and 1 for male. The variable X6 was coded 1 for American Indian and 0 for non-American Indian. The variable X7 was coded 1 for Black and 0 for non-Black. Therefore, a white student would be coded 0 for X6 and 0 for X7. The interaction variables were computed by multiplying the main effects together. For example, the interaction of field independence/dependence and cerebral dominance was represented by the dummy variable X14 and was computed by X14 = X1 * X4. A listing of all the independent variables is found in the Appendix.

The model for these data using this analysis is:

$$Y = B_0 + B_1X1 + B_2X2 + B_3X3 + B_4X4 + B_5X12 + B_6X13 + B_7X14 + B_8X23 + B_9X24 + B_{10}X34 + B_{11}X123 + B_{12}X124 + B_{13}X134 + B_{14}X234 + B_{15}X1234 + error.$$

Results of the Evaluation of Assumptions

The use of regression analysis requires that several practical matters be considered, such as the ratio of cases to variables, presence of outliers in the sample, checks on the assumptions of no multicollinearlity and non-singularity and then the normality, homoscedasticity and linearity of the residuals.

With 240 students in the sample data and 15 independent variables (4 main effects and 11 interactions), the case to variable ratio was about 16 to 1, above the minimum requirements for regression.

With the use of a $p < .01$ criterion, one outlier among the independent variables was identified and deleted from the analysis. There were 10 cases that had missing data for one of the independent variables (X4).

The SPSS-X CONDESCRIPTIVE program was used to examine the distributions of the variables. The output from this program is located in the Appendix. To test for normality of the independent variables, the skewness scores were examined and ranged from -0.4 to 0.3, none was statistically significantly different from zero. Therefore, there was no need to transform the variables.

The SPSS-X PEARSON CORR program was used to determine the correlation coefficients between the main effects. The output of this program is located in the Appendix. As none of these correlations was in excess of 0.5, the variables appear not to be redundant. The SPSS-X REGRESSION program does have default values to terminate analysis if tolerance for some variable is too low. It was assumed that the covariates race and gender were reliable as they were self-report variables so no adjustments were made for unreliability of covariates.

Results of the Regression Analysis

SPSS-X REGRESSION was used to compute a hierarchical multiple regression between Y and X1, X2, X3, and X4. The SPSS-X output is located in the Appendix. A complete regression solution is provided at the end of each of the steps 1 through 5. At the end of step one in which the covariates of race and gender (X5,X6,X7) were entered multiple R is 0.31 and $R^2 = 0.10$. Race and gender account for 10 percent of the variance in mathematics achievement scores.

The greatest unique contribution came from the variable X7, whether a student is Black. The part correlation squared of 0.08 indicated that 8 percent of the variance is accounted for reliably ($F = 17.09$, $df = 1, 182$, $p < .001$) and uniquely by this variable. The B coefficient of -7.011 indicated that a Black student can be expected to score 7 points less on the mathematics subtest of the MAT.

The variable X6, whether a student is American Indian, has a part correlation squared of 0.03. This variable reliably ($F = 5.798$, df = 1, 182, $p < .017$) predicts 3 percent of the variance in mathematics achievement scores. The B coefficient for X6 is -4.901 which indicated that a American Indian student can be expected to score 5 points less on the mathematics subtest of the MAT than a student who is not American Indian.

The third covariate X5 indicates gender. With a part correlation squared of .0069 and an insignificant F test (F = .240, df = 1, 182, $p = .6244$), gender does not reliably account for any of the variance in mathematics achievement scores.

With the entry of the main effects X1, X2, X3, X4 in step 2 of the hierarchical regression program, multiple R is 0.58 and $R^2 = 0.34$. To determine if the main effects are statistically significant after the effects of race and gender have been statistically eliminated, F(inc) was calculated using the following formula:

$$F(inc) = \frac{(R_{wi}{}^2 - R_{wo}{}^2)/M}{(1 - R_{wi}{}^2)/df_{res}}$$

in which F(inc) is the incremental F ratio, $R_{wi}{}^2$ is multiple R^2 achieved with the added subset of independent variables, $R_{wo}{}^2$ is the multiple R^2 without the additional subset of independent variables, M is the number of IV's in the added subset, and df_{res} is the residual degrees of freedom in the final analysis of the variance table. The degrees of freedom for this F(inc) are (M, df_{res}). F(inc) for step 2 was calculated to be 16.15 with df = 1, 178. Thus there was a reliable increase in R^2 of the main effects at $p < 0.01$.

The main effect making the greatest unique contribution was X2, three dimensional spatial visualization, with a part correlation squared of .07. This variable reliably predicts mathematics achievement ($F = 18.2$, $df = 1,178$, $p < .0001$) and it uniquely accounts for 7 percent of the variance. It has a B coefficient of .3 which means an increase in 1 point on the score of the CCT would have an expected increase of .3 of a point on the mathematics subtest of the MAT.

Next in order of unique contributions comes the variable X1, field independence/dependence. It is a reliable predictor ($F = 9.684$, $df = 1,178$, $p < .01$) and with a part correlation squared of .04, it uniquely predicts 4 percent of the variance. The B coefficient for X1 is 0.4 which means an increase of 1 point on the GEFT would correspond with an increase of 0.4 of a point in the mathematics subtest score of the MAT.

The variable X3, two dimensional spatial visualization does not reliably predict mathematics achievement ($F = 2.78$, $df = 1,178$, $p = .0974$). The fourth variable X4, cerebral dominance, does not reliably predict mathematics achievement ($F = 1.00$, $df = 1,178$, $p = .3187$).

The difference between the increased R^2 and the unique contributions ($.24013 - .06769 - .0360 = .1364$ or 14 percent) represents the amount of the variance that X1, X2, X3, X4 jointly contribute to R^2 after the effects of race and gender have been statistically eliminated.

After step 3 in which the 6 two-way interactions were entered into the equation, $R = .59$ and $R^2 = 0.35$. Then F(inc) was calculated and found to be 0.60 with $df = 1,175$. Thus, there is no reliable increase in the prediction of mathematics achievement by the addition of the two-way interactions over and above the main effects and covariates. After step 4 in which the 4 three-way interactions were entered into the equation, $R = 0.59$ and $R^2 = 0.35$. So F(inc) = 0.055 and again there is no reliable increase in the prediction of mathematics achievement by the addition of the three-way interactions. On step 5, the REGRESSION program would not enter the four-way interaction into the equations as the tolerance limit of 0.01 had been reached. This indicated there is no statistical significance in the four way interaction.

In summary, the addition of the main effects in step 2 resulted in a significant increase in R^2, but the addition of the interactions in steps 3, 4, and 5 did not reliabily improve R^2.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

This study was an attempt to explore the effects of four independent variables--field independence/dependence, two dimensional and three dimensional spatial visualization and cerebral dominance. Their interactions on the mathematics achievement scores of tenth grade students after the effects of the covariates, race and gender, had been statistically eliminated. The sample (n = 240) was chosen from tenth grade students at Muskogee High School during the school year 1986-87. Four measuring instruments, Group Embedded Figures Test, Card Rotations Test, Cube Comparison Test and Your Styles Of Learning questionnaire, were administered to the sample in April, 1987. The dependent variable, mathematics achievement, was the mathematics subtest raw score of the MAT which was made available from the school records. The data were analyzed using a hierarchical multiple regression, entering the covariates of race and gender in the first step. The four main effects were entered on the second step, the six two-way interactions on the third step, the four three-way interactions on the fourth step, and the single four way interaction was entered on the fifth step. It was determined that the covariates of race and gender accounted for 10 percent of the variance in mathematics achievement. When a student's race was Black, this accounted uniquely for 8 percent of the variance. When a student's race was

American Indian, this accounted for 3 percent of the variance. Gender was not found to be a reliable predictor of mathematics achievement. The addition of the main effects accounted for 24 percent of the variance in mathematics achievement scores over and above the effects of race and gender. The reliable predictors were three dimensional spatial visualization, accounting uniquely for 7 percent of the variance, and field independence/dependence, accounting uniquely for 4 percent of the variance. Cerebral dominance and two dimensional spatial visualization were not found to be reliable predictors of mathematics achievement scores. The addition of the interactions did not significantly increase multiple R squared.

Conclusions

The evidence provided in this study is not sufficient to reject the null hypotheses numbered 1 through 11 in Chapter I. Sufficient evidence was found to reject the null hypotheses numbered 12 and 13. Sufficient evidence was not found to reject hypotheses 14 and 15.

