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Pointing behaviors of preschoolers during logo mastery

Brinkley, Vickie McCann, Ph.D.
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U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

POINTING BEHAVIORS OF PRESCHOOLERS DURING LOGO MASTERY

by

Vickie McCann Brinkley

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Cursor pointing behavior was examined as a conceptual strategy used by preschoolers to guide their microcomputer manipulations. Thirty-eight 4- and 5-year old children, categorized by field independence/field dependence, were trained to an established criterion in Logo and then presented a series of Logo problems with a counterbalanced problem set in using three cursor types (standard triangular turtle cursor, cross-shaped cursor, and circular cursor). It was hypothesized that young children adopted an initial pointing strategy as the first of several developmental stages involved in Logo programming. Subjects were required to solve a sequence of Logo problems occurring equally within the four quadrants of a computer screen (upper-lower, right-left). Data were analyzed for keystrokes, errors, task closure, and task success by field dependence vs. field independence, treatment level, and quadrant.

Findings from a repeated measures ANOVA revealed significant keystroke effects for quadrant ($p = .0538$) and treatment ($p = .0307$). A similar repeated measures ANOVA for error differences showed a significant main effect for quadrant ($p = .0001$). Tukey's ad hoc comparisons showed a significant difference between upper left and lower left quadrants for keystrokes and between upper and lower quadrants for errors. The comparisons tests showed that

the triangular cursor was significantly different from the cross and circular cursor for keystrokes but not for errors. Means analyses showed the following: 1) Field independent subjects scored higher on task closure and task success than field dependents, 2) subjects scored the highest level of task closure and task success with the triangular cursor, second highest with the cross, and the poorest with the circular cursor, and 3) subjects scored higher on task closure and task success in the upper right quadrant, followed by the upper left, and lastly, by the lower left and right quadrants. Univariate analyses showed subjects used more RIGHT than LEFT turns, more FORWARD than BACK moves, and more BIG than SMALL steps.

It was concluded that subjects did use the cursor heading to point toward the desired destination. They used more right turns, forward and big steps, and performed more successful manipulations in the upper quadrants.

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CHAPTER I

BACKGROUND

LOGO, created by Seymour Papert at MIT, is a programming language for children. Because LOGO is simple, straightforward, and individualized, it often is touted as a programming language that can benefit all ages (Papert, 1980). However, for the past 20 years, researchers have debated the actual cognitive programming and transfer benefits for children who learn LOGO (Campbell, Fein, Scholnick, Schwartz & Frank, 1986; Clements, 1986; Clements & Gullo, 1984; Emihovich & Miller, 1986; Pea, Kurland, & Hawkins, 1985). Some have even debated the validity of using abstract microcomputer tasks with preoperational children (Brady & Hill, 1984). However, empirical evidence has shown that four-year-olds are able to learn LOGO syntax (the basic, primitive commands), which allows them to maneuver the "turtle" (LOGO cursor) via distance (FORWARD, BACK) and direction (RIGHT, LEFT) commands in its microworld (Brinkley & Watson, 1988; Clements, 1986; Miller & Emihovich, 1986, Shade & Watson, 1987; Watson, Lange, & Brinkley, in preparation). It seems unlikely, however, that preoperational children can master either the semantics or the cognitive concepts necessary to understand what rotating the "turtle" (i.e., 90 or 45 degrees) and then moving it FORWARD or BACK in the LOGO microworld means. The children are performing successfully, but research to date does not explain what level of cognitive strategy the young child is using to problem-solve the four 90 degree turns necessary to design a LOGO "box".

Recent research by Campbell et al. (1986), Clements and Gullo (1984), Emihovich and Miller (in press), Howard, Sheets, Ingles, Wheatley-Heckman, and Watson (1988), Myrick, Proia, Hatfield, and Watson (1988), Solomon and Perkins (1987), and Watson et al., (in preparation), has been undertaken to explore the process by which children learn to program in LOGO. Campbell et al. (1986) found that children tended to use more FORWARD than BACK steps, more RIGHT than LEFT turns, and more FORWARD steps than any other move in their LOGO manipulations. Watson et al. (in preparation) also found a preferred use of BIG FORWARD steps and RIGHT turns. It seems doubtful that children fully comprehend the reversible implications of the opposing LOGO commands (RIGHT/LEFT and FORWARD/BACK) despite their demonstratable skill executing commands in order to move the "turtle" in a given direction. Therefore, young children seem to perseverate on the FORWARD moves and RIGHT turns. However, young children's understanding may be related not only to their conception of the problem, but also to their individual learning strategies, i.e., Field Dependence-Independence (FDI).

