The Use of Logo-Turtle Graphics in a Training Program to Enhance Spatial Visualization

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ABSTRACT

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This study examined the relatively obscure area of the effects of Training on Spatial Visualization as well as the controversial topic of sex differences and Spatial Visualization. A semi-structured course in elementary Logo-Turtle Graphics was designed and used as a Training program. The Training program lasted for five weeks and thirty-six subjects participated in the experiment.

The Eliot-Price Spatial Test (EPST: Eliot and Price, 1975) was used as both the pre- and the post-test. A 2 x 2 ANCOVA with sex and treatment as between subject factors with two levels (female/male and training/control respectively) and scores in the EPST before and after the experiment were used respectively, as the covariate and the dependent variable.

The results indicated no significant differences between the experimental and control groups, as well as an absence of sex differences. However, Logo-Turtle Graphics seemed to stimulate a positive group learning environment between the sexes. Recommendations for further research in this area, based on the results of this study, are offered.

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CHAPTER 1

THE PROBLEM

Over the last thirty years researchers have noted that Spatial Visualization ability is not always well developed through the ordinary school curriculum (Brown, 1954; Brinkmann, 1966; Kidder, 1977; Moses, 1982). Consequently, various attempts have been made to enhance Spatial Visualization ability through training programs (Blade and Watson, 1955, Brinkmann, 1966; Wolfe, 1970; Burnett and Lane, 1980; Goldin and Thorndyke, 1981).

In 1966, Erwin H. Brinkmann used a self-instructional training program to teach Spatial Visualization to eighth grade students. The program was a short course in elementary geometry and it emphasized such topics as the basic elements of point, line, angle and simple plane figures. Brinkmann found a significant improvement on a spatial perception measure (Brinkmann, 1966, p. 180). In 1980, Burnett and Lane also found a significant improvement in Spatial Visualization ability after some college students received training in specific mathematical courses. This study will attempt to add research to the area of training and its effects on Spatial Visualization ability.

The Statement Of The Problems

The researcher was interested in determining:

1. If a younger group of grades 4, 5, and 6 students could benefit from a semi-

structured training program utilizing the computer language LOGO-TURTLE GRAPHICS while they are developmentally defining a concept of space.

2. If sex differences already exist in Spatial Visualization ability within these age groups and whether the training program will eradicate these sex differences.

Context of the Problem

The term Spatial Visualization ability by definition refers to the same capacity as that of the term Visual Spatial ability (McGee, 1979; Maccoby and Jacklin, 1974). According to McGee, Spatial Visualization ability is defined as the ability "to mentally rotate, twist or invert a pictorially presented stimulus subject" (p. 893). On the other hand, Maccoby and Jacklin state that Visual-Spatial Ability involves "the visual perception of figures or objects in space and how they are related to each other" (p. 246).

It is precisely this lack of agreement between terms and definitions which has hindered valuable research in the area over the years. It is a complex area and on two occasions since 1957 efforts were made to clarify it. Researchers Michael, Guilford, Fruchter, and Zimmerman (1957) and McGee (1979) have reviewed and interpreted the literature and have pointed out the familiarities of definitions. McGee has even stated that when spatial ability is analyzed we find two distinct factors: Spatial Visualization and Spatial Orientation. This study focuses on Spatial Visualization as it is defined by McGee (1979, p. 893).

Controversy has existed over whether Spatial Visualization is an innate ability (Goldberg and Meredith, 1975, Benbow and Stanley, 1980) or it may be developed through experience (Sherman, 1967; Fennema and Sherman, 1977a; Kolata, 1980; Tobias, 1982). Supporting the view of Brinkmann (1966) the researcher acknowledges the possibility of innate influences on Spatial Visualization ability but also notes that some factors which effect the development of Spatial Visualization ability may be taught (e.g. estimating and discrimation).

Researchers have also claimed that while social experiences can effect the development of Spatial Visualization ability, boys and girls experience different socialization processes; the difference would result in more advantageous experiences for boys in developing Spatial Visualization ability.

According to Sherman (1967) and Salkind (1976) boys spend more time than girls on aiming activities and games, model construction, building with blocks and fixing bicycles. These activities are able to provide numerous opportunities for developing Spatial Visualization ability. Training may also bring about the necessary experiences. Brinkmann (1966), while emphasizing estimation in his training program, was also able to conclude that there were no significant sex differences and that girls do as well as boys on spatial visualization tasks if they are given the opportunities to learn.

Piaget and Inhelder (1956) and Tanner and Inhelder (1958) believe that all cognitive skills, including Spatial Visualization, are developed through physical interaction with the environment. These researchers claim that a child's earliest spatial concepts are topological in nature and that later, when a child is developing projective and euclidean concepts she or he takes into account and extends topological concepts. Indeed, Inhelder proposes that the richer the opportunities for tactile explorations the better chances will arise for developing spatial representations Piaget and Inhelder in their book "The Child's Conception of Space" (1956) state that between the ages of 7-8 and 11-12 years old,

> concrete operations schemata are coordinated sufficiently to be combined and consequently, for each one to be mentally explored in alternate directions. (p. 454)

They go on to say that:

> this type of reversible combination represents the initial equilibrium state reached by internalized actions and thus constitute the first truly operational system. With the further development of operational co-ordination

> it becomes possible to conceive of several systems simultaneously. (p. 455)

During this crucial period 7-8 and 11-12 years old when a child is developing a concept of space, steps should be taken, to ensure that experiences abound to provide for this development.

Evidently what is clear from the research is that in order to enhance Spatial Visualization ability we must provide equal opportunities to experience activities which emphasize the development of this particular ability for both of the sexes.

With the existing technology available a computing environment could possibly provide a training program as well as this equal opportunity. The computing Language Logo - Turtle Graphics, with its foundations originating from the work of Jean Piaget, provides an interactive environment with experiences in manipulating "objects" on a TV monitor (Papert, 1980). The usage of Turtle Graphics involves taking into account spatial relationships, such as mentally rotating the turtle in space so many steps to the left or right and moving forwards or backwards before typing in a desired command. At the end of each command by pressing the return key, the user observes immediate feedback.

The Significance of The Study

The development of Spatial Visualization, one component of Spatial Ability, is important because our knowledge of the world is influenced by the way we interpret and organize information. Many lessons on subjects taught in school, especially arithmetic, use pictures, diagrams and concrete materials that must be interpreted and used in specific ways (Young, 1982, p.38). Guay and McDaniel (1977) have reported a positive relationship between the level of achievement in Mathematics and Spatial Visualization ability with students at the elementary level.

The mandate of the elementary school system is to lay a basic foundation for advanced work in various subjects (touched on at the elementary level) in the secondary schools. If this is the case then specific instruction given at the elementary level to develop Spatial Visualization ability should lead to better use of this ability at the secondary level. Blade and Watson (1955) found that all the students in their training study who had had precollege experience which included high school instruction in mechanical drawing, had high spatial ability.

Since 1964, Smith (p. 298) stated that spatial abilities including Spatial Visualization were necessary for the successful study of most practical and technical subjects and of the more advanced branches of mathematics, physics and engineering. He also stated that high spatial ability is required in most scientific and technological occupations.

Technological advances have begun to change the workforce. Certain jobs become obsolete and new fields of employment are developing. Dale (1980) in her report on "The Impact Of Federal Government Employment Strategies On Women" in Canada noted that since 1966 Canada has experienced a continuous unemployment problem. Between 1966 and 1978 the unemployment rate climbed from 3.5% to 8.4%, adding an estimated 646,000 to the number of the unemployed. New jobs no longer reduce unemployment but rather a large proportion of the jobs remain unfilled. Dale states that the reason jobs remain unfilled is because of a lack of qualified people to do the jobs available. According to industrial estimates, within a few years computers will become the primary tools in 25% of all jobs (Keisler, Sproull, and Eccles, 1983).

At the most elementary level of computer technology, that of computer games, Spatial Visualization ablity is required. Keisler et al. (1983) notes that in order "to zoom through space and shoot down aliens, quick judgements of spatial relationships are needed" (p. 46).

According to The Organization For Economic Co-operation and Development (1980), in Canada women's average educational attainments are lower than men. Although young women's qualifications are approaching that of young men, they are concentrated in the fields of arts and humanities and women are underrepresented in scientific and technical fields. Thus although the general level of education of women is increasing, they are not equipped to enter many of the scientific and technical fields (O.E.C.D., 1980; Maccoby and Jacklin, 1974). Researchers such as Fennema and Sherman (1977b) claim that decisions made to go into these areas of employment are influenced by persistent stereotypes developed during a child's formative years and continues through adolescence and into adulthood.

Presently provision is made within the school curriculum for remedial reading classes, of which boys are overrepresented. But although evidence indicates that girls do poorly on spatial visualization tasks beginning approximately around eleven years old, provision is not normally made to provide remedial instruction in spatial visualization skills, or indeed any spatial skills in the schools (Maccoby and Jacklin, 1974). Sherman (1977) has also recommended self-instructional programmed packages for increasing Spatial Visualization ability. These packages would provide tools for teachers wishing to improve the skill of a student deficient in Spatial Visualization ability.

Finally, research has shown that Spatial Visualization ability is essential in scientific and technological occupations. These occupations are required in the present job market, as technological advances continually occur. Students of both sexes should receive training and be competent in this skill before leaving the school system, so that they may be equipped to enter these new technical fields. The foundation should be initiated in the elementary schools. Computer technology and a semi-structured training program could make this possible.