It was found that there was a difference in mathematics achievement among students with differing degrees of field independence/dependence. Students who were more field independent had higher mathematics achievement scores. There was also a difference in mathematics achievement among students with differing degrees of three dimensional spatial visualization ability. Students who could mentally manipulate three dimensional objects tended to have higher mathematics achievement scores. There appeared to be no difference in mathematics achievement in students who preferred either a right brain, left brain, or integrated brain thinking style. The results of this study indicated none of the interactions between the main effects significantly increased the prediction of mathematics achievement.

Implications of the Study

The results of this study indicate that some of the variance in mathematics achievement can be reliably attributed to the cognitive style factors of field independence/dependence, two dimensional and three dimensional spatial visualization and cerebral dominance. The multiple R squared in this study was .35. This indicates that 35 percent of the variance in mathematics achievement is attributable to the factors that were included in this study. Therefore, 65 percent of the variance can be attributed to other factors. Of the variables that were determined to be reliable predictors, the racial variable made the greatest unique contribution. Of the cognitive style variables, field independence/dependence was a reliable predictor as the review of literature had indicated. The factor of three dimensional spatial visualization was also determined to be a reliable predictor and again that was supported by the review of literature.

The factor of cerebral dominance was determined not to be a reliable predictor of mathematics achievement. One of the aims of this study was to explore the effects of this variable upon mathematics achievement in light of the popular myth that "mathematics types are left-brain thinkers." As this variable is measured by the YSLC questionnaire, there was no correlation ($r = 0.0234$, $p = .376$) with mathematics achievement. This could indicate several possibilities. Cerebral dominance may not be what is measured by the YSLC questionnaire. The workings of the brain are probably much too complex to be accurately measured by a relatively simple paper and pencil questionnaire. Another factor may be the order in which the instruments were administered to the students. It was the last instrument given and test fatigue may have caused some students to take it less seriously.

It is of interest that gender was not a reliable predictor of mathematics achievement. The review of literature indicated that in other studies (Fennema and Sherman, 1978; Sherman, 1979), some of the variance in mathematics achievement was attributed to gender. It is a popular "myth" that boys do better in mathematics than girls.

The student who prefers a right brain thinking style is not at a disadvantage in a mathematics classroom. The student who is field dependent can be at a small disadvantage in a mathematics classroom. The student who does not have high spatial visualization may have a small disadvantage in a mathematics classroom especially if he is weak in the skill of mentally rotating three dimensional objects.

Suggestions for Further Research

The results of this study show that the variables three dimensional spatial visualization and field independence/dependence are reliable predictors of mathematics achievement once the effects of race and gender are removed. Further research is suggested to explore the correlation between three dimensional spatial visualization and mathematics achievement and between field independence/dependence annd mathematics achievement. The results of this correlational study cannot be interpreted to imply higher levels of three dimensional spatial visualization cause greater achievement in mathematics, but further research could explore this question. It may be that spending more time on mathematical topics that emphasize three dimensional spatial visualization such as solid geometry would be of benefit in enhancing the student's three dimensional spatial visualization.

The results of medical research indicate three dimensional spatial visualization is a function of the right hemisphere of the brain in most people. Bratt (1981) concluded that public school curriculum favors a strong left hemisphere learning style. In particular, the mathematics curricula often places heavy emphasis on computational skills which require left brain processing skills. Further research is suggested to explore whether the addition of more mathematical topics requiring right brain processing skills would improve mathematics achievement. There are students who have high spatial ability and who may prefer using right brain processing skills, but are unsuccessful in mathematics. It may be possible to encourge their success in mathematics by capitalizing on their strengths.

The cognitive style factor of cerebral dominance was not found to be an important factor in mathematics achievement using the YSLC questionnaire. Further research would be indicated to explore other instruments for measuring this factor. Wheatley et al. (1978) suggest that electroencephalography (EEG) may be particularly useful. It may be possible to devise or select other paper and pencil test to more accurately measure the performance of each mode of thought (right brain, left brain) without sophisticated electronics.

Measures of mathematics achievement other than the MAT could be considered in further research. The MAT is mainly a test of computational skill. Problem solving is a factor of mathematics achievement that Wheatley et al., (1978) claim is dependent on the smooth integration of thinking skills of both hemispheres of the brain. Concept understanding is another factor of mathematics achievement which may be influenced by the cognitive style factors in this study.

Affective variables may influence the cognitive style factors of cerebral dominance, spatial visualization, and field independence/dependence. For example, a student with math anxiety may associate the figures on the measuring instruments used in this study (GEFT, CRT, and CCT) with "math things" and experience anxiety while taking these tests. The cognitive style factors may influence affective variables. For example, students who prefer right brain thinking style may be more emotional as medical research suggests a link between emotions and the right hemisphere of the brain.

The results of this study show that the racial variables accounted for a significant portion of the variance in mathematics achievement as measured by the MAT. This might indicate that the MAT may contain racial biases. This could be explored in further research. The sample in this study included only the race categories Black, American Indian and white. Further study might be done with a sample containing Hispanic and Oriental students.

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APPENDIX

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16 MAR 88    SPSS-X RELEASE 2.2  FOR IBM/MVS
14:44:08     OKLAHOMA STATE UNIVERSITY        IBM 3081K          MVS/XA 2.1.1


FOR MVS/XA 2.1.1         OKLAHOMA STATE UNIVERSITY            LICENSE NUMBER 972

USE INFO OVERVIEW FOR MORE INFORMATION ON:

* INCLUDE - TO BRING IN COMMAND FILES                  * IMPROVEMENTS IN:
* RENAME VARS - TO RENAME VARIABLES                    *    MANOVA
* AUTORECODE - TO RECODE STRINGS AS NUMBERS            *    TABLES
* DROP DOCUMENTS                                       *

   1  0 00050001  TITLE 'CARMENT DISSERTATION STUDY'
   2  0 00060038  DATA LIST RECORDS = 1/1 X1 1-2 X2 4-5 X3 7-9 X4 11-12
   3  0 00061040                X5 17 X6 19 X7 20 Y 22-23

THE ABOVE DATA LIST STATEMENT WILL READ   1 RECORDS FROM FILE INLINE  .

          VARIABLE    REC  START    END        FORMAT  WIDTH  DEC

          X1            1      1      2        F           2    0
          X2            1      4      5        F           2    0
          X3            1      7      9        F           3    0
          X4            1     11     12        F           2    0
          X5            1     17     17        F           1    0
          X6            1     19     19        F           1    0
          X7            1     20     20        F           1    0
          Y             1     22     23        F           2    0

END OF DATALIST TABLE.


   4  0 00062029  COMPUTE X12=X1*X2
   5  0 00063029  COMPUTE X13=X1*X3
   6  0 00064029  COMPUTE X14=X1*X4
   7  0 00065029  COMPUTE X23=X2*X3
   8  0 00066029  COMPUTE X24=X2*X4
   9  0 00067029  COMPUTE X34=X3*X4
  10  0 00068029  COMPUTE X123=X1*X2*X3
  11  0 00069029  COMPUTE X234=X2*X3*X4
  12  0 00069129  COMPUTE X124=X1*X2*X4
  13  0 00069229  COMPUTE X134=X1*X3*X4
  14  0 00069329  COMPUTE X1234=X1*X2*X3*X4
  15  0 00070001  VAR LABELS X1'FIELD I-D'/
  16  0 00080001                X2 'SPATIAL VIS 3-D'/
  17  0 00090001                X3 'SPATIAL VIS 2-D'/
  18  0 00100001                X4 'CEREBRAL DOM'/
  19  0 00120040                X5 'GENDER'/
  20  0 00121040                X6 'NATIVE AMER'/
  21  0 00122040                X7 'BLACK'/
  22  0 00123028                X12 'FIELD-SV3D'/
  23  0 00124028                X13 'FIELD-SP2D'/
  24  0 00125028                X14 'FIELD-CD'/
  25  0 00126028                X23 'SV3D-SV2D'/
  26  0 00127028                X24 'SV3D-CD'/
  27  0 00128028                X34 'SV2D-CD'/
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16 MAR 88    CARMENT DISSERTATION STUDY
14:44:09     OKLAHOMA STATE UNIVERSITY       IBM 3081K         MVS/XA 2.1.1

  28   0 00129028              X123 'FIELD-SV3D-SV2D'/
  29   0 00129128              X234 'SV3-SV2-CD'/
  30   0 00129228              X124 'FIELD-SV3-CD'/
  31   0 00129328              X134 'FIELD-SV2-CD'/
  32   0 00129428              X1234 'FIELD-SV2-SV3-CD'/
  33   0 00130001              Y 'MATH ACHIEVE'
  34   0 00140001  LIST VARIABLES = ALL/CASES=196

THERE ARE    493040 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS    493040 BYTES.