FDI is conceptualized as being measured on a bipolar continuum (Kogan, 1983). Field dependence is defined as a global learning strategy, one which focuses on holistic processing incorporating both relevant and irrelevant information. Field dependent children are more person- than task-oriented and find restructuring tasks to be more difficult than their counterparts. Field independence is defined as an analytical learning strategy which focuses on and separates details and relevant information from the organized whole. Field independent children are object-oriented and perform better on tasks requiring spatial perspective taking and restructuring (Kogan, 1983; Witkin, Moore, Goodenough, & Cox, 1977). In other words, children in one category tend to think about and approach problem solving very differently than their counterparts. This suggests that there may be stylistic differences both in a child's perception of LOGO tasks and in mastery of specific required manipulations.

Campbell et al., (1986) hypothesized that kindergarteners were using a concentric circle conceptualization to organize and determine the direction and distance needed for moving the "turtle" cursor when problem solving. This method of manipulation would require that the child shed Piaget's notion of egocentricity and adopt the perspective of the "turtle". Perhaps instead of conceiving of the computer screen in oblique angles, children are using syntonic learning to problem solve, i.e., they are pointing the heading of the "turtle" in the direction of the target, and moving from that reference just as they often physically turn their own bodies in the direction of their focused attention (Papert, 1980). Papert (1980) defines syntonic learning as learning which is relevant and meaningful to an individual's sense of what is normal and important in his environment. Therefore, determining "turtle" heading by using body gestures (pointing, turning self, etc.) as directional cues is illustrative of syntonic learning (Papert, 1980).

To date little empirical research has been reported to explain the process by which preoperational children master abstract microcomputer manipulations. Are they able to shed their egocentricity and take the perspective of the "turtle" to decide which direction and distance commands are needed? Or are they using another spatial developmental scheme in their processing? Is syntonic learning an important feature of this process? Further research is needed to resolve these question.

Purpose of Research

This study was designed to investigate the mental manipulations that preoperational children employ as they problem-solve in LOGO. Preschoolers who were enrolled in a university day care program and had spent the preceding six months in LOGO training exploring a series of pre-math and spatial development microworlds constituted the research sample. These children worked on age-appropriate LOGO problem-solving tasks twice weekly, and were skilled with software and the microcomputer manipulations. The proposed study (referred to in this experiment as the faces study) used a preprogrammed combination of LOGO (1982) and Sprite LOGO (1984) software which allowed the "turtle" cursor to take on a variety of different shapes (see Figure 1). The children (who were categorized by their FDI scores on the Preschool Embedded Figures Test (PEFT)) (Coates, 1972) used three different cursors on three consecutive days (one cursor per day) to reproduce the same four task card patterns on the computer screen. All tasks required 45 degree turns. The standard LOGO turtle's (isosceles triangle) heading changed direction to point toward the destination as instructed by the child using simple, basic LOGO commands. The Sprite LOGO cross-shaped cursor was also programmed to change heading. The shape of the cross ensured that there was always an arm pointing in the direction of any 45 degree angle the child chose (an inherently artificial heading). The circle, by definition, had no manipulable heading; therefore, rotation was not necessary. Unlike the cross, the circle could not be pointed. This design allowed for evaluation of whether the children were in fact using pointing strategies to problem solve in LOGO, and addressed learning strategy differences in task success, distance and direction preference, number of errors and keystrokes, and task closure.

Figure 1

Task success was conceptually defined as completing the task using less than the allotted 3.5 minutes of time per card with zero errors. Errors, keystrokes, RIGHT/LEFT turns, FORWARD/BACK steps, and BIG/SMALL steps were defined as a summated count across card and treatment levels. Rate of task closure was calculated by summing scores across task cards which the child completed during the study.

Literature was drawn from educational computing, stylistic differences, and spatial development sources and focused on the process issue. It was hypothesized that preschoolers would use syntonic learning to first point the "turtle" in the direction of the target destination and then continue to problem-solve by manipulating the "turtle" strictly from the direction of its focused heading rather than by thinking "RIGHT, FORWARD, etc." in any meaningful way.