CHAPTER 2

REVIEW OF RELATED RESEARCH

Spatial Visualization, One Component of Spatial Ability

Research on Spatial Ability has existed since the 1920's, when the study of Practical and Mechanical abilities began (McFarlane, 1925; Kelley, 1928). Indeed, over the last sixty years extensive research has indicated that Spatial Ability is a major factor in Human Intelligence (Thorndike, 1921; Thurstone, 1938, 1950; Michael, et al., 1957). Yet, although research supports the importance of Spatial Ability and the fact that its factors are used as Basic Skills on many Intelligence Tests, Spatial Ability has attained very little status in its relationship to the development of Intelligence (Burnett and Lane, 1980).

A lack of recognition for Spatial Ability can probably be attributed to the early efforts to predict scholastic success. Smith (1964) points out that in an effort to predict scholastic success, psychologists have relied heavily on success in reading and writing and hence the tests found most suitable consisted of verbal materials. A standardized verbal score became used as a measurement of intelligence. Researchers such as McFarlane (1925) used terms like "concrete" and "abstract" synonymously to respectively distinguish between Spatial and Verbal abilities. This terminology indicated that children with high spatial ability were less likely to be capable of abstract thought than verbally gifted children. Spatial

Ability Tests were therefore used to measure concrete and practical skills, which together with manual and mechanical abilities, were able to predict success in technical and artistic fields (Smith, 1964).

Researchers initially argued whether a spatial factor did exist over and above General Intelligence and if the spatial factor could be subdivided. In 1925 McFarlane identified a group factor in addition to General Intelligence. Persons possessing this practical ability, a result of the group factor, were proficient at analyzing and judging concrete spatial relations. Kelley (1928) identified two subfactors of Spatial Ability which appeared in samples of kindergarten and nine-year old children. The first subfactor involved the perception and retention of geometric forms and the second a facility for the mental manipulation of shapes.

The existence of a spatial factor and its subdivisions have been corroborated by definitive research since the late 1940's (Guilford & Lacey, 1947; Guilford & Zimmerman, 1947; Thurstone, 1950; French, 1951; Smith, 1948). McGee (1979) reviewed the spatial ability literature and summarized the contributions of the above mentioned researchers. The subsequent section of this literature review weighs heavily on his work.

Research by Guilford and Lacey (1947), and Guilford and Zimmerman (1947) indicated the existence of two spatial factors: Spatial Visualization (Vz) and Spatial Relations

(SR). Spatial Visualization was described as the ability to imagine the rotation of depicted objects, the folding or unfolding of flat patterns, the relative changes of objects in space or the motion of machinery. Spatial Relations was described as the comprehension of the arrangements of elements within a visual stimulus pattern.

In 1938 Thurstone isolated a Spatial factor but it was not until 1950 that he identified seven primary abilities in visual thinking and related three of them to visual orientation in space. The first was designated as S_1, which represented the ability to recognize the identity of an object when it was seen from different angles or the ability to visualize a rigid configuration when it was moved into different positions. The second factor identified by Thurstone was S_2, which represented the ability to imagine movement of internal displacement among parts of a total configuration. The third factor S_3 involved the ability to think about those spatial relations in which the body orientation of the observer is an essential part of the problem.

French (1951) identified a visualization factor (V_i) described as the ability to manipulate objects and an orientation factor (So) described as an ability to remain unconfused by the varying orientations in which a spatial pattern may be presented.

Besides the factorial studies described above, numerous studies have supported the existence of a spatial factor and or its subdivisions. Smith (1964, p. 90) notes that the American Psychological Association concluded after a symposium on Spatial Abilities held in Washington, D.C. in 1952, that Spatial Ability was complex and still not well defined or understood. It was proposed that this complexity was due to the increasing development of test items and the exhaustive factorizations made possible by the use of modern computing devices. The proceedings of the symposium can be found in the 1954 issue of the Journal of Educational and Psychological Measurement.

In 1957, Michael and collaborators tried to ameliorate the complex problem of defining Spatial Ability by synthesizing findings in the field before 1957. They examined several factorizations of Spatial Ability and utilized the results of the above mentioned researchers.

McGee (1979) adapted the Michael et al. (1957) work and included a factorization by Ekstrom, French and Harmon (1976). Appendix E outlines factorizations made. This new factorization suggest that visualization ability requires that a figure be mentally restructured into components for manipulation whereas the whole figure is manipulated in spatial orientation.

As a result of the reviewed and interpreted works by McGee (1979) and Michael, et al. (1957) there appears to be two distinct spatial abilities : Spatial Visualization and Spatial Orientation. Spatial Visualization involves the ability "to mentally rotate, twist or invert a pictorially presented stimulus subject" (McGee, 1979, p. 893). This definition would include (refer to Appendix E) the Vz factor reported in Guilford and Lacey's (1947) research; Thurstone's S_2 factor (Thurstone, 1950); the V_i factor proposed by French 1951 and the Vz factor proposed by Ekstrom, et al. (1976).

Spatial Orientation would involve "the comprehension of the arrangements of elements within a visual stimulus pattern and the aptitude to remain unconfused by the changing orientation in which a spatial configuration may be presented" (McGee, 1979, p.893). Referring again to Appendix E, Spatial Orientation would include the SR factor in Guilford and Lacey's work (1947); S_1 and S_3 factors of Thurstone's work (1950); S and So factors by French, (1951) and S, an ability included by Ekstrom et al. (1976).

Factors Influencing The Development Of Spatial Visualization

At least six factors which are all interrelated affect the development of Spatial Visualization. They include genetic, hormonal, neurological and environmental influences (such as training) as well as age and sex. Genetic evidence proposes that Spatial Visualization ability is as equally or more heritable than verbal ability (Block, 1968; Defries, Vandenberg, McClearn, Kuse, and Wilson, 1974; McGee, 1978). A number of studies have suggested that Spatial Visualization may be enhanced by an X-Linked, recessive gene (Bock and Kolakowski, 1973; Goodenough, Gandini, Olkin, Pizzamiglio, Thayer and Witkin, 1977; Guttman, 1974;

Goldberg and Meredith 1975; Yen, 1975). It is proposed that more males than females have the X-Linked recessive gene, hence they do better on Spatial Visualization tasks. However, the hypothesis for a recessive X-Linked inheritance of Spatial Visualization is not confirmed and, in addition, this area is not well researched.

A lack of definitive research also exist for hormonal influences. Petersen (1976) demonstrated that less androgenized masculine males scored higher on Spatial tests than more androgenized boys. These studies tend to use crude methods to measure variables, and so are not very conclusive pieces of research.

Neurological studies involve the lateral organization of the brain. Recent research on hemisphere specialization suggests that the right cerebral hemisphere is specialized for spatial processing. Research indicates that males have greater specialization than females, therefore well developed spatial abilities (Erhlichman, 1972; Kimura, 1969). This factor is providing more insight on spatial abilities and seems to hold some conclusive evidence in its support.

Some studies have reported sex differences in Spatial Visualization (Tapley and Bryden, 1977; Sanders, Soares, and D'Aquila, 1982; Sherman, 1967). Sex differences seem to appear in the development of Spatial Visualization at puberty. Maccoby & Jacklin (1974) confirmed through a thorough review of the literature that boys excel in spatial abilities. According to Maccoby & Jacklin this sex difference is inherent. Sherman (1967, 1977) takes a completely different view and proposes that sex differences in spatial abilities are determined by social and cultural influences. Increasingly more evidence supports this view (Tobias, 1982; Kolata, 1980; Fennema and Sherman, 1977a). Researchers Fennema and Sherman (1977b) have investigated the area of sex differences and mathematics, and sex differences and Spatial Visualization ability, and have stated that "spatial visualization skills may be closely related to sexual stereotypes held by our society" (p. 371).

Training And Spatial Visualization

Research supporting the teaching or the cultivation of Spatial Visualization is minimal and extremely controversial. Some researchers feel that Spatial Visualization is static and unchangeable (Goldberg and Meredith, 1975; Benbow and Stanley, 1980).

However, many researchers have used various training strategies to enhance Spatial Visualization ability. Churchill, Curtis, Coombs, and Hassell (1942) and Blade and Watson (1955) claim significant improvements in Spatial Visualization for subjects after enrollment in engineering courses. These courses emphasized drafting, mechanical drawing, and descriptive geometry. Miller, Boismier, and Hooks (1969) reported that posttests results indicated overall gains among subjects after training in spatial conceptualization. The study comprised of 34 7-yr-old children, who participated in three different training programs and a control group. The three training programs were a teacher-directed training program, an automated (written sequences) and minimal assistance from experimenter program and a combination of these two programs made up the third training program. In 1970, Wolfe found significant differences in Junior High school students who received direct training in Spatial Visualization. Sherman (1974) found evidence that indicated that males and females improved with practice on the Rod and Frame Test. Burnett and Lane (1980) using college courses as a variable found that students majoring in mathematics and the physical sciences showed an improvement in Spatial Visualization over the students majoring in Humanities and the social sciences.

In 1966, Brinkmann used a short course in elementary geometry to teach Spatial Visualization skills. He pointed out that when geometry is used to enhance Spatial Visualization, emphasis must be placed on the use of problem-solving as a process for solving the task, rather than manipulating abstractions, through logical thought. Along the same lines as Brinkmann's conclusions, several researchers have recently suggested and used geometrical activities in their training programs to enhance Spatial Visualization skills (Kidder, 1977; Young, 1982; Inskeep, 1970; Moses, 1982; Giles, 1982). The Soviet Union has reorganized its geometric curriculum to emphasize these ideas. The reader is directed to Wirzup's article

"Breakthroughs In The Psychology Of Learning and Teaching Geometry" (1976).