      779 BYTES OF MEMORY REQUIRED FOR LIST PROCEDURE.
      152 BYTES HAVE ALREADY BEEN ACQUIRED.
      627 BYTES REMAIN TO BE ACQUIRED.
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X1	X2	X3	X4	X5	X6	X7	Y	X12	X13	X14	X23	X24	X34	X123	X234	X124	X134	X1234
10	21	160	76	0	1	0	29	210.00	1600.00	760.00	3360.00	1596.00	12160.00	33600.00	255360.0	15960.00	121600.0	2553600
6	22	76	66	1	0	0	29	132.00	456.00	396.00	1672.00	1452.00	5016.00	10032.00	110352.0	8712.00	30096.00	662112.0
11	14	92	64	0	0	0	23	154.00	1012.00	704.00	1288.00	896.00	5888.00	14168.00	82432.00	9856.00	64768.00	906752.0
5	-1	126	65	0	0	0	24	-5.00	630.00	325.00	-126.00	-65.00	8190.00	-630.00	-8190.00	-325.00	40950.00	-40950.0
7	11	120	83	0	0	1	35	77.00	840.00	581.00	1320.00	913.00	9960.00	9240.00	109560.0	6391.00	69720.00	766920.0
8	12	80	78	0	0	1	23	96.00	640.00	624.00	960.00	936.00	6240.00	7680.00	74880.00	7488.00	49920.00	599040.0
9	-6	108	73	0	0	0	30	-54.00	972.00	657.00	-648.00	-438.00	7884.00	-5832.00	-47304.0	-3942.00	70956.00	-425736
11	17	48	74	1	0	0	26	187.00	528.00	814.00	816.00	1258.00	3552.00	8976.00	60384.00	13838.00	39072.00	664224.0
3	18	112	66	0	1	0	40	54.00	336.00	198.00	2016.00	1188.00	7392.00	6048.00	133056.0	3564.00	22176.00	399168.0
2	10	103	71	1	0	0	40	20.00	206.00	142.00	1030.00	710.00	7313.00	2060.00	73130.00	1420.00	14626.00	146260.0
6	-7	133	62	0	0	0	28	-42.00	798.00	372.00	-931.00	-434.00	8246.00	-5586.00	-57722.0	-2604.00	49476.00	-346332
1	5	87	73	0	1	0	21	5.00	87.00	73.00	435.00	365.00	6351.00	435.00	31755.00	365.00	6351.00	31755.00
3	12	110	65	1	0	1	30	36.00	330.00	195.00	1320.00	780.00	7150.00	3960.00	85800.00	2340.00	21450.00	257400.0
2	-4	40	64	1	1	0	21	-8.00	80.00	128.00	-160.00	-256.00	2560.00	-320.00	-10240.0	-512.00	5120.00	-20480.0
4	14	55	.	0	0	0	39	56.00	220.00	.	770.00	.	.	3080.00	.	.	.	.
6	13	144	72	1	0	1	30	78.00	864.00	432.00	1872.00	936.00	10368.00	11232.00	134784.0	5616.00	62208.00	808704.0
15	0	80	.	1	0	0	41	.00	1200.00	.	.00	.00	.	.00	.00	.00	.	.00
3	4	105	75	1	0	0	36	12.00	315.00	225.00	420.00	300.00	7875.00	1260.00	31500.00	900.00	23625.00	94500.00
6	7	84	75	0	0	0	41	42.00	504.00	450.00	588.00	525.00	6300.00	3528.00	44100.00	3150.00	37800.00	264600.0
2	12	136	66	1	0	0	23	24.00	272.00	132.00	1632.00	792.00	8976.00	3264.00	107712.0	1584.00	17952.00	215424.0
9	10	112	72	1	0	0	30	90.00	1008.00	648.00	1120.00	720.00	8064.00	10080.00	80640.00	6480.00	72576.00	725760.0
18	25	123	86	1	0	0	43	450.00	2214.00	1548.00	3075.00	2150.00	10578.00	55350.00	264450.0	38700.00	190404.0	4760100
0	11	112	69	0	1	0	17	.00	.00	.00	1232.00	759.00	7728.00	.00	85008.00	.00	.00	.00
12	12	107	85	1	0	0	46	144.00	1284.00	1020.00	1284.00	1020.00	9095.00	15408.00	109140.0	12240.00	109140.0	1309680
7	5	90	73	0	0	0	30	35.00	630.00	511.00	450.00	365.00	6570.00	3150.00	32850.00	2555.00	45990.00	229950.0
5	9	56	75	0	0	0	27	45.00	280.00	375.00	504.00	675.00	4200.00	2520.00	37800.00	3375.00	21000.00	189000.0
14	6	88	79	0	1	0	37	84.00	1232.00	1106.00	528.00	474.00	6952.00	7392.00	41712.00	6636.00	97328.00	583968.0
8	22	126	70	1	1	0	31	176.00	1008.00	560.00	2772.00	1540.00	8820.00	22176.00	194040.0	12320.00	70560.00	1552320
10	-6	21	70	1	0	1	19	-60.00	210.00	700.00	-126.00	-420.00	1470.00	-1260.00	-8820.00	-4200.00	14700.00	-88200.0
8	7	118	76	0	0	0	41	56.00	944.00	608.00	826.00	532.00	8968.00	6608.00	62776.00	4256.00	71744.00	502208.0
5	18	128	67	1	0	0	49	90.00	640.00	335.00	2304.00	1206.00	8576.00	11520.00	154368.0	6030.00	42880.00	771840.0
18	28	63	64	0	0	0	48	504.00	1134.00	1152.00	1764.00	1792.00	4032.00	31752.00	112896.0	32256.00	72576.00	2032128
6	2	30	65	0	0	1	34	12.00	180.00	390.00	60.00	130.00	1950.00	360.00	3900.00	780.00	11700.00	23400.00
16	19	154	77	1	0	0	27	304.00	2464.00	1232.00	2926.00	1463.00	11858.00	46816.00	225302.0	23408.00	189728.0	3604832
8	-1	89	70	0	0	1	28	-8.00	712.00	560.00	-89.00	-70.00	6230.00	-712.00	-6230.00	-560.00	49840.00	-49840.0
13	19	109	69	0	0	0	44	247.00	1417.00	897.00	2071.00	1311.00	7521.00	26923.00	142899.0	17043.00	97773.00	1857687
13	6	112	75	1	0	0	42	78.00	1456.00	975.00	672.00	450.00	8400.00	8736.00	50400.00	5850.00	109200.0	655200.0
17	20	78	62	0	0	0	16	340.00	1326.00	1054.00	1560.00	1240.00	4836.00	26520.00	96720.00	21080.00	82212.00	1644240
5	6	26	88	0	0	1	18	30.00	130.00	440.00	156.00	528.00	2288.00	780.00	13728.00	2640.00	11440.00	68640.00
0	0	131	73	0	0	1	32	.00	.00	.00	.00	.00	9563.00	.00	.00	.00	.00	.00
2	12	30	76	1	0	1	29	24.00	60.00	152.00	360.00	912.00	2280.00	720.00	27360.00	1824.00	4560.00	54720.00
15	22	61	76	1	0	0	40	330.00	915.00	1140.00	1342.00	1672.00	4636.00	20130.00	101992.0	25080.00	69540.00	1529880
16	-2	92	74	0	0	1	31	-32.00	1472.00	1184.00	-184.00	-148.00	6808.00	-2944.00	-13616.0	-2368.00	108928.0	-217856
14	21	80	82	0	0	0	44	294.00	1120.00	1148.00	1680.00	1722.00	6560.00	23520.00	137760.0	24108.00	91840.00	1928640
2	2	64	66	0	0	0	41	4.00	128.00	132.00	128.00	132.00	4224.00	256.00	8448.00	264.00	8448.00	16896.00
7	18	120	76	0	0	0	37	126.00	840.00	532.00	2160.00	1368.00	9120.00	15120.00	164160.0	9576.00	63840.00	1149120
5	-8	32	72	1	0	1	28	-40.00	160.00	360.00	-256.00	-576.00	2304.00	-1280.00	-18432.0	-2880.00	11520.00	-92160.0
4	4	72	67	1	0	0	19	16.00	288.00	268.00	288.00	268.00	4824.00	1152.00	19296.00	1072.00	19296.00	77184.00
9	18	90	.	1	0	0	38	162.00	810.00	.	1620.00	.	.	14580.00	.	.	.	.
2	8	124	67	1	0	0	33	16.00	248.00	134.00	992.00	536.00	8308.00	1984.00	66464.00	1072.00	16616.00	132928.0
16	18	100	70	1	0	0	50	288.00	1600.00	1120.00	1800.00	1260.00	7000.00	28800.00	126000.0	20160.00	112000.0	2016000