Hypotheses

Within an experimental situation designed to explore the thinking process children use for manipulation in LOGO programming, the following was hypothesized:

1. There will be differences between treatment levels for total number of keystrokes.
2. There will be differences between treatment levels for total number of errors.
3. Young children will use the heading of the "turtle" to point in the direction of the target destination.
   a. They will have the most success and a higher rate of task completion with the standard isosceles triangular "turtle" cursor.
   b. They will have the next level of success and a lower rate of task completion with the cross-shaped "turtle" cursor.
   c. They will have the least success and the lowest rate of task completion with the circular "turtle" cursor.
4. Young children will use more RIGHT than LEFT turns.

5. Young children will use more FORWARD than BACK steps.
6. Young children will use more BIG than SMALL steps.
7. There will be a difference between learning strategies for total number of keystrokes.
8. There will be a difference between learning strategies for total number of errors.
9. There will be a difference in levels of success and task closure between field dependent and field independent children.
    a. Field independent children will be the most successful and complete the greatest number of the 12 problem-solving tasks.
    b. Field dependent children will be the least successful and complete fewer of the 12 problem-solving tasks.
10. There will be differences between quadrants for total number of keystrokes.
11. There will be differences between quadrants for total number of errors.
12. There will be differences in levels of success and task closure between quadrants.
    a. Children will have the most success and a higher rate of task closure in the upper right quadrant.

b. Children will have the next level of success and rate of task closure in the upper left quadrant.

c. Children will have the third level of success and rate of task closure in the lower right quadrant.

d. Children will have the lowest level of success and rate of task closure in the lower left quadrant.

<u>Limitations</u>

The non-random sample limited external validity. Generalizations should be restricted to similar university settings and children with similar LOGO experience.

Partial counterbalancing of treatment levels helped guard against testing and interaction of treatment effects. The homogeneous population helped guard against incorrectly accepting the null hypothesis (Type II error).

CHAPTER II

REVIEW OF THE LITERATURE

Microcomputers and LOGO

Much of the learning/teaching of the future will be done by microprocessed technology (Howard et al., 1988; Myrick et al., 1988). The educational use of microcomputers has already moved from graduate research in the 60's into the elementary and preschools in the 80's (Shade & Nida, 1983). It is important that children become familiar and comfortable with the technology in a non-threatening environment and that we as educators understand how children relate to computers. Therefore, the pro and con debates questioning the advisability of computer use have subsided. The debates are gradually being replaced with questions concerning the most age-appropriate classroom uses and the processes which children use to master the abstract operations required for computer interactions (Campbell et al., 1986; Clements & Gullo, 1984; Emihovich & Miller, in press; Howard et al., 1988; Myrick et al., 1988; Solomon & Perkins, 1987; Watson et al., in preparation).

Papert (1980) viewed LOGO microworlds as being a unique "context for learning", making LOGO more than just another programming language for children. Using LOGO, children have the advantage of being able to focus on and think about their thinking rather than simply producing outcomes (Emihovich and Miller, in press; Papert, 1980; Solomon & Perkins, 1987; Watson et al., in preparation). LOGO affords children the opportunity to explore problem-solving techniques according to their own individual learning strategy and competence level. Children are able to maneuver in terms of an Eucledian frame of reference (right, left, up, down, top, bottom, etc.) without really understanding the construct. In other words, LOGO microworlds allow the child to utilize an egocentric perspective and perform syntonic strategies to guide their computer manipulations (Papert, 1980).

Quadrant effects. Research has shown that children use FORWARD, RIGHT, and BIG moves more than others; FORWARD is used more frequently than all other moves (Campbell et al., 1986; Fay & Mayer, 1987; Gallini, 1987; Watson et al., in preparation). Although literature does not address quadrant effects per se, it is logical to assume that children using more FORWARD and RIGHT moves would be working more often and more successfully in the top right quadrant of the screen. Campbell et al., (1986) theorized that kindergarten children would have more control and flexibility if they would view the screen as a series of concentric circles rather than as a grid or rectangular coordinate system divided into quadrants.

However, Watson and his Children and Technology (CAT) colleagues at the University of North Carolina at Greensboro hypothesize that children's LOGO problem-solving skills may go through a progressive developmental sequence. According to Watson's hypothesis, children would use pointing behaviors (resulting in potential quadrant effects) as an initial stage in this developmental sequence. Campbell's (Campbell et al., 1986) concentric circle perspective would be a later stage in the sequence. Several current CAT research studies are addressing this quadrant issue (Watson, Lange, and Brinkley, in preparation; Easton & Watson, in progress; Rembert & Watson, in progress).