Support for the cultivation of Spatial Visualization can be inferred from Piaget and Inhelder (1956). These researchers propose that spatial abilities seem to develop through two distinct cognitive levels: Perceptual and Representational Levels. The perceptual level occurs as a result of learning based on seeing, touching and manipulating objects. While the representational level takes into account the knowledge of the Perceptual level and expands upon it, by performing mental operations not only when an object is present, but also when the object can be imagined (Piaget and Inhelder, 1956, pp. 17-18).

Much research has focused on the Perceptual level (Williford, 1972; Turner, 1967; Shah, 1969) but not much research has looked at the Representational level. Kidder (1972) devised a training study which fostered through concrete examples Euclidean Transformations at the representational level. Kidder (1972, 1974) strongly suggests that although a child may be able to learn at the Perceptual level, he or she may not be able to learn at the Representational level. Therefore activities promoting the ability to perform spatial tasks at the Representational level should be fostered. This crucial period occurs between the ages of 9-12 years of age (Piaget and Inhelder, 1956).

Most of the above mentioned research on training and Spatial Visualization has involved subjects at the junior high school level and extending into adulthood. Research at the elementary school level is minimal. Yet the transition from the perceptual to the representational level of spatial abilities occurs between the ages of 9-12 years old, while children are still in the elementary school. In 1977, Connor, Serbin, and Schackman, in an attempt to improve performance on the Children's Embedded Figures Test (a spatial orientation test) found that training resulted in significant improvement for girls, but not for boys. The ages of the children involved in the study ranged from 6-10 years old. Although the study focused on Spatial Orientation and not Spatial Visualization, Michael, et al. (1957) points out that there is a high correlation between the two abilities, hence the possiblity of teaching Spatial Visualization skills at these age levels. Guay and McDaniel (1977) have noted that even at the elementary level, high and low spatial ability is evident. Taking all the information into account it seems reasonable to assume that it is possible to enhance spatial visualization skills through a training program.

Logo Turtle Graphics And Spatial Visualization

Considering the previous discussion any cultivation of Spatial Visualization abilities seems to require certain criteria:

1. Providing concrete experiences.
2. Providing geometric experiences.

Both of these criteria can be found in Logo-Turtle Graphics.

A more detailed description of the Logo computing language will now be discussed in this section. Logo-Turtle Graphics has nine easily understood usable commands. It reflects user interests by creating graphically shapes, scenes and games which the user chooses to design.

The "turtle", which is really a cursor on a graphics screen, can move forward and backwards in a particular direction relative to itself or it can rotate its heading to the left or right on the screen. Papert (1980) states that provision of its own position and heading helps to concretize the ideas of the user. The user can identify with the turtle and relate the information provided by the turtle to his or her own body while moving the turtle about the screen to create a specific procedure.

When a user moves the turtle around the screen she or he is teaching the turtle what to do. This means that the user must first hypothesize and understand what is going to happen on the screen before she or he actually types in a command (Weir, 1981). Papert emphasizes that "to make an idea more concrete a person must focus on the structure of what is learned" (Papert, 1980, p. 158).

Logo's interactive environment emphasizes a process not a product. That is,

> the initial tasks are structured to enable direct feedback on the intermediate steps during the solving of a problem. (Weir, 1981 p. 6)

Provision of this immediate feedback means that what a user might have intended to do and what actually happens can easily be seen. Papert (1980) and Lawler (1982) state that Logo-Turtle Graphics provides geometric experiences in manipulating "objects" on a television monitor which gives users the opportunity to become familiar with the turtle and the procedures they create. Through these "microworlds" a user can propose and test out procedures used.

One of the few studies that have used Logo-Turtle Graphics to teach Spatial Visualization was carried out by Weir (1979). Weir used Logo-Turtle Graphics to help cerebral palsy students develop spatial and linguistic abilities. Her findings indicated that Logo-Turtle Graphics is a source for experience in "visio-spatial problem-solving activities" (p. 10). Further, she found that logo-Turtle Graphics was a useful activity in the school curriculum.

Logically, Geometry and Spatial Visualization are related. One of the requirements of Spatial Visualization is that an object should be mentally rotated, twisted or inverted. This is also an important requirement of Geometry. This particular view is supported by Fennema (1977) and as mentioned earlier Guay and McDaniel (1977) also reported a positive relationship between mathematical achievement and spatial abilities in elementary school children.

Ross and Howe (1981) in their review of the literature and their own research related to Logo-Turtle Graphics and learning mathematics, provide evidence that implies that

Logo might be able to teach mathematicat ideas. Hence the inference that working through geometrical explorations could possibly lead to an increase in Spatial Visualization ability. Users are investigating visual relationships when they attempt to build and debug programs. In support of this statement, Billings (1983) suggested that,

> The interactivity, graphics and motion capabilities of the computer, as well as its ability to store information make it a useful tool in the formation and application of concepts. (p. 19)

Researchers Di Sessa (1977), Gagne and White (1978), Billings (1983), and Noss (1983) have pointed out that how a person uses a concept is important. Through usage of the turtle to draw shapes on a TV monitor, a user must truly understand the concept of rotating to the left or to the right and estimation of distances between two points. Di Sessa strongly supports the teaching of procedural thinking over deductive thinking. Subsequently Di Sessa states that provision of experience in informal geometry paves the way for a better understanding of mathematical concepts, one of which is geometry.

Recently researchers Turkle and Podell (1984) reported the results of their twelve week pilot project, which emphasized developing thinking and problem solving skills using Logo-Turtle Graphics. They noted that the students used mathematical concepts like estimation of distances and angles while programing.

Research therefore indicates that Logo-Turtle Graphics can provide experiences which could develop some mathematical concepts, for example, estimation of distances and angles. These same concepts were emphasized in Brinkmann's study in 1966 in an effort to enhance Spatial Visualization. His training program as mentioned earlier produced improvements in Spatial Visualization ability. Researchers Brinkmann (1966) and Di Sessa (1977) also indicate that procedural thinking may be more advantageous than deductive thinking when learning new concepts. Consequently, since Logo-Turtle Graphics is a procedural language it should provide a sound foundation for the development of Spatial Visualization skills.

Finally over the last few years school administrators have begun to spend larger sums of money purchasing microcomputers and creating computing environments (Billings, 1983). The technology is available and this usage of Logo-Turtle Graphics in the elementary school or indeed any other institutions, can provide a first chance at experiencing the new technologies, and possibly enhancing Spatial Visualization as well as alleviating sex differiences which might exist.

CHAPTER 3

METHOD

Hypotheses

Statement of the Hypotheses

The purpose of this research was to test the following hypotheses:

1. A semi-structured training program utilizing the use of Logo Turtle-Graphics, an interactive procedural computer programming language, would enhance Spatial Visualization ability.
2. Through a provision for equal opportunities to explore spatial relationships, given by the semi-structured training program, sex differences which might exist prior to the training program could be eradicated once the subjects have experience the program.

Subjects

The total number of subjects included thirty six English speaking, racially mixed elementary school children– eighteen girls and eighteen boys from grades four and five/six. The subjects were selected through a list of criteria given to the teachers and principal of the Roslyn School in Montreal. (The list of criteria may be found in Appendix A). Eighteen of the subjects were randomly assigned to an experimental group, while the remaining eighteen were assigned to a control group. Mean ages for these groups are given in Table 1.

Table 1

Mean Ages of Subjects in Years

(cell sizes in parenthesis)

Treatment Condition	Sex: Female	Male
EXP.	10.5 (10)	8.5 (8)
CONT.	8.5 (8)	10.5 (10)

Materials

The Eliot Price Spatial Test

The Eliot-Price Spatial test (EPST) is a paper and pencil instrument designed to measure the ability to perceive and to imagine object arrangements from different viewpoints. It is a pictorial adaptation of Piaget's three mountain task (Piaget and Inhelder, 1956). Each test page consists of a photograph of five blocks arranged on a large black baseboard and six side-view photographs of these same blocks taken from various positions around the board block arrangement (Eliot and Price, 1975, p. 1).

The EPST produces a single score (between 0 and 180) for each subject, once they have completed the thirty items. The score is calculated by noting the deviation between the subject's choice of positions either to the left or right of the correct location of the side view on the lettered circle (Eliot and Price, 1975, p. 6). The lowest possible score for an item is 6, while the highest possible score is 0. The total score for the 30 items is calculated by summing all of the item scores. The highest raw score possible is 0, and the lowest raw score possible is 180 (Eliot and Price, 1975, p. 7).

The test materials for the test included a test booklet, a test answer sheet, and a pencil with an eraser (see Appendix D). The adminstrative procedures for the test can be found in the "Working Manual for the Eliot-Price Test" (Eliot and Price, 1975, pp. 4-6).

Descriptive statistics and reliability coefficients are reported by Eliot and Price (1975) for an earlier version of the test including six extra items. These six items were later excluded from the revised version (the one used in the present study) due to low discrimination power. Results show for fourth-graders (N=27) a mean of 93.3 and a standard deviation of 18.78; for fifth-graders (N=24), the numbers were 70.7 and 29.32, respectively; and for sixth-graders (N=32), 51.1 and 34.19, respectively. Reliability co-efficients (Cronbach's alpha) for the revised version are .713 , .893 and .934 for fourth-, fifth- and sixth-graders respectively. A test-retest reliability coefficient of .896 was found by using twenty seventh-graders, based on ten day intervals.

Correlations with a number of other tests were obtained in order to establish the congruent validity of the Eliot-

Price test (Eliot and Price, 1975, p. 27). These included the revised Minnesota Paper Formboard test, the NFER Matchbox Corners test, a Mental Rotations test, the Gottschaldt Embedded Figures test and the Guilford-Zimmerman Spatial Orientation and Spatial Visualization. An MTMM (multitrait-multimethod) analysis proved the EPST to have more convergent and discriminant validity than the Guilford-Zimmerman tests, and to be overall satisfactory.