16 MAR 88 CARMENT DISSERTATION STUDY
14:44:10 OKLAHOMA STATE UNIVERSITY IBM 3081K MVS/XA 2.1.1

X1	X2	X3	X4	X5	X6	X7	Y	X12	X13	X14	X23	X24	X34	X123	X234	X124	X134	X1234
5	-9	52	71	0	0	1	31	-45.00	260.00	355.00	-468.00	-639.00	3692.00	-2340.00	-33228.0	-3195.00	18460.00	-166140
12	25	104	73	1	0	0	43	300.00	1248.00	876.00	2600.00	1825.00	7592.00	31200.00	189800.0	21900.00	91104.00	2277600
12	13	150	73	0	0	0	38	156.00	1800.00	876.00	1950.00	949.00	10950.00	23400.00	142350.0	11388.00	131400.0	1708200
1	-4	21	.	1	0	1	30	-4.00	21.00	.	-84.00	.	.	-84.00	.	.	.	.
10	9	132	73	0	0	0	45	90.00	1320.00	730.00	1188.00	657.00	9636.00	11880.00	86724.00	6570.00	96360.00	867240.0
18	0	112	73	0	0	0	38	.00	2016.00	1314.00	.00	.00	8176.00	.00	.00	.00	147168.0	.00
15	30	79	71	0	1	0	35	450.00	1185.00	1065.00	2370.00	2130.00	5609.00	35550.00	168270.0	31950.00	84135.00	2524050
12	8	113	82	1	0	0	45	96.00	1356.00	984.00	904.00	656.00	9266.00	10848.00	74128.00	7872.00	111192.0	889536.0
9	15	136	58	0	0	0	39	135.00	1224.00	522.00	2040.00	870.00	7888.00	18360.00	118320.0	7830.00	70992.00	1064880
18	26	126	82	1	0	0	48	468.00	2268.00	1476.00	3276.00	2132.00	10332.00	58968.00	268632.0	38376.00	185976.0	4835376
2	18	108	72	1	0	0	34	36.00	216.00	144.00	1944.00	1296.00	7776.00	3888.00	139968.0	2592.00	15552.00	279936.0
4	2	114	61	0	0	0	37	8.00	456.00	244.00	228.00	122.00	6954.00	912.00	13908.00	488.00	27816.00	55632.00
4	7	52	74	1	0	1	25	28.00	208.00	296.00	364.00	518.00	3848.00	1456.00	26936.00	2072.00	15392.00	107744.0
10	-2	70	71	0	1	0	30	-20.00	700.00	710.00	-140.00	-142.00	4970.00	-1400.00	-9940.00	-1420.00	49700.00	-99400.0
4	18	115	74	0	1	0	29	72.00	460.00	296.00	2070.00	1332.00	8510.00	8280.00	153180.0	5328.00	34040.00	612720.0
4	9	41	70	0	0	1	38	36.00	164.00	280.00	369.00	630.00	2870.00	1476.00	25830.00	2520.00	11480.00	103320.0
10	21	122	63	0	0	0	44	210.00	1220.00	630.00	2562.00	1323.00	7686.00	25620.00	161406.0	13230.00	76860.00	1614060
9	2	56	69	1	0	0	45	18.00	504.00	621.00	112.00	138.00	3864.00	1008.00	7728.00	1242.00	34776.00	69552.00
10	15	94	74	1	0	0	48	150.00	940.00	740.00	1410.00	1110.00	6956.00	14100.00	104340.0	11100.00	69560.00	1043400
16	18	122	62	1	0	0	48	288.00	1952.00	992.00	2196.00	1116.00	7564.00	35136.00	136152.0	17856.00	121024.0	2178432
11	20	120	70	1	0	0	48	220.00	1320.00	770.00	2400.00	1400.00	8400.00	26400.00	168000.0	15400.00	92400.00	1848000
17	22	122	81	1	0	1	38	374.00	2074.00	1377.00	2684.00	1782.00	9882.00	45628.00	217404.0	30294.00	167994.0	3695868
9	-1	112	77	0	0	0	31	-9.00	1008.00	693.00	-112.00	-77.00	8624.00	-1008.00	-8624.00	-693.00	77616.00	-77616.0
5	6	122	65	0	0	1	24	30.00	610.00	325.00	732.00	390.00	7930.00	3660.00	47580.00	1950.00	39650.00	237900.0
1	10	57	70	1	0	0	42	10.00	57.00	70.00	570.00	700.00	3990.00	570.00	39900.00	700.00	3990.00	39900.00
15	2	144	75	0	0	0	29	30.00	2160.00	1125.00	288.00	150.00	10800.00	4320.00	21600.00	2250.00	162000.0	324000.0
7	3	59	72	0	0	0	26	21.00	413.00	504.00	177.00	216.00	4248.00	1239.00	12744.00	1512.00	29736.00	89208.00
15	17	105	64	1	0	0	55	255.00	1575.00	960.00	1785.00	1088.00	6720.00	26775.00	114240.0	16320.00	100800.0	1713600
7	4	100	65	1	1	0	26	28.00	700.00	455.00	400.00	260.00	6500.00	2800.00	26000.00	1820.00	45500.00	182000.0
7	12	71	78	1	0	0	42	84.00	497.00	546.00	852.00	936.00	5538.00	5964.00	66456.00	6552.00	38766.00	465192.0
4	2	74	75	1	0	1	49	8.00	296.00	300.00	148.00	150.00	5550.00	592.00	11100.00	600.00	22200.00	44400.00
17	9	100	76	1	0	0	36	153.00	1700.00	1292.00	900.00	684.00	7600.00	15300.00	68400.00	11628.00	129200.0	1162800
13	9	77	70	1	0	0	47	117.00	1001.00	910.00	693.00	630.00	5390.00	9009.00	48510.00	8190.00	70070.00	630630.0
10	2	80	71	0	0	1	35	20.00	800.00	710.00	160.00	142.00	5680.00	1600.00	11360.00	1420.00	56800.00	113600.0
0	18	146	73	0	1	0	26	.00	.00	.00	2628.00	1314.00	10658.00	.00	191844.0	.00	.00	.00
2	-6	34	79	1	0	1	20	-12.00	68.00	158.00	-204.00	-474.00	2686 00	-408.00	-16116.0	-948.00	5372.00	-32232.0
14	21	73	66	0	0	0	50	294.00	1022.00	924.00	1533.00	1386.00	4818.00	21462.00	101178.0	19404.00	67452.00	1416492
5	4	77	74	0	0	0	32	20.00	385.00	370.00	308.00	296.00	5698.00	1540.00	22792.00	1480.00	28490.00	113960.0
17	0	121	.	1	1	0	43	.00	2057.00	.	.00	.00	.	.00	.00	.00	.	.00
0	-6	0	62	1	0	1	14	.00	.00	.00	.00	-372.00	.00	.00	.00	.00	.00	.00
14	0	94	65	0	0	0	34	.00	1316.00	910.00	.00	.00	6110.00	.00	.00	.00	85540.00	.00
3	-2	101	74	0	0	0	26	-6.00	303.00	222.00	-202.00	-148.00	7474.00	-606.00	-14948.0	-444.00	22422.00	-44844.0
9	0	130	66	1	0	0	22	.00	1170.00	594.00	.00	.00	8580.00	.00	.00	.00	77220.00	.00
14	2	70	80	0	1	0	33	28.00	980.00	1120.00	140.00	160.00	5600.00	1960.00	11200.00	2240.00	78400.00	156800.0
6	4	60	76	1	0	0	29	24.00	360.00	456.00	240.00	304.00	4560.00	1440.00	18240.00	1824.00	27360.00	109440.0
17	38	136	66	1	0	0	47	646.00	2312.00	1122.00	5168.00	2508.00	8976.00	87856.00	341088.0	42636.00	152592.0	5798496
11	5	52	64	0	1	0	22	55.00	572.00	704.00	260.00	320.00	3328.00	2860.00	16640.00	3520.00	36608.00	183040.0
0	2	19	73	0	0	1	20	.00	.00	.00	38.00	146.00	1387.00	.00	2774.00	.00	.00	.00
7	10	46	76	1	1	0	44	70.00	322.00	532.00	460.00	760.00	3496.00	3220.00	34960.00	5320.00	24472.00	244720.0
10	12	148	65	1	0	0	19	120.00	1480.00	650.00	1776.00	780.00	9620.00	17760.00	115440.0	7800.00	96200.00	1154400
18	30	160	66	1	0	0	48	540.00	2880.00	1188.00	4800.00	1980.00	10560.00	86400.00	316800.0	35640.00	190080.0	5702400