FDI

Learning strategies. The definition of a cognitive learning strategy is an aggregate of personality and mental characteristics that determine the way one reacts to various situations (Bennett, 1979; Saracho, 1984a; Witkin et al., 1977). FDI is a dimension of an individual's cognitive learning strategy: it identifies the strategy with which one thinks, remembers, and understands (Saracho & Spodek, 1981). FDI is a highly consistent and stable characteristic; however, it is amenable to change (Saracho, 1983, 1984b; Witkin et al., 1977). Literature reporting sex differences in FDI evidence conflicting results. Some studies have found that males tend to be slightly more field dependent than females (Coates, 1972; Coates, Lord, & Jackabovics, 1975; Watson et al., in preparation). Other studies have found males to be more field independent (McGilligan & Barclay, 1974; Witkin, Moore, Friedman, & Owen, 1976). Saracho (1983) hypothesized that age differences might confound sex differences.

Learning strategy differences. The most significant factor in children's school success may be the way they learn, or manipulate and process information (Dunn, Dunn, & Price, 1977; Saracho, 1984a). Field dependent learners are characterized by a visual, spatial, and holistic strategy (Holland, 1982; Kane, 1984; Saracho, 1983; Saracho & Spodek, 1981). Field dependents are often described as impulsive and/or "creative" problem solvers. Often, the field dependent "creative" approach does not lead to the most efficient or correct solution to traditional problems typically requiring convergent logic and answers (one right approach to a problem providing one correct solution) (Kane, 1984; Kogan, 1976, 1983; Watson et al., in preparation; Witkin et al., 1977).

Field independent learners are characterized by a verbal and detail-oriented strategy (Kane, 1984). Field independents seem to have an advantage within the traditional educational paradigm because schools seem to reinforce convergent thinking by definition (Kane, 1984; Kogan, 1976, 1983; Watson et al., in preparation; Witkin et al., 1977). Field dependent strategists (global thinkers) prefer group and open-ended learning while their field independent counterparts (analytic thinkers) prefer independent, impersonal, direct instructional methods. Field dependent learners need external reinforcement, but frequently ignore environmental cues, whereas field independent learners are intrinsically motivated and make good use of environmental cues (Holland, 1982; Kane, 1984; Saracho, 1983; Saracho & Spodek, 1981). All of these strategy differences influence the way a child approaches learning and problem solving.

Spatial Development Theory

Cognitive mapping is an inferred mental construct which depicts a person's internal spatial representations of the environment (Newcombe, 1981; Siegel, 1981). Both children and adults use cognitive mapping skills as they observe, act on, and move about both familiar and unfamiliar environments. Although cognitive mapping details differ between children and adults, the developmental sequence of cognitive mapping is the same for all ages (Siegel, 1981). The developmental sequence is an hierarchical ordering of landmarks (salient objects in the environment), routes (relationships between these landmarks), and configurations (integrations of routes that become frames of reference) (Anooshian, Pascal, & McCreath, 1984; Siegel, 1981; Siegel & White, 1975). Piaget (Piaget

& Inhelder, 1967) classified preschooler's stage of spatial development as topological. A topological perspective perceives spatial relationships egocentrically. Piaget (Piaget & Inhelder, 1967) theorized that preoperational children encode these visual cues or landmarks in a subjective relationship to self rather than in an objective relationship to other environmental objects. Associated cue learning is also important for young children as they develop spatial knowledge, i.e., use of gravitational cues to learn the difference between up and down, or associating the wearing of a watch on the left (or right) arm in differentiating between right and left (Wohlwill, 1981).

Hart (1981) hypothesized that children's spatial abilities are related not only to intellectual ability, but to such variables as "degree of access to the landscape and their freedom to manipulate it" (p. 195). Although Hart was specifically referring to explorations within geographic environments, one of the exceptional features and real advantages of LOGO is that it provides children with the opportunity to manipulate and control an abstract microworld environment (Lawler, 1982; Papert, 1980).

Children working with LOGO microworlds are operating on an abstract, small-scale environment [one which can be acted on or observed versus acted in or explored (large-scale environment)] (Siegel, 1981). There are no landmarks to serve as salient cues on the computer screen itself.