The Computers

There were five computers in the computer classroom: one Apple 11 plus and four Apple 11e computers. Each computer had one disk drive and a colour monitor attached to it. The computers were setup in a circle around a classroom (designated the computer classroom). The room was well ventilated with several windows. The Apple Logo version of Logo-Turtle Graphics was used in the training program. The children came to the computer room for their Logo session.

The Training Program

The training program comprised worksheets which introduced new Logo commands and provided opportunities for using these new commands through specific exercises (see Appendix B). Two books were used to provide guidelines for the development of the worksheets: A. Kwok, R. Sones and L. Hochglaube book's "The Workbook for Learning Logo" (1983) and Logo Computer Systems' publication "Introduction to Programming through Turtle Graphics" (1982). All the worksheets emphasized the opportunity to rotate the turtle in space, so that the development of Spatial Visualization ability could be maximized. For example, in Appendix B - Activity 2, the student had to rotate the turtle in space on the monitor and then draw on paper what he or she had created and seen on the monitor.

Each new command was specifically taught through a semi-structured process, by the experimenter. This semi-structured process involved some teacher-directed activities during the first fifteen minutes of each forty-five minute session, and free exploration by the students of the capabilities of each new command, in combinations with others, during the last thirty minutes of each session.

During the first fifteen minutes the experimenter introduced each new command or commands by first asking all the students to gather around one computer while each new command and its capaabilities were illustrated on the monitor. A few students at this time were encouraged to participate while others observed. Following the initial introduction of the new commands, the students were asked to sit at a large round table in the middle of the classroom. The experimenter then asked the students to fill in the blanks on the respective worksheet or write on a separate sheet of paper, the written name for each command. The objective of this activity was obtained through a series of questions and answers as well as guidance from the experimenter.

Following this activity, the students were invited to work in groups of two per computer. They were asked to experiment with the new commands by working through a series of exercises developed by the experimenter. For example, using Worksheet 1-Introduction to Logo-Turtle Graphics and Turtle's First commands in combination with Activity 1 (see Appendix B, pp. 54-55) the students were asked to fill in the blanks for the first seven commands and then ask to work through Activity 1 in groups of two per computer. Finally, they were encouraged to use these commands and create their own pictures on the screen.

Each new worksheet build upon the knowledge of the other. For instance, before a student learned how to use the PU (pen-up) command (see Appendix B, pp. 54-55), she or he had to learn to use the first seven commands listed in part two of Introduction to Logo-Turtle Graphics - Turtle's First Commands. Each new worksheet was therefore an evaluation device for previously taught commands. A glance at Appendix B- Building Shapes 1,2 and 3 clearly explicates this statement.

The children were also encouraged to discuss commands and use procedures they created amongst themselves. Whenever the subjects had difficulties deciding which way the turtle should be rotated in order to draw a specific design, they were shown how to "play turtle". "Playing turtle" simply refers to putting themselves in the position the turtle is on the screen, then turning their bodies and moving to the desired position that they would like the turtle to be at on the screen, before typing in the desired commands.

The worksheets covered the Logo primitives, making procedures, editing procedures, saving procedures, building shapes, turtle's field - wrap, fence and window, poly, spi and arc procedures.

Procedure

The treatment lasted for five weeks with two forty-five minute sessions in the first week and three forty-five minute sessions thereafter, in the computer classroom each week. The time allotted was a constraint because the research was carried out in a genuine school setting. The computer sessions were given every Monday, Tuesday, Wednesday and Thursday mornings between 8.15 and 9 45 a.m and on Tuesday and Thursday afternoons between 12.50 and 1.35 p.m. The children worked in groups of two per computer. The subjects decided on who they wanted for a partner during the first 45 minute session. Each child in the group took turns typing and giving commands. The control group participaced in regular classroom activities such as Language Arts, Mathematics or Physical Education while the experimental group received the treatment.

The Eliot-Price Spatial test was administered to both the experimental and the control subjects in groups of five, before and after the training program. The subjects were asked to indicate on an answer sheet where, on a lettered circle around the standard photograph they would have to stand in order to see each of the side-view photographs (Eliot and Price, 1975, p. 1). The tests were given pictorially with very little additional verbal information, and scoring the test did not require a great deal of time or computer facilities. The test was not administered to the subjects in the computer classroom but in another classroom in the school. Total testing time lasted approximately twenty minutes.

CHAPTER 4

RESULTS

The data obtained can be found in Appendix C.

Means and standard deviations of scores obtained in the EPST for the four groups are shown in Table 2.

Table 2

Means And Standard Deviations Of Scores Obtained In The EPST

Group		Cont.	Cont.	Exp.	Exp.
Sex		Male	Female	Male	Female
N.		10	8	8	10
Pre. T.	Mean	74.0	75.4	68.0	74.0
	S.D.	26.0	21.9	29.9	23.0
Post. T.	Mean	65.6	68.5	67.3	66.1
	S.D.	32.9	33.4	31.7	34.7

Means and standard deviations are found to be similar to those reported by Eliot and Price (1975) and mentioned before. Reliability coefficients (Cronbach's Alpha) were .876 for the pretest and .935 for the post-test. Test-retest reliability was measured using Pearson Correlation Coefficients, which were found to be .729 for the experimental group, .852 for the control group, and .786 for the two groups pooled together ($p < .001$ in all cases).

Both hypotheses were tested by means of a 2 X 2 ANCOVA, with sex and treatment as between subject factors with two levels (female/male and training /control respectively), score in EPST after treatment ("post-test") as the dependent variable, and score in the EPST before treatment ("pre-test") as the covariate. All samples (grades 4, 5/6) were pooled together, for there is no reason to expect any difference in performance of subjects in these groups (Eliot and Price, 1975).

The results of this ANCOVA are shown in Table 3.

Table 3

Sex By Treatment Analysis Of Post-Test

	Sum of Squares	Degrees of Freedom	Mean Square	F	Tail Prob.
Group	106.3	1	106.3	.25	.6216
Sex	77.84	1	77.84	.18	.6726
GS	174.43	1	174.43	.41	.5277
1-ST COVAR	22195.453	1	22195.453	51.90	.0000
Error	13257.346	31	427.65635		

Adjusted cell means are shown in Table 4.

Table 4

Adjusted Cell Means

Group	Cont.	Cont.	Exp.	Exp.
Sex	Male	Female	Male	Female
Post	64.52	65.99	72.43	65.02

In order to test the assumption of homogeneity of the regression equations (or in other words, of no covariate-by-factors interaction), the procedure suggested in Nie, Hull, Jenkins, Steinbrenner and Bent (1975, pp. 381-383) was followed. Regression of post-test with group, sex, pre-test, group-by-pre-, and sex-by-pre- gives an R square of .63335; regression of post with group, sex and pre- gives an R square of .62709. Thus,

$$F_{inter} = \frac{(R^2_{full} - R^2_{no\ inter}) / (k_1 + k_2 + k_3 + k_1 k_3 + k_2 k_3)}{(1 - R^2_{full}) / (N - k - 1)} = \frac{0.00626/2}{0.36665/30}$$

$$= 0.2561$$

which is not significant at the $\alpha = 0.05$ level ($F_{.05}(2,30) = 4.17$).

Gain scores were obtained by computing pre- minus post-scores. Relative gain was computed as the gain score divided by the greatest of pre- and post- scores. Examination of relative gain reveals no obvious disparities: for sixteen students (45%) the latter is less than .01, and for only six students (16%) this was greater than .60 (the remaining fourteen [39%] showing a relative gain between .02 and .59). Of the six students for whom the relative gain was greater than .6, two were male-exp., two were female-exp., one was male-control, and one was female control.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

The results of this study clearly indicate an absence of significant differences between the experimental and control groups. The validity of the ANCOVA as a means to assess this was established by the non-significance of F-inter (see page 34). Sex differences were also not present before or after the experimental period. This chapter will therefore fulfill two objectives. It will first discuss the lack of significant differences when research outlined in the problem and literature review chapters supported what should have been significant results. Secondly, it will outline the contribution made by the results of the study towards research in the area, as well as offer recommendations for future research in the area of Training and Spatial Visualization ability.

Initially Logo-Turtle Graphics seemed to be an appropriate learning material through which any training program intended at developing Spatial Visualization ability might succeed. According to researchers such as Papert (1980) and Turkle and Podell (1984) Logo could provide experiences for estimating distances and angles, as well as providing (through "microworlds" and "playing turtle") opportunities to develop problem-solving skills and drawing geometrical shapes. The above-mentioned concepts which Logo-Turtle graphics supposedly stimulated were all listed earlier as essential to the development of Spatial

Visualization ability (Brinkmann, 1966; Kidder, 1977; Piaget and Inhelder, 1956). Consequently, either Logo- Turtle Graphics did not provide these opportunities or the experimental period was too short to indicate significant results.

The possibility of producing significant results over a longer period of time draws support from studies such as Weir (1979) and Turkle and Podell (1984) which reported positive but not empirically significant results. Weir's project, in progress at the time in 1979, had already lasted eighteen months when the results were reported and was continuing. Turkle and Podell's project lasted for a period of twelve weeks. However, the effectiveness of using Logo-Turtle Graphics in a training program could have been greatly jeopardized if it had been extended over a longer period. The researcher would have had to take into account the external influences such as afterschool computer classes or maturation.