X1	X2	X3	X4	X5	X6	X7	Y	X12	X13	X14	X23	X24	X34	X123	X234	X124	X134	X1234
14	-8	91	65	0	0	0	29	-112.00	1274.00	910.00	-728.00	-520.00	5915.00	-10192.0	-47320.0	-7280.00	82810.00	-662480
10	4	126	64	1	1	0	37	40.00	1260.00	640.00	504.00	256.00	8064.00	5040.00	32256.00	2560.00	80640.00	322560.0
11	16	144	69	1	0	0	35	176.00	1584.00	759.00	2304.00	1104.00	9936.00	25344.00	158976.0	12144.00	109296.0	1748736
7	6	10	77	1	0	1	14	42.00	70.00	539.00	60.00	462.00	770.00	420.00	4620.00	3234.00	5390.00	32340.00
1	-5	90	72	0	0	1	26	-5.00	90.00	72.00	-450.00	-360.00	6480.00	-450.00	-32400.0	-360.00	6480.00	-32400.0
9	32	150	71	0	0	0	37	288.00	1350.00	639.00	4800.00	2272.00	10650.00	43200.00	340800.0	20448.00	95850.00	3067200
11	-2	95	60	1	0	1	41	-22.00	1045.00	660.00	-190.00	-120.00	5700.00	-2090.00	-11400.0	-1320.00	62700.00	-125400
8	-2	112	80	0	0	0	39	-16.00	896.00	640.00	-224.00	-160.00	8960.00	-1792.00	-17920.0	-1280.00	71680.00	-143360
6	14	123	67	1	0	0	28	84.00	738.00	402.00	1722.00	938.00	8241.00	10332.00	115374.0	5628.00	49446.00	692244.0
13	8	75	91	0	0	0	39	104.00	975.00	1183.00	600.00	728.00	6825.00	7800.00	54600.00	9464.00	88725.00	709800.0
1	6	60	71	0	0	0	35	6.00	60.00	71.00	360.00	426.00	4260.00	360.00	25560.00	426.00	4260.00	25560.00
7	4	36	72	1	0	0	30	28.00	252.00	504.00	144.00	288.00	2592.00	1008.00	10368.00	2016.00	18144.00	72576.00
17	24	115	66	1	0	0	48	408.00	1955.00	1122.00	2760.00	1584.00	7590.00	46920.00	182160.0	26928.00	129030.0	3096720
11	24	148	75	0	0	0	41	264.00	1628.00	825.00	3552.00	1800.00	11100.00	39072.00	266400.0	19800.00	122100.0	2930400
5	12	148	77	0	0	0	33	60.00	740.00	385.00	1776.00	924.00	11396.00	8880.00	136752.0	4620.00	56980.00	683760.0
9	16	134	70	0	0	0	36	144.00	1206.00	630.00	2144.00	1120.00	9380.00	19296.00	150080.0	10080.00	84420.00	1350720
5	2	68	73	0	0	0	20	10.00	340.00	365.00	136.00	146.00	4964.00	680.00	9928.00	730.00	24820.00	49640.00
7	-4	46	79	1	0	0	6	-28.00	322.00	553.00	-184.00	-316.00	3634.00	-1288.00	-14536.0	-2212.00	25438.00	-101752
9	16	126	77	0	0	0	40	144.00	1134.00	693.00	2016.00	1232.00	9702.00	18144.00	155232.0	11088.00	87318.00	1397088
18	22	79	72	1	1	0	43	396.00	1422.00	1296.00	1738.00	1584.00	5688.00	31284.00	125136.0	28512.00	102384.0	2252448
6	6	113	72	0	0	0	51	36.00	678.00	432.00	678.00	432.00	8136.00	4068.00	48816.00	2592.00	48816.00	292896.0
8	26	91	70	0	0	0	46	208.00	728.00	560.00	2366.00	1820.00	6370.00	18928.00	165620.0	14560.00	50960.00	1324960
18	19	143	64	0	0	0	45	342.00	2574.00	1152.00	2717.00	1216.00	9152.00	48906.00	173888.0	21888.00	164736.0	3129984
5	4	75	68	1	0	0	12	20.00	375.00	340.00	300.00	272.00	5100.00	1500.00	20400.00	1360.00	25500.00	102000.0
3	18	115	78	1	0	1	35	54.00	345.00	234.00	2070.00	1404.00	8970.00	6210.00	161460.0	4212.00	26910.00	484380.0
4	-6	43	79	0	0	1	26	-24.00	172.00	316.00	-258.00	-474.00	3397.00	-1032.00	-20382.0	-1896.00	13588.00	-81528.0
17	20	86	80	0	0	0	47	340.00	1462.00	1360.00	1720.00	1600.00	6880.00	29240.00	137600.0	27200.00	116960.0	2339200
1	4	58	77	1	0	0	42	4.00	58.00	77.00	232.00	308.00	4466.00	232.00	17864.00	308.00	4466.00	17864.00
12	16	144	68	0	0	0	40	192.00	1728.00	816.00	2304.00	1088.00	9792.00	27648.00	156672.0	13056.00	117504.0	1880064
12	0	64	66	1	0	0	21	.00	768.00	792.00	.00	.00	4224.00	.00	.00	.00	50688.00	.00
8	6	69	59	1	0	0	38	48.00	552.00	472.00	414.00	354.00	4071.00	3312.00	24426.00	2832.00	32568.00	195408.0
10	6	64	77	1	0	0	25	60.00	640.00	770.00	384.00	462.00	4928.00	3840.00	29568.00	4620.00	49280.00	295680.0
6	13	137	65	0	0	0	24	78.00	822.00	390.00	1781.00	845.00	8905.00	10686.00	115765.0	5070.00	53430.00	694590.0
2	-9	6	82	0	0	0	26	-18.00	12.00	164.00	-54.00	-738.00	492.00	-108.00	-4428.00	-1476.00	984.00	-8856.00
10	-5	11	64	0	0	0	17	-50.00	110.00	640.00	-55.00	-320.00	704.00	-550.00	-3520.00	-3200.00	7040.00	-35200.0
6	9	132	67	0	1	0	36	54.00	792.00	402.00	1188.00	603.00	8844.00	7128.00	79596.00	3618.00	53064.00	477576.0
7	15	55	78	0	1	0	43	105.00	385.00	546.00	825.00	1170.00	4290.00	5775.00	64350.00	8190.00	30030.00	450450.0
2	0	46	71	0	0	0	21	.00	92.00	142.00	.00	.00	3266.00	.00	.00	.00	6532.00	.00
16	12	72	68	0	0	0	52	192.00	1152.00	1088.00	864.00	816.00	4896.00	13824.00	58752.00	13056.00	78336.00	940032.0
12	12	100	70	0	0	0	24	144.00	1200.00	840.00	1200.00	840.00	7000.00	14400.00	84000.00	10080.00	84000.00	1008000
12	10	80	74	0	1	0	27	120.00	960.00	888.00	800.00	740.00	5920.00	9600.00	59200.00	8880.00	71040.00	710400.0
7	26	106	74	1	0	1	43	182.00	742.00	518.00	2756.00	1924.00	7844.00	19292.00	203944.0	13468.00	54908.00	1427608
9	-6	14	67	1	0	0	13	-54.00	126.00	603.00	-84.00	-402.00	938.00	-756.00	-5628.00	-3618.00	8442.00	-50652.0
6	0	116	69	1	0	1	30	.00	696.00	414.00	.00	.00	8004.00	.00	.00	.00	48024.00	.00
15	22	98	76	0	0	0	36	330.00	1470.00	1140.00	2156.00	1672.00	7448.00	32340.00	163856.0	25080.00	111720.0	2457840
16	12	94	67	0	0	0	34	192.00	1504.00	1072.00	1128.00	804.00	6298.00	18048.00	75576.00	12864.00	100768.0	1209216
15	12	76	67	1	0	0	24	180.00	1140.00	1005.00	912.00	804.00	5092.00	13680.00	61104.00	12060.00	76380.00	916560.0
7	18.	93	70	0	0	0	43	126.00	651.00	490.00	1674.00	1260.00	6510.00	11718.00	117180.0	8820.00	45570.00	820260.0
10	6	84	70	0	0	1	31	60.00	840.00	700.00	504.00	420.00	5880.00	5040.00	35280.00	4200.00	58800.00	352800.0
2	-6	11	67	1	0	1	33	-12.00	22.00	134.00	-66.00	-402.00	737.00	-132.00	-4422.00	-804.00	1474.00	-8844.00
7	10	44	75	0	1	0	13	70.00	308.00	525.00	440.00	750.00	3300.00	3080.00	33000.00	5250.00	23100.00	231000.0