However, research has found that 3- and 4-year-old children navigate egocentrically when no reference landmarks are available (Acredolo, 1977). Therefore, young children interacting with the computer might be using egocentric, syntonic learning to draw on associated small-scale environmental cues when organizing problem-solving strategies. For example, children might focus first on a salient classroom object located in the direction that they wish to move the "turtle". Next children would rotate the "turtle" toward that object. Lastly, children would move the "turtle" along the desired route to the destination point. Using such a strategy, children would be combining microcomputer skills, individual learning strategies, syntonic learning, and basic spatial development skills to perform an abstract pattern replication task within a LOGO microworld.

CHAPTER III

METHODOLOGY

Subjects

Subjects were 40 male and female four- and five-year old children enrolled in the two university day care centers on the campus of the University of North Carolina at Greensboro. These children were from predominantly well-educated, professional families. Although this was a more select group than general day care populations, the expensive equipment, specialized software, and the pretrained sample necessitated use of this non-probability convenience sample. Some attrition was expected because of lack of parental permission and absences due to illness or travel.

Twenty-one children were enrolled in one center and 19 in the other. Two children did not participate in the study. One parent objected to structured computer use with preschoolers. Another parent failed to provide signed permission before the target starting date. Ages ranged from 3.42-6.21 years, with a mean of 4.91 years.

Children were categorized as either field dependent or field independent by a median split of PEFT scores. However, because of the structure of the group scores (range of 10-23), two extra children were placed in the field independent category. An actual median split would have placed 2 children with scores of 19 into the field dependent group and another 4 also with scores of 19 into the field independent group. Therefore, eighteen children were categorized as field dependent, and 21 as field independent. There were 13 field dependent and 8 field independent males and 5 field dependent and 12 field independent females respectively (see Table 1).

Design

The research design was a quasi-experimental repeated measures design. Children were categorized as either field dependent or field independent by the PEFT posttest scores administered at the conclusion of the preceding math/space curriculum study (Spring, 1988). The treatment levels (e.g. cursor type) were partially counterbalanced to control for pretraining practice effects. The three orders were as follows: 1) triangle, cross, circle, 2) cross, circle, triangle, and 3) circle, triangle, cross. To ensure equivalence, children within the FDI categories were randomly assigned to the three treatment orders. A repeated measures design was used to investigate within-subjects effects as related to treatment levels and quadrants.

Table 1

Crosstabulation for Subjects by Learning Style (2) and Sex (2)

	Learning Style FD	Learning Style FI	Row Total
Male	13	8	21 55.3
Female	5	12	17 44.7
Column Total	18 47.4	20 52.6	38 100.0

Variables of Interest

Independent Variables. The independent variables were cognitive learning strategy, treatment level, and quadrant. The learning strategy variable had the following two levels: field dependence and field independence. Treatment levels were comprised of triangular, cross-shaped, and circular cursor (see Figure 1). Quadrant levels referred to the following four areas of the computer screen: upper right, upper left, lower left, and lower right (see Figure 2).

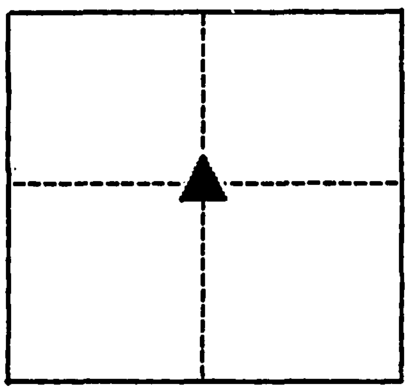


Figure 2

Note: "Turtle" HOME position in center of screen.

Dependent Variables. The dependent variables of interest were total number of keystrokes, errors, time, RIGHT and LEFT turns, FORWARD, BACK, BIG and SMALL steps, success, and task closure across all card and treatment levels. These dependent variables typically have been used in prior research which focused on tracking and comparing children's LOGO manipulations (Campbell et al., 1986; Fay & Mayer, 1987; Howard et al., 1988; Myrick et al., 1988; Watson et al., in preparation).

Success was operationally defined as completing the task in less than the allotted 3.5 minutes with zero errors. Task closure was operationally defined as a successful manipulation of the "turtle" from Point A to Point B (efficiency of route was not relevant here). Percentage of task closure was operationally defined as the percent of total tasks completed across all levels. Percentage of RIGHT turns was the percent of total turns (RIGHT and LEFT) which were RIGHT turns. Percentage of FORWARD steps was the percent of total steps (FORWARD and BACK) which were FORWARD. Percentage of BIG steps was the percent of the total steps (BIG and SMALL) which were BIG.

Prior LOGO Training