A semi-structured training program was favoured over a structured or a laissez-faire approach in an effort to provide maximum interest in Logo-Turtle Graphics. Several conversations with teachers using Logo-Turtle Graphics seemed to indicate that a structured approach provided very few chances for developing problem-solving skills; while a laissez-faire approach could create eventual disillusionment and a lack of interest. Hence, all the avenues were examined in order to provide ample opportunities to learn Logo-Turtle Graphics efficiently and at the same time enhance Spatial Visualization ability. Consequently, a lack of significant results questions what exactly Logo-Turtle Graphics does teach.

The second hypothesis looked at sex differences before and after the training program. The results are similar to existing research. Sex differences were not evident among these groups. Girls seemed to spend as much time as boys creating procedures and did equally well as boys. The girls were never inhibited by the boys and indeed defended themselves verbally on occasion. Interestingly, the subjects whether boys or girls frequently volunteered to help each other without the experimenter's intervention. Therefore, Logo-Turtle Graphics seemed to stimulate group learning and a sharing of ideas among the sexes.

Further research should therefore attempt to categorize the concepts or stages of development implicit in the development of Spatial Visualization ability. Over the last thirty years, very little research has examined this area. The research that has been carried out is sparse and comparable. McGee's 1979 review of the literature includes a definition of Spatial Visualization ability but does not categorize the stages or concepts which comprise Spatial Visualization ability. Most research to date continues to further divide the area of Spatial Ability itself rather than attempting to clarify its components, such as Spatial Visualization. A list of stages or concepts which could be identified as important in the development of Spatial Visualization ability would give educational remedial specialists or teachers guidelines to identify students who might be deficient in this ability.

The lack of definitive research in Spatial Visualization ability provided very few usable spatial tests. Most spatial tests such as the Gerald Melnick-Rotation of the Landscape (Melnick, 1977) and Laurendeau and Pinard-Piagetian Three-Mountain test (Laurendeau and Pinard, 1970) required long observational periods as well as long question and answer sequences. These tests also required individual examinations. Time and assistance was at a premium in this research and so a test which would allow a large group to be tested at one time was essential. The Eliot-Price test was chosen because it seemed to measure what other researchers and McGee's definition assumed is meant by Spatial Visualization ability. Also, it was completed in approximately twenty minutes and it was easy to tabulate the scores.

Logo-Turtle Graphics generally did not completely fail to create positive results; instead, it stimulated group learning and therefore research in this area should be fostered. Logo-Turtle Graphics could therefore be used as a programming language or as a basic foundation to an introduction to computer technology in the schools.

Future research with Logo-Turtle Graphics in a training program to enhance Spatial Visualization ability should consider extending the experimental period although some effects from external influences should be expected. Smaller samples might also be observed to determine, through procedures developed and verbal or physical actions, what specifically subjects learn when interacting with the turtle.

Earlier in this thesis it was clearly pointed out that Spatial Visualization ability was a difficult area to study but yet an area which should be researched extensively because of the possiblity that it may play an important role in the development of human intelligence. This research has merely touched the tip of the problem by noting the difficulty of locating concise research and explicating the unclarified area that Spatial Visualization encompasses.

The existence of sex differences in Spatial Visualization ability beginning at puberty and continuing into adulthood indicates a problem. Society is now more competitive than it has ever been. Women must be able to compete equally well in the job market and mainly in the developing areas related to new technologies. Therefore, although research indicates no sex differences for the age group studied, further research should be carried out in this area. A possible research design might encompass a longitudinal study in which male and female subjects would be tested for continual development of Spatial Visualization ability at least four times during the school year. This design is suggested because it is presumed that changes must occur between the ages of 10-12 years old since sex differences according to Maccoby and Jacklin (1974) appear at puberty. Thus Spatial Visualization ability with support from research should become an area of study within the present school curriculum. It would not be a specific subject but a major area to be covered within the mathematics curriculum.

Investigating both the areas of Spatial Visualization ability and Logo-Turtle Graphics was difficult because of few reported studies and poorly documented results. Very little research has been carried out in Spatial Visualization ability with the age group studied. Competent and knowledgeable researchers must clarify and expand this area.

Research focusing on Logo-Turtle Graphics is available but is mostly observational and not well documented. To the best of my knowledge no research exists at the present time which pinpoints exactly what Logo-Turtle Graphics teaches in terms of mathematical concepts or indeed any other concepts. A great deal of research is needed in this area so that Logo-Turtle Graphics can truly play an important role in the educational system. The computer language is no doubt powerful but educators must know more about what it develops within a user. Reports from Logo-Turtle Graphics projects must also be more explanatory with regard to the research design used as well as what was taught during the treatment period.

Concerning the use of Logo-Turtle Graphics in a training program to enhance Spatial Visualization, further studies should be carried out to determine its effects on other age groups. As well, different learning ability groups may be considered in such studies. Thus, for example, use of Logo-Turtle Graphics in a Spatial Visualization training program with slow and normal learners within certain age groups could show differential effects; also, such intervention could have some effects with normal learners within a critical age group (such as the one in which traditionally sex differences start showing).

It is hoped that future research will shed light onto the relationship or mutual effects, if any, of Spatial Visualization ability and the learning of Logo-Turtle Graphics.

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APPENDIX A

Criteria For Entrance To Research Project

1. The child must be successfully experiencing encounters in his or her mathematics and reading programs.
2. Participants must be self-motivated and exhibit sufficient interest to learn to use a computer.
3. This study is opened to an equal number of boys and girls.
4. The children should be able to participate in three computer sessions a week.
5. The children should not have had Logo-Turtle Graphics experiences before entrance into the study.
6. The children should not have a computer at home.

APPENDIX B

INTRODUCTION TO LOGO-TURTLE GRAPHICS

1. Starting up (Booting) Logo

   -Place the Apple Logo Diskette in the Disk Drive

   -Close the Disk Drive Door

   -Turn the Computer On

   -Turn the Monitor On

   -Wait for Message

   -Press Return Key

   -Welcome to Logo ---- Type ST or CS (to see turtle)

2. Turtle's First Commands

   ST ____________

   HT ____________

   FD ____________

   BK ____________

   RT ____________

   LT ____________

   CS ____________

   PU ____________

   PD ____________

   PE ____________

   HOME

ACTIVITY 1

Try A Few Commands On Your Own

1. Type....

CS		RETURN
FD	75	RETURN
RT	90	RETURN
BK	__	RETURN
LT	__	RETURN

2. Try More On Your Own

CS		RETURN
__	__	RETURN
__	__	RETURN
__	__	RETURN
__	__	RETURN

ACTIVITY 2

DRAW WHAT YOU SEE

1. TYPE ...

   CS [RETURN]

   FD 50 [RETURN]

2. TYPE ...

   CS [RETURN]

   BK 50 [RETURN]

3. TYPE ...

   CS [RETURN]

   LT 45 [RETURN]

4. TYPE ...

   CS [RETURN]

   RT 45 [RETURN]

ACTIVITY 2 CONT'D

DRAW WHAT YOU SEE

5. TYPE . . .

CS	RETURN
FD 50	RETURN
RT 45	RETURN
FD 50	RETURN

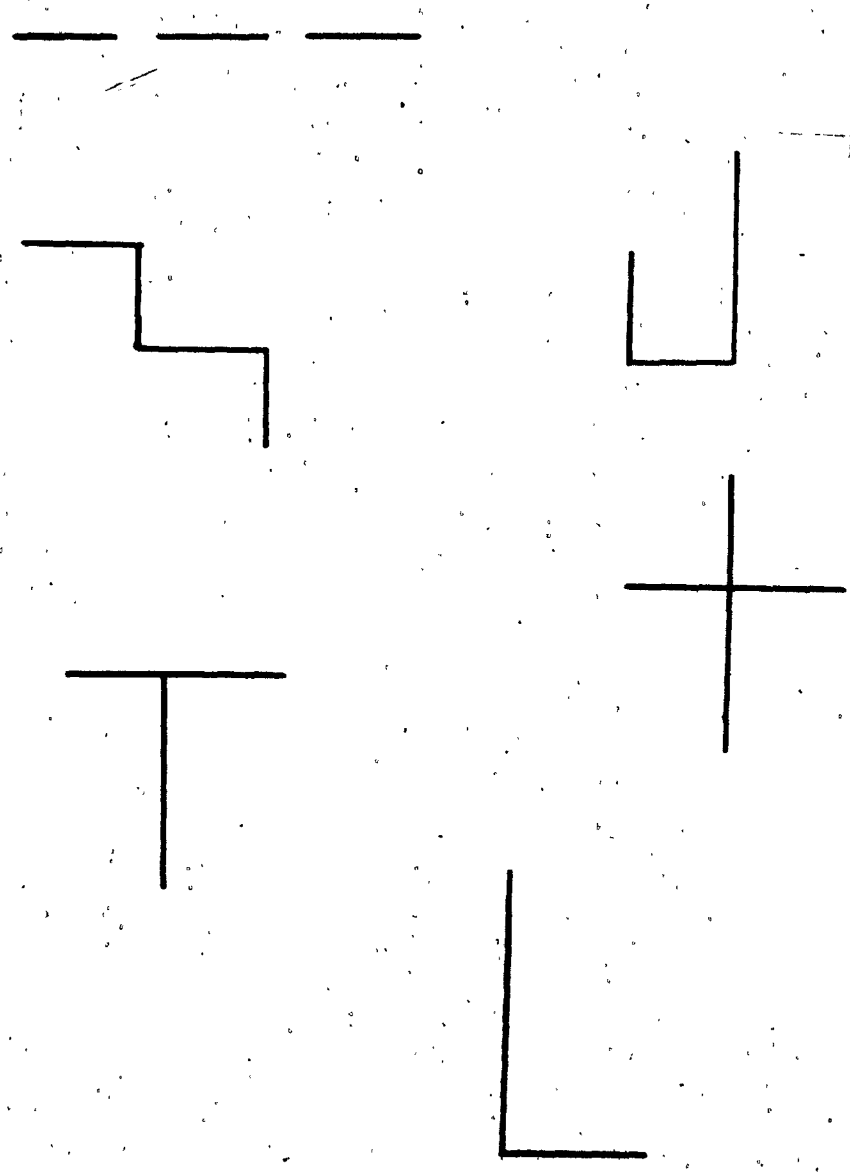
6. TYPE . . .