16 MAR 88   CARMENT DISSERTATION STUDY
14:44:10   OKLAHOMA STATE UNIVERSITY   IBM 3081K   MVS/XA 2.1.1

X1	X2	X3	X4	X5	X6	X7	Y	X12	X13	X14	X23	X24	X34	X123	X234	X124	X134	X1234
10	20	108	74	1	0	0	43	200.00	1080.00	740.00	2160.00	1480.00	7992.00	21600.00	159840.0	14800.00	79920.00	1598400
0	3	88	76	0	0	1	27	.00	.00	.00	264.00	228.00	6688.00	.00	20064.00	.00	.00	.00
11	2	139	70	0	0	0	50	22.00	1529.00	770.00	278.00	140.00	9730.00	3058.00	19460.00	1540.00	107030.0	214060.0
5	2	83	68	0	0	0	34	10.00	415.00	340.00	166.00	136.00	5644.00	830.00	11288.00	680.00	28220.00	56440.00
4	9	72	71	0	0	1	23	36.00	288.00	284.00	648.00	639.00	5112.00	2592.00	46008.00	2556.00	20448.00	184032.0
4	7	85	73	0	0	0	37	28.00	340.00	292.00	595.00	511.00	6205.00	2380.00	43435.00	2044.00	24820.00	173740.0
9	10	76	73	0	1	0	26	90.00	684.00	657.00	760.00	730.00	5548.00	6840.00	55480.00	6570.00	49932.00	499320.0
11	12	40	78	1	0	0	37	132.00	440.00	858.00	480.00	936.00	3120.00	5280.00	37440.00	10296.00	34320.00	411840.0
10	13	142	81	0	0	0	35	130.00	1420.00	810.00	1846.00	1053.00	11502.00	18460.00	149526.0	10530.00	115020.0	1495260
18	23	130	.	0	0	0	53	414.00	2340.00	.	2990.00	.	.	53820.00	.	.	.	.
13	3	55	64	0	0	0	44	39.00	715.00	832.00	165.00	192.00	3520.00	2145.00	10560.00	2496.00	45760.00	137280.0
4	-2	0	80	0	0	1	25	-8.00	.00	320.00	.00	-160.00	.00	.00	.00	-640.00	.00	.00
18	30	122	71	1	0	0	45	540.00	2196.00	1278.00	3660.00	2130.00	8662.00	65880.00	259860.0	38340.00	155916.0	4677480
12	18	108	68	1	0	1	32	216.00	1296.00	816.00	1944.00	1224.00	7344.00	23328.00	132192.0	14688.00	88128.00	1586304
5	12	115	62	0	0	0	39	60.00	575.00	310.00	1380.00	744.00	7130.00	6900.00	85560.00	3720.00	35650.00	427800.0
2	0	81	67	1	0	1	15	.00	162.00	134.00	.00	.00	5427.00	.00	.00	.00	10854.00	.00
14	11	98	71	0	0	0	41	154.00	1372.00	994.00	1078.00	781.00	6958.00	15092.00	76538.00	10934.00	97412.00	1071532
4	12	97	69	0	0	0	43	48.00	388.00	276.00	1164.00	828.00	6693.00	4656.00	80316.00	3312.00	26772.00	321264.0
7	4	116	.	1	0	0	34	28.00	812.00	.	464.00	.	.	3248.00	.	.	.	.
10	6	131	62	0	0	0	29	60.00	1310.00	620.00	786.00	372.00	8122.00	7860.00	48732.00	3720.00	81220.00	487320.0
17	10	113	76	0	0	0	39	170.00	1921.00	1292.00	1130.00	760.00	8588.00	19210.00	85880.00	12920.00	145996.0	1459960
9	-5	83	66	0	0	0	21	-45.00	747.00	594.00	-415.00	-330.00	5478.00	-3735.00	-27390.0	-2970.00	49302.00	-246510
18	5	89	75	1	0	0	49	90.00	1602.00	1350.00	445.00	375.00	6675.00	8010.00	33375.00	6750.00	120150.0	600750.0
9	1	111	64	0	0	0	35	9.00	999.00	576.00	111.00	64.00	7104.00	999.00	7104.00	576.00	63936.00	63936.00
8	15	94	65	0	1	0	45	120.00	752.00	520.00	1410.00	975.00	6110.00	11280.00	91650.00	7800.00	48880.00	733200.0
5	0	135	72	0	0	0	26	.00	675.00	360.00	.00	.00	9720.00	.00	.00	.00	48600.00	.00
5	15	101	70	1	0	0	24	75.00	505.00	350.00	1515.00	1050.00	7070.00	7575.00	106050.0	5250.00	35350.00	530250.0
9	-9	56	80	1	0	1	25	-81.00	504.00	720.00	-504.00	-720.00	4480.00	-4536.00	-40320.0	-6480.00	40320.00	-362880
5	16	98	65	0	0	0	29	80.00	490.00	325.00	1568.00	1040.00	6370.00	7840.00	101920.0	5200.00	31850.00	509600.0
6	16	82	79	0	0	1	38	96.00	492.00	474.00	1312.00	1264.00	6478.00	7872.00	103648.0	7584.00	38868.00	621888.0
5	-6	5	64	1	0	0	27	-30.00	25.00	320.00	-30.00	-384.00	320.00	-150.00	-1920.00	-1920.00	1600.00	-9600.00
13	18	146	62	1	1	0	31	234.00	1898.00	806.00	2628.00	1116.00	9052.00	34164.00	162936.0	14508.00	117676.0	2118168
6	6	124	.	0	1	0	25	36.00	744.00	.	744.00	.	.	4464.00	.	.	.	.
4	3	83	71	0	1	0	26	12.00	332.00	284.00	249.00	213.00	5893.00	996.00	17679.00	852.00	23572.00	70716.00
7	-9	74	71	0	0	1	30	-63.00	518.00	497.00	-666.00	-639.00	5254.00	-4662.00	-47286.0	-4473.00	36778.00	-331002
10	14	66	62	0	1	0	25	140.00	660.00	620.00	924.00	868.00	4092.00	9240.00	57288.00	8680.00	40920.00	572880.0
8	14	88	68	1	0	0	36	112.00	704.00	544.00	1232.00	952.00	5984.00	9856.00	83776.00	7616.00	47872.00	670208.0
15	16	145	.	1	0	0	31	240.00	2175.00	.	2320.00	.	.	34800.00	.	.	.	.
12	2	60	62	0	0	0	30	24.00	720.00	744.00	120.00	124.00	3720.00	1440.00	7440.00	1488.00	44640.00	89280.00
6	-8	-11	78	1	0	1	22	-48.00	-66.00	468.00	88.00	-624.00	-858.00	528.00	6864.00	-3744.00	-5148.00	41184.00
15	10	114	69	0	0	0	35	150.00	1710.00	1035.00	1140.00	690.00	7866.00	17100.00	78660.00	10350.00	117990.0	1179900
3	-2	26	78	1	0	1	24	-6.00	78.00	234.00	-52.00	-156.00	2028.00	-156.00	-4056.00	-468.00	6084.00	-12168.0
13	8	60	.	1	0	0	40	104.00	780.00	.	480.00	.	.	6240.00	.	.	.	.

NUMBER OF CASES READ = 196   NUMBER OF CASES LISTED = 196

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16 MAR 88    CARMENT DISSERTATION STUDY
14:44:10     OKLAHOMA STATE UNIVERSITY       IBM 3081K        MVS/XA 2.1.1

PRECEDING TASK REQUIRED        0.21 SECONDS CPU TIME;        1.21 SECONDS ELAPSED.