CS	RETURN
FD 50	RETURN
LT 45	RETURN
FD 50	RETURN
HOME	RETURN

7. TYPE . . .

CS	RETURN
___ ___	RETURN
___ ___	RETURN
___ ___	RETURN
___ ___	RETURN

ACTIVITY 3



SPECIAL KEYS

?	Start Typing
←	Erase Key
RETURN	Cursor (Blinking Light) goes to starting position
SHIFT	When held down, types top characters on keys
CTRL / CONTROL	When held down, allows you to use letter keys for special functions
SPACE BAR	Moves one space forward

Screen Modes/Drawing Mode

CONTROL L ____________________ only picture on screen

T ____________________ only words on screen

S ____________________ picture and words on screen

Colour

SETBG __________

SETPC __________

0 ____________________

1 ____________________

2 ____________________

3 ____________________

4 ____________________

5 ____________________

MAKING PROCEDURES

-Using the TO command :

For example, writing a procedure for a square, you would type:

```
? To SQUARE      <------  To Title
  FD 40
  RT 90
  FD 40
  RT 90
  FD 40          <------  Steps of Procedure
  RT 90
  FD 40
  END            <------  Ends the Procedure
```

-The Monitor will say: SQUARE defined (This message means that you have now taught the turtle how to draw a square).

-ER " or ERASE " : Erases the memory of the SQUARE procedure you have defined, so that you may use that name for a different square.

For Example: TYPE

ER "SQUARE

-SQUARE can also be defined in a different way for example:

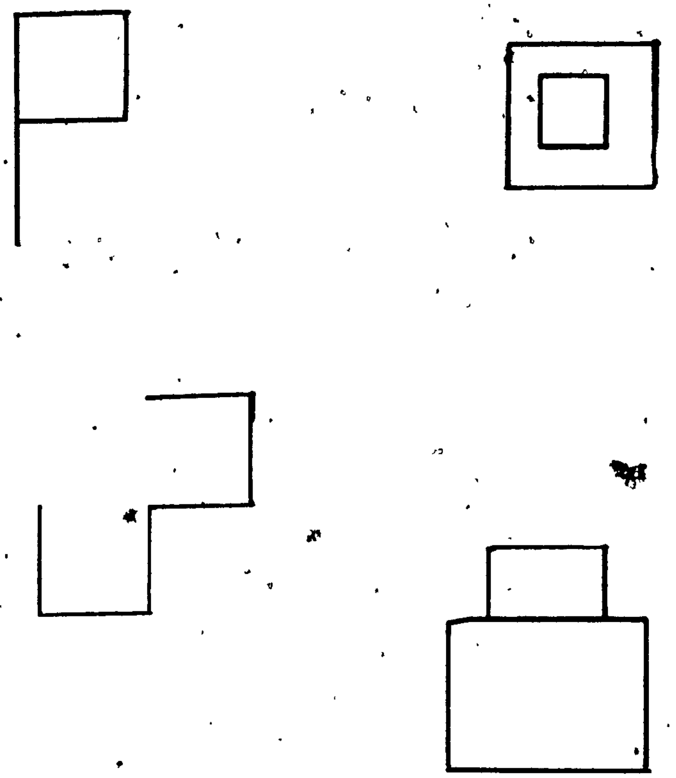
```
? To SQUARE
> Repeat 4 [FD 40 RT 90]
> End
```

-The square can be used as a command over and over. Try this:

```
? SQUARE
FD 10
SQUARE
```

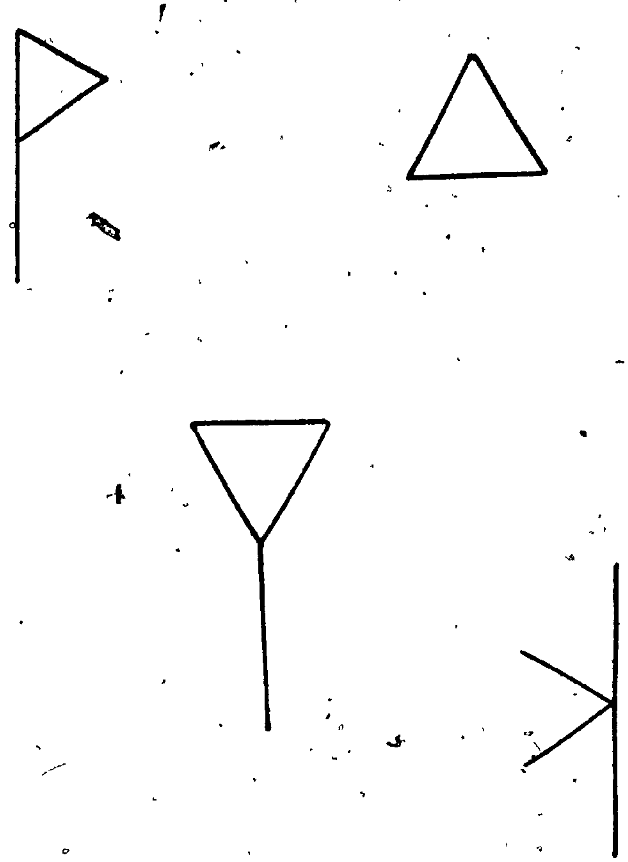
-Experiment with SQUARES

BUILDING SHAPES 1



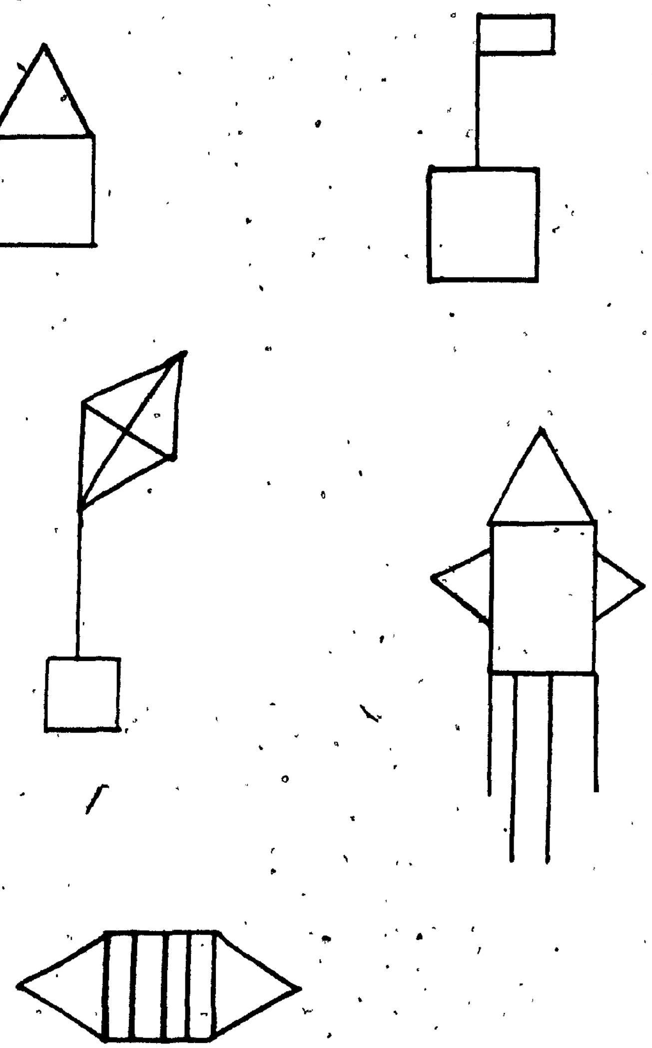
Now make some procedures on your own using the commands you know.

BUILDING SHAPES 2



Now make some procedures on your own using the commands you know

BUILDING SHAPES 3



Now make some procedures on your own using the commands you know.

EDITING PROCEDURES

-Making changes or fixing problems is called EDITING

To enter the Logo Editor type:

ED " ________________ ⟵ Title of Procedure

To correct a mistake press the arrow ⟶

over each correct character until you get to your mistake

Go over the mistake then press the left arrow ⟵

this erases your error

Now type the correct character

Press CONTROL / CTRL > C — When you are finished EDITING (this brings you back to the drawing mode)

-Control Keys

Outside/Inside Editor

CONTROL

A ________________

B ________________

D ________________

E ________________

F ________________

K ________________

G ________________

Only Inside Editor

CONTROL

N ________________

O ________________

P ________________

C ________________

SAVING PROCEDURES

1. Type:

   [CONTROL] T

   POTS

2. Erase the procedures you do not need by typing,

   ER "________ ← NAME OF PROCEDURE

3. Type:

   SAVE "________ ← TYPE IN THE FILE NAME YOU WISH TO USE

4. Type:

   CATALOG -To check if what you have saved is on your file diskette; Before turning off the computer

*THE NEXT TIME YOU TURN ON THE COMPUTER

Type:

CATALOG

LOAD "________ ← Logo loads the file you saved on your diskette into the computer's workspace

MANAGING YOUR WORKSPACE

As you interact with the turtle and define procedures with Logo, Logo puts these NEW procedures in your computer's workspace.

WORKSPACE

To see what is in your workspace you may use three commands:

POTS

POPS

PO "

POTS -Prints out all the Procedures in your workspace.

POPS -Prints out the Commands of all the Procedures in your workspace.

PO " -Prints out each Individual Procedure and its Commands.

ER "
ERASE " — - Erases Procedures from the workspace (see Making Procedures worksheet).

ERASEFILE " - Erases Files saved on a diskette.

ERALL - Erases ALL PROCEDURES from the workspace

CATALOG - Displays a List of all the Files on a diskette

-<u>VARIABLES</u>: - SIDE

SIZE

The character, : (colon), informs Logo, that the word to which it is prefixed names a container which can have in it a number, or another word.

For Example : Lets make <u>different size SQUARES</u>.

Using the Editor, change the SQUARE procedure by typing,

```
TO SQUARE :SIZE

FD :SIZE

RT 90

FD :SIZE

RT 90

FD :SIZE

RT 90

FD :SIZE

END
```

- Once SQUARE is defined, experiment with the procedure.

-VARIABLES CON'T

-POLY

You can vary the number of STEPS turtle makes.

You can vary how much it TURNS

The following procedure takes two inputs:

- -number of steps
- -amount of turn

```
TO POLY   :STEP   :ANGLE
FD   :STEP
RT   :ANGLE
POLY   :STEP   :ANGLE
END
```

Try this,

```
POLY   30   90
POLY   30   120
POLY   30   60
POLY   30   72
POLY   30   40
```

-Now change - the number of steps

- the amount of the turn

SPIRALS

- The POLY procedure makes the turtle draw closed figures

  The turtle draws closed figures because it goes forward and rotates a fixed amount and it eventally gets back to where it started.

- The turtle will draw a Spiral by increasing its forward step on each round of the procedure.

- We will change POLY to SPI and make a spiral procedure.

Try this,

```
ED "POLY
```

Now change the name of the procedure from POLY to SPI (thus making a spiral drawing).

Changing the recursion line,

tell SPI to ADD 2 steps to :STEP

Thus,

```
TO SPI :STEP :ANGLE
FD :STEP
RT :ANGLE
SPI :STEP + 2 :ANGLE
END
```

- Now Try SPI

```
SPI 5 90
SPI 5 120
```

*Try SPI with other inputs

TURTLE DRAWS ARCS

-Many projects require only pieces of a circle. For these cases you may use:

ARCR (ARC RIGHT)

ARCL (ARC LEFT)

These procedures need two inputs:

RADIUS of the circle

NUMBER of degrees of arc

-Try this,

Load "STARTUP (Startup is a file, which already has definitions for some procedures such as CIRCLER, CIRCLEL).

ARCR 30 90

ARCR 30 90

-Use the Arc procedures to make a fish.

-Make -Petals

-Flowers

-Swans

(For these projects you will need other procedures such as:

-REPEAT

-SIDE

WRAP, FENCE, WINDOW

-WRAP

The turtle can Walk OFF one edge of the screen and on at the opposite edge. It does not change direction.

Type: CS

FD 50

PR POS

* Logo responds

0.20.

Notice That the turtle is 20 steps and not 500 steps from the centre.

-FENCE

Boundaries can be set up so that the turtle cannot move off the screen.

Type: FENCE

CS

FD 500

* Logo responds

Turtle out of bounds

The turtle will act this way until you type: WRAP

-WINDOW

Allows turtle to move off the screen, but the turtle does not wrap (Turtle might be invisible to you but it is still carrying out your orders).

Type:

CS

WINDOW

FD 500

PR POS

* Logo responds 0.500

TRY using SPI after typing FENCE
WINDOW
WRAP

```
CS
FENCE
SPI 5 125 2

CS
WINDOW
SPI 5 125 2
```

Interrupt SPI by typing CONTROL G

```
CS
WRAP
SPI 5 125 2
```

THE TURTLE'S FIELD

- Turtle has a Position and a Heading

  Heading - Degrees (like a compass reading with 0 or North at the top of the screen).

- When the Turtle starts up its heading is Ø

- After CS Turtle has a heading of Ø

Try:

RT 90

PRINT Heading

* Logo responds ____________

Heading states the turtle's direction (it does not make something happen).

Position is described by 2 numbers, which indicate how far turtle is from the centre of the screen.

Position at the start is [Ø Ø]

horizontal or x axis — vertical or y axis

If the turtle is west or south of the centre, the number will be prefixed by a - (minus sign).

For Example: Type

LT 99

FD 30

PRINT Pos (POS is the short name for position)

* Logo responds

-30.0.

The turtle is 30 steps west of the centre along the horizontal.

BK 60

PRINT POS

* Logo responds

30.0.

Now the Turtle is 30 steps east of the centre along the horizontal.

RT 90

FD 52

PRINT POS

* Logo responds

30.52.

The Turtle is 30 steps east of the centre and 52 steps north of the centre.

Now Type:

BK 104

PRINT POS

* Logo responds

30. -52.

The Turtle is now southwest of the centre 30 steps east and 52 steps south.

APPENDIX C

THE DATA OBTAINED

SUBJ. NO.	GRADE	GROUP	PRE	POST	SEX	AGE
01	4	1	60	21	1	10
02	4	1	95	87	0	10
03	4	1	74	79	0	10
04	4	1	80	88	0	10
05	4	1	100	94	1	10
06	4	1	65	91	1	10
07	4	1	78	75	1	10
08	4	1	84	97	1	10
09	4	1	84	93	0	10
10	4	1	82	90	1	10
11	4	0	58	42	1	10
12	4	0	90	85	0	10
13	4	0	95	87	1	10
14	4	0	94	97	0	10
15	4	0	68	86	0	10
16	4	0	84	81	1	10
17	4	0	92	79	0	10
18	4	0	83	80	0	10
19	4	0	90	83	0	10
20	4	0	89	98	1	10
21	5/6	1	84	71	0	11
22	5/6	1	82	86	0	11
23	5/6	1	38	15	0	11
24	5/6	1	17	22	1	12
25	5/6	1	87	85	1	11
26	5/6	1	07	19	0	12
27	5/6	1	80	08	1	11
28	5/6	1	87	78	1	11
29	5/6	0	33	23	1	11
30	5/6	0	63	24	1	11
31	5/6	0	96	89	0	11
32	5/6	0	88	104	1	11
33	5/6	0	75	24	0	11
34	5/6	0	31	07	0	11
35	5/6	0	93	89	1	12
36	5/6	0	24	26	0	12