  36  0 00208041  PEARSON CORR X1 X2 X3 X4 X5 X6 X7 Y
  37  0 00208114  STATISTICS 1

*****PEARSON CORR PROBLEM REQUIRES     1472 BYTES WORKSPACE *****
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16 MAR 88 CARMENT DISSERTATION STUDY
14:44:11 OKLAHOMA STATE UNIVERSITY IBM 3081K MVS/XA 2.1.1

VARIABLE	CASES	MEAN	STD DEV
X1	196	8.6888	4.9717
X2	196	8.9541	9.6451
X3	196	90.3571	37.4976
X4	186	71.2957	5.9760
X5	196	.4439	.4981
X6	196	.1429	.3508
X7	196	.2143	.4114
Y	196	33.4949	9.7020

- - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C O E F F I C I E N T S - - - - - - - - - - - -

	X1	X2	X3	X4	X5	X6	X7	Y
X1	1.0000	.4096	.2930	.0093	.0561	-.0302	-.3333	.4355
	(196)	(196)	(196)	(186)	(196)	(196)	(196)	(196)
	P= .	P= .000	P= .000	P= .450	P= .218	P= .337	P= .000	P= .000
X2	.4096	1.0000	.4807	.0087	.0768	.0747	-.3193	.4822
	(196)	(196)	(196)	(186)	(196)	(196)	(196)	(196)
	P= .000	P= .	P= .000	P= .453	P= .142	P= .149	P= .000	P= .000
X3	.2930	.4807	1.0000	-.1264	-.0956	.0386	-.3414	.3489
	(196)	(196)	(196)	(186)	(196)	(196)	(196)	(196)
	P= .000	P= .000	P= .	P= .043	P= .091	P= .296	P= .000	P= .000
X4	.0093	.0087	-.1264	1.0000	.0006	-.0512	.1695	.0451
	(186)	(186)	(186)	(186)	(186)	(186)	(186)	(186)
	P= .450	P= .453	P= .043	P= .	P= .497	P= .244	P= .010	P= .271
X5	.0561	.0768	-.0956	.0006	1.0000	-.1300	.0840	.0360
	(196)	(196)	(196)	(186)	(196)	(196)	(196)	(196)
	P= .218	P= .142	P= .091	P= .497	P= .	P= .035	P= .121	P= .308
X6	-.0302	.0747	.0386	-.0512	-.1300	1.0000	-.2132	-.1158
	(196)	(196)	(196)	(186)	(196)	(196)	(196)	(196)
	P= .337	P= .149	P= .296	P= .244	P= .035	P= .	P= .001	P= .053
X7	-.3333	-.3193	-.3414	.1695	.0840	-.2132	1.0000	-.2644
	(196)	(196)	(196)	(186)	(196)	(196)	(196)	(196)
	P= .000	P= .000	P= .000	P= .010	P= .121	P= .001	P= .	P= .000
Y	.4355	.4822	.3489	.0451	.0360	-.1158	-.2644	1.0000
	(196)	(196)	(196)	(186)	(196)	(196)	(196)	(196)
	P= .000	P= .000	P= .000	P= .271	P= .308	P= .053	P= .000	P= .

(COEFFICIENT / (CASES) / 1-TAILED SIG) " . " IS PRINTED IF A COEFFICIENT CANNOT BE COMPUTED

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PRECEDING TASK REQUIRED        0.11 SECONDS CPU TIME;        0.85 SECONDS ELAPSED.

  38  0 00208214  CONDESCRIPTIVE X1 X2 X3 X4 Y
  39  0 00208323  STATISTICS 1,2,5,8,9,10,11

>WARNING 11003
>THE NEW DEFAULT COLUMN-STYLE PRINTING CANNOT BE USED FOR THIS CONDESCRIPTIVE,
>AS THERE ARE TOO MANY STATISTICS TO PRINT ON ONE LINE PER VARIABLE.  OLD STYLE
>PRINTING WILL BE USED INSTEAD.


THERE ARE    494376 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS    494352 BYTES.

      370 BYTES OF MEMORY REQUIRED FOR CONDESCRIPTIVE PROCEDURE.
       10 BYTES HAVE ALREADY BEEN ACQUIRED.
      360 BYTES REMAIN TO BE ACQUIRED.
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16 MAR 88 CARMENT DISSERTATION STUDY
14:44:12 OKLAHOMA STATE UNIVERSITY IBM 3081K MVS/XA 2.1.1

NUMBER OF VALID OBSERVATIONS (LISTWISE) = 186.00

VARIABLE X1 FIELD I-D

MEAN	8.689	S.E. MEAN	.355	STD DEV	4.972
SKEWNESS	.231	S.E. SKEW	.174	RANGE	18.000
MINIMUM	0	MAXIMUM	18		

VALID OBSERVATIONS - 196 MISSING OBSERVATIONS - 0

VARIABLE X2 SPATIAL VIS 3-D

MEAN	8.954	S.E. MEAN	.689	STD DEV	9.645
SKEWNESS	.218	S.E. SKEW	.174	RANGE	47.000
MINIMUM	-9	MAXIMUM	38		

VALID OBSERVATIONS - 196 MISSING OBSERVATIONS - 0

VARIABLE X3 SPATIAL VIS 2-D

MEAN	90.357	S.E. MEAN	2.678	STD DEV	37.498
SKEWNESS	-.444	S.E. SKEW	.174	RANGE	171.000
MINIMUM	-11	MAXIMUM	160		

VALID OBSERVATIONS - 196 MISSING OBSERVATIONS - 0

VARIABLE X4 CEREBRAL DOM

MEAN	71.296	S.E. MEAN	.438	STD DEV	5.976
SKEWNESS	.331	S.E. SKEW	.178	RANGE	33.000
MINIMUM	58	MAXIMUM	91		

VALID OBSERVATIONS - 186 MISSING OBSERVATIONS - 10

VARIABLE Y MATH ACHIEVE

MEAN	33.495	S.E. MEAN	.693	STD DEV	9.702
SKEWNESS	-.125	S.E. SKEW	.174	RANGE	49.000
MINIMUM	6	MAXIMUM	55		

VALID OBSERVATIONS - 196 MISSING OBSERVATIONS - 0

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16 MAR 88    CARMENT DISSERTATION STUDY
14:44:13     OKLAHOMA STATE UNIVERSITY       IBM 3081K        MVS/XA 2.1.1

PRECEDING TASK REQUIRED        0.10 SECONDS CPU TIME;        1.34 SECONDS ELAPSED.

  40  0 00208440  REGRESSION VARIABLES X1 X2 X3 X4 X5 X6 X7 X12 X13 X14
  41  0 00208531    X23 X24 X34 X123 X124 X134 X234 X1234 Y/
  42  0 00208634    STATISTICS=ANOVA R CHA COEF ZPP/
  43  0 00208728    DEPENDENT=Y/
  44  0 00209040    METHOD=ENTER X5 X6 X7/
  45  0 00209228    METHOD=ENTER X1 X2 X3 X4/
  46  0 00209428    METHOD=ENTER X12 X13 X14 X23 X24 X34/
  47  0 00209628    METHOD=ENTER X123 X134 X234 X124/
  48  0 00209828    METHOD=ENTER X1234/
  49  0 00209935    CASEWISE=DEPENDENT PRED RESID/
  50  0 00210034

THERE ARE    494112 BYTES OF MEMORY AVAILABLE.
THE LARGEST CONTIGUOUS AREA HAS    493744 BYTES.