Note. GROUP : 1 = EXPERIMENTAL
0 = CONTROL

SEX : 1 = FEMALE
0 = MALE

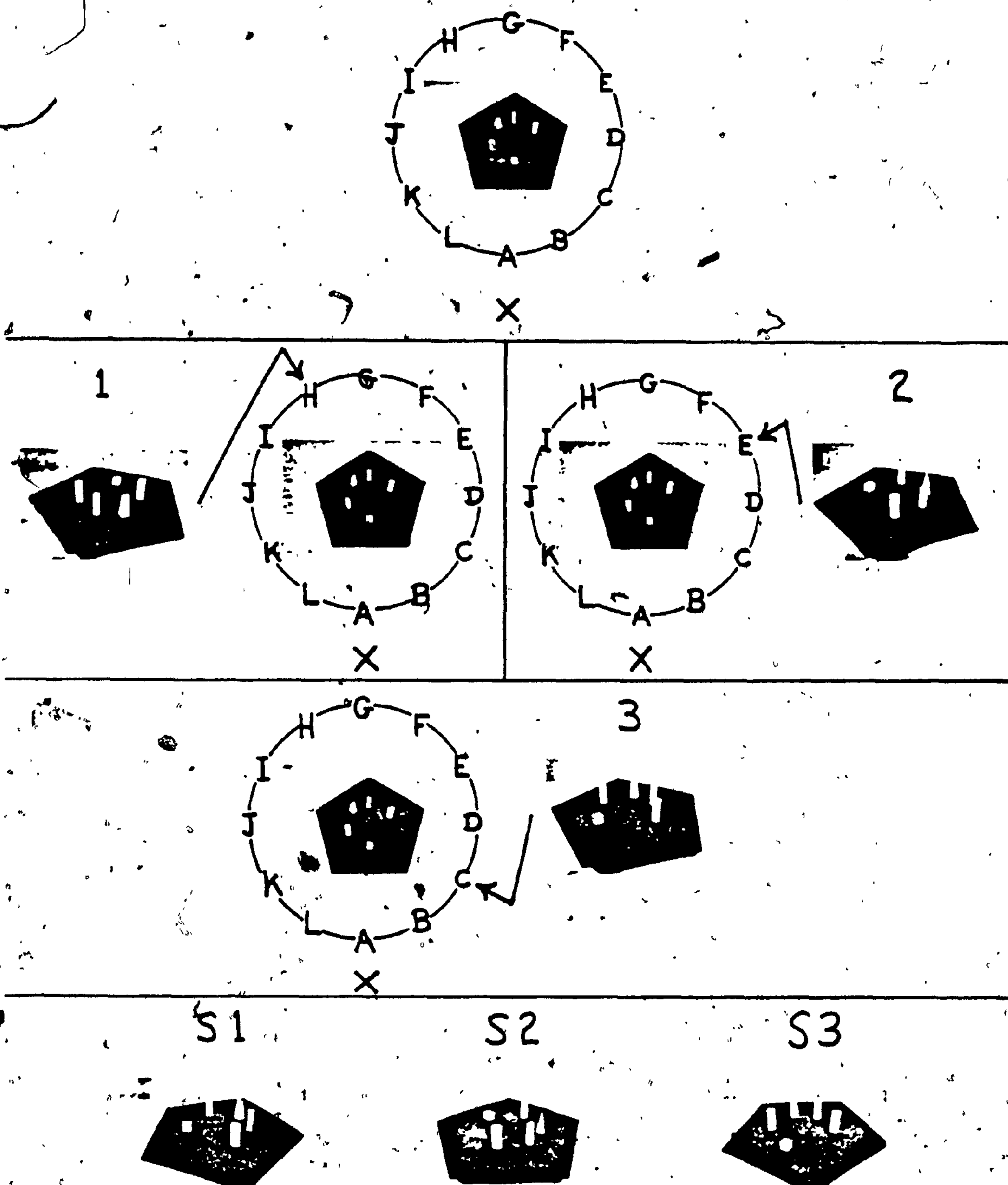
APPENDIX D

ELIOT - PRICE TEST

PLEASE DO NOT MARK THIS BOOKLET. DO NOT OPEN UNTIL SIGNAL IS GIVEN. USE YOUR ANSWER SHEET

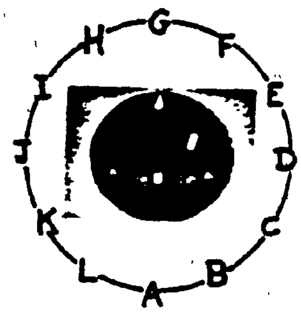
Eliot-Price Spatial Test

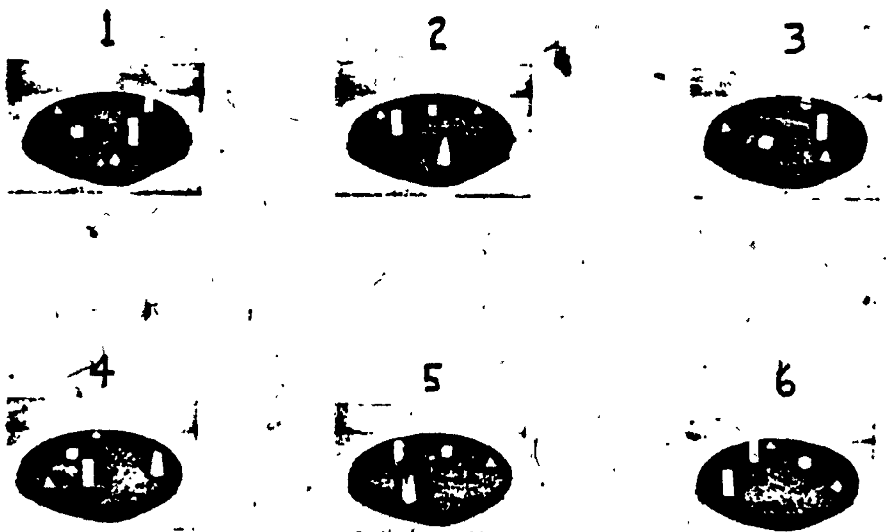
PART D



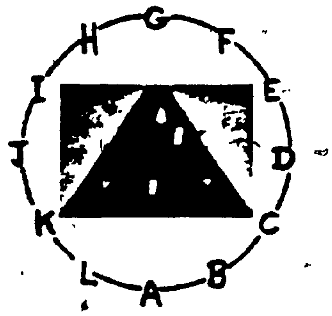
WAIT BEFORE YOU TURN THE PAGE

Eliot-Price Spatial Test





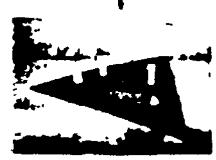
Eliot-Price Spatial Test



7

8

9

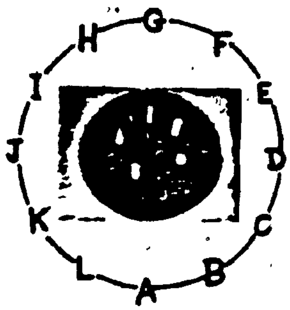


10

11

12

Eliot-Price Spatial Test



13

14

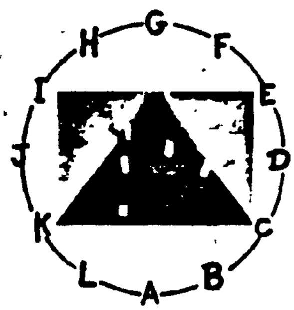
15

16

17

18

Eliot-Price Spatial Test



19

20

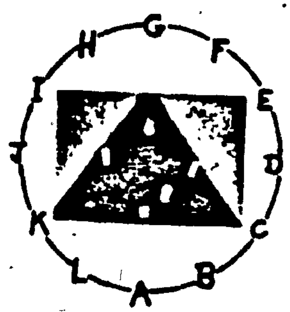
21

22

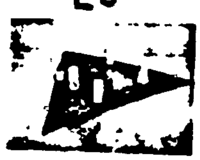
23

24

Eliot-Price Spatial Test

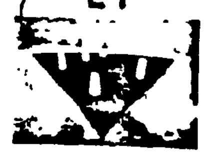


25



26

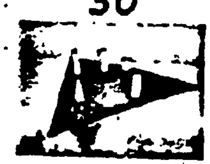
27



28

29

30



____________ Name ____________

Section ____________

Eliot-Price Spatial Test   Answer Sheet

PART D

Examples:	S1	A	B	C	D	E	F	G	H	I	J	K	L
	S2	A	B	C	D	E	F	G	H	I	J	K	L
	S3	A	B	C	D	E	F	G	H	I	J	K	L
Items:	1.	A	B	C	D	E	F	G	H	I	J	K	L
	2.	A	B	C	D	E	F	G	H	I	J	K	L
	3.	A	B	C	D	E	F	G	H	I	J	K	L
	4.	A	B	C	D	E	F	G	H	I	J	K	L
	5.	A	B	C	D	E	F	G	H	I	J	K	L
	6.	A	B	C	D	E	F	G	H	I	J	K	L
	7.	A	B	C	D	E	F	G	H	I	J	K	L
	8.	A	B	C	D	E	F	G	H	I	J	K	L
	9.	A	B	C	D	E	F	G	H	I	J	K	L
	10.	A	B	C	D	E	F	G	H	I	J	K	L
	11.	A	B	C	D	E	F	G	H	I	J	K	L
	12.	A	B	C	D	E	F	G	H	I	J	K	L
	13.	A	B	C	D	E	F	G	H	I	J	K	L
	14.	A	B	C	D	E	F	G	H	I	J	K	L
	15.	A	B	C	D	E	F	G	H	I	J	K	L
	16.	A	B	C	D	E	F	G	H	I	J	K	L
	17.	A	B	C	D	E	F	G	H	I	J	K	L
	18.	A	B	C	D	E	F	G	H	I	J	K	L
	19.	A	B	C	D	E	F	G	H	I	J	K	L
	20.	A	B	C	D	E	F	G	H	I	J	K	L
	21.	A	B	C	D	E	F	G	H	I	J	K	L
	22.	A	B	C	D	E	F	G	H	I	J	K	L
	23.	A	B	C	D	E	F	G	H	I	J	K	L
	24.	A	B	C	D	E	F	G	H	I	J	K	L
	25.	A	B	C	D	E	F	G	H	I	J	K	L
	26.	A	B	C	D	E	F	G	H	I	J	K	L
	27.	A	B	C	D	E	F	G	H	I	J	K	L
	28.	A	B	C	D	E	F	G	H	I	J	K	L
	29.	A	B	C	D	E	F	G	H	I	J	K	L
	30.	A	B	C	D	E	F	G	H	I	J	K	L

APPENDIX E

Table 1

Summary of Spatial Visualization and Spatial Orientation Factor Symbols and Descriptions

Investigator	Spatial visualization factor		Spatial orientation factor	
	Symbol	Description	Symbol	Description
Guilford and Lacey, (1947)	V	An ability to imagine the rotation of depicted objects, the folding or unfolding of flat patterns, the relative changes of position of objects in space, the motion of machinery. This visualization factor is strongest in tests that present a stimulus pictorially and in which some manipulation or transformation to another visual arrangement is involved.	SR	An ability to determine relationships between different spatially arranged stimuli and responses and the comprehension of the arrangement of elements within a visual stimulus pattern.
Thurstone (Note 1)	S_2	An ability to visualize a configuration in which there is movement or displacement among the internal parts of the configuration.	S_1	An ability to recognize the identity of an object when it is seen from different angles or an ability to visualize a rigid configuration when it is moved into different positions.
			S_3	An ability to think about those spatial relations in which the body orientation of the observer is an essential part of the problem.
French (1951)	V_i	An ability to comprehend imaginary movements in three-dimensional space or the ability to manipulate objects in the imagination.	S	An ability to perceive spatial patterns accurately and to compare them with each other.
			SO	An ability to remain unconfused by the varying orientations in which a spatial pattern may be presented. Dimensionality is less important to the factor than the rotational position of presentations.
Ekstrom, French, and Harman (Note 3)	VZ	An ability to manipulate or transform the image of spatial patterns into other arrangements; requires either the mental restructuring of a figure into components for manipulation or the 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 to objects in space; requires that a figure be perceived as a whole.

Note. Adapted from Michael, Guilford, Fruchter, and Zimmerman (1957, Table 1, p. 188).

Note. From "Human Spatial Abilities: Psychometric studies and environmental, genetics, hormonal, and neurological influences" by Mark McGee, Psychological Bulletin, 1979, 86, 889-918.