     8684 BYTES OF MEMORY REQUIRED FOR REGRESSION PROCEDURE.
        0 MORE BYTES MAY BE NEEDED FOR RESIDUALS PLOTS.
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16 MAR 88    CARMENT DISSERTATION STUDY
14:44:14     OKLAHOMA STATE UNIVERSITY       IBM 3081K        MVS/XA 2.1.1

                              * * * *   M U L T I P L E   R E G R E S S I O N   * * * *

LISTWISE DELETION OF MISSING DATA

EQUATION NUMBER 1     DEPENDENT VARIABLE..   Y     MATH ACHIEVE

BEGINNING BLOCK NUMBER  1.  METHOD:  ENTER       X5        X6        X7

VARIABLE(S) ENTERED ON STEP NUMBER  1..     X7         BLACK
                                    2..     X5         GENDER
                                    3..     X6         NATIVE AMER

MULTIPLE R           .31344                                            ANALYSIS OF VARIANCE
R SQUARE             .09824        R SQUARE CHANGE      .09824                          DF      SUM OF SQUARES       MEAN SQUARE
ADJUSTED R SQUARE    .08338        F CHANGE            6.60946         REGRESSION        3          1732.61735         577.53912
STANDARD ERROR      9.34776        SIGNIF F CHANGE      .0003          RESIDUAL        182         15903.28050          87.38066

                                                                       F =        6.60946       SIGNIF F =  .0003

------------------------------ VARIABLES IN THE EQUATION ------------------------------

VARIABLE              B          SE B        BETA    CORREL  PART COR   PARTIAL         T   SIG T

X7            -7.011645      1.696055    -.298497  -.257972  -.290997  -.292991    -4.134   .0001
X5              .686143      1.399143     .034886   .031454   .034519   .036327      .490   .6244
X6            -4.905912      2.037196    -.174707  -.115293  -.169510  -.175728    -2.408   .0170
(CONSTANT)    35.221181      1.052658                                              33.459   .0000

END BLOCK NUMBER    1    ALL REQUESTED VARIABLES ENTERED.
```

* * * * M U L T I P L E R E G R E S S I O N * * * *

EQUATION NUMBER 1 DEPENDENT VARIABLE.. Y MATH ACHIEVE

BEGINNING BLOCK NUMBER 2. METHOD: ENTER X1 X2 X3 X4

VARIABLE(S) ENTERED ON STEP NUMBER	4..	X4	CEREBRAL DOM
	5..	X3	SPATIAL VIS 2-D
	6..	X1	FIELD I-D
	7..	X2	SPATIAL VIS 3-D

MULTIPLE R	.58170		
R SQUARE	.33837	R SQUARE CHANGE	.24013
ADJUSTED R SQUARE	.31235	F CHANGE	16.15070
STANDARD ERROR	8.09647	SIGNIF F CHANGE	.0000

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE
REGRESSION	7	5967.50914	852.50131
RESIDUAL	178	11668.38871	65.55275

F = 13.00481 SIGNIF F = .0000

------------------------------ VARIABLES IN THE EQUATION ------------------------------

VARIABLE	B	SE B	BETA	CORREL	PART COR	PARTIAL	T	SIG T
X7	-2.082048	1.646061	-.088636	-.257972	-.077115	-.094383	-1.265	.2076
X5	-.233182	1.240924	-.011856	.031454	-.011456	-.014083	-.188	.8512
X6	-4.414658	1.792063	-.157213	-.115293	-.150190	-.181574	-2.463	.0147
X4	.102241	.102251	.062578	.045054	.060961	.074736	1.000	.3187
X3	.031729	.019039	.121782	.359276	.101604	.123948	1.667	.0974
X1	.430293	.138255	.216702	.421953	.189750	.227179	3.112	.0022
X2	.328879	.077067	.326897	.488668	.260175	.304654	4.267	.0000
(CONSTANT)	17.661871	7.668924					2.303	.0224

END BLOCK NUMBER 2 ALL REQUESTED VARIABLES ENTERED.

* * * * MULTIPLE REGRESSION * * * *

EQUATION NUMBER 1 DEPENDENT VARIABLE.. Y MATH ACHIEVE

BEGINNING BLOCK NUMBER 3. METHOD: ENTER X12 X13 X14 X23 X24 X34

VARIABLE(S) ENTERED ON STEP NUMBER 8.. X12 FIELD-SV3D
9.. X23 SV3D-SV2D
10.. X13 FIELD-SP2D

MULTIPLE R	.59310		
R SQUARE	.35177	R SQUARE CHANGE	.01339
ADJUSTED R SQUARE	.31472	F CHANGE	1.20521
STANDARD ERROR	8.08250	SIGNIF F CHANGE	.3094

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE
REGRESSION	10	6203.70735	620.37073
RESIDUAL	175	11432.19050	65.32680

F = 9.49642 SIGNIF F = .0000

------------------------------ VARIABLES IN THE EQUATION ------------------------------

VARIABLE	B	SE B	BETA	CORREL	PART COR	PARTIAL	T	SIG T
X7	-1.908271	1.660508	-.081238	-.257972	-.069943	-.086546	-1.149	.2520
X5	.045013	1.258956	.002289	.031454	.002176	.002703	.036	.9715
X6	-4.212918	1.805057	-.150029	-.115293	-.142049	-.173747	-2.334	.0207
X4	.091827	.102617	.056204	.045054	.054462	.067490	.895	.3721
X3	.022855	.037790	.087722	.359276	.036809	.045671	.605	.5461
X1	-.009019	.420651	-.004542	.421953	-.001305	-.001621	-.021	.9829
X2	.632667	.229657	.628853	.488668	.167665	.203872	2.755	.0065
X12	.002813	.014463	.038324	.498588	.011836	.014699	.194	.8460
X23	-.003538	.001869	-.400507	.440581	-.115201	-.141641	-1.893	.0600
X13	.004288	.004477	.273634	.480040	.058290	.072210	.958	.3395
(CONSTANT)	19.741209	8.289013					2.382	.0183

END BLOCK NUMBER 3 TOLERANCE = .010 LIMITS REACHED.

16 MAR 88 CARMENT DISSERTATION STUDY
14:44:15 OKLAHOMA STATE UNIVERSITY IBM 3081K MVS/XA 2.1.1

* * * * MULTIPLE REGRESSION * * * *

EQUATION NUMBER 1 DEPENDENT VARIABLE.. Y MATH ACHIEVE

BEGINNING BLOCK NUMBER 4. METHOD: ENTER X123 X134 X234 X124

VARIABLE(S) ENTERED ON STEP NUMBER 11.. X123 FIELD-SV3D-SV2D

MULTIPLE R	.59379			
R SQUARE	.35259		R SQUARE CHANGE	.00083
ADJUSTED R SQUARE	.31166		F CHANGE	.22195
STANDARD ERROR	8.10053		SIGNIF F CHANGE	.6382

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE
REGRESSION	11	6218.27113	565.29738
RESIDUAL	174	11417.62672	65.61854

F = 8.61490 SIGNIF F = .0000

------------------------------ VARIABLES IN THE EQUATION ------------------------------

VARIABLE	B	SE B	BETA	CORREL	PART COR	PARTIAL	T	SIG T
X7	-1.895231	1.664442	-.080683	-.257972	-.069456	-.086002	-1.139	.2564
X5	.092694	1.265817	.004713	.031454	.004467	.005551	.073	.9417
X6	-4.240959	1.810062	-.151027	-.115293	-.142917	-.174884	-2.343	.0203
X4	.091263	.102853	.055858	.045054	.054124	.067115	.887	.3761
X3	.015571	.040909	.059763	.359276	.023217	.028843	.381	.7039
X1	-.114573	.477428	-.057701	.421953	-.014638	-.018190	-.240	.8106
X2	.513591	.341852	.510495	.488668	.091642	.113163	1.502	.1348
X12	.017095	.033604	.232928	.498588	.031031	.038538	.509	.6116
X23	-.002249	.003317	-.254531	.440581	-.041350	-.051323	-.678	.4987
X13	.005590	.005270	.356722	.480040	.064702	.080155	1.061	.2903
X123	-1.49364E-04	3.1705E-04	-.238800	.461142	-.028737	-.035692	-.471	.6382
(CONSTANT)	20.245151	8.376086					2.417	.0167

END BLOCK NUMBER 4 TOLERANCE = .010 LIMITS REACHED.

VITA

Deborah Grant Carment

Candidate for the Degree of

Doctor of Education

Thesis: THE ROLE OF FIELD INDEPENDENCE/DEPENDENCE, SPATIAL VISUALIZATION, AND CEREBRAL DOMINANCE IN MATHEMATICS ACHIEVEMENT OF TENTH GRADE STUDENTS

Major Field: Curriculum and Instruction

Biographical:

Personal Data: Born in Casa Grande, Arizona, October 24, 1947, the daughter of Earl and Gerrie Grant.

Education: Graduated from Muskogee Central High School, Muskogee, Oklahoma, in May, 1965; received Bachelor of Science degree in Chemistry from Oklahoma State University, Stillwater, Oklahoma, in May, 1969; received Master of Education degree from Northeastern State University, Tahlequah, Oklahoma, in August, 1982; completed requirements for the Doctor of Education degree at Oklahoma State University in May, 1988.

Professional Experience: Instructor of Mathematics, Division of Natural Sciences and Mathematics, Northeastern State University, Tahlequah, Oklahoma, August, 1984 to present.

Professional Organizations: National Council of Teachers of Mathematics, The Mathematical Association of America, and Kappa Mu Episilon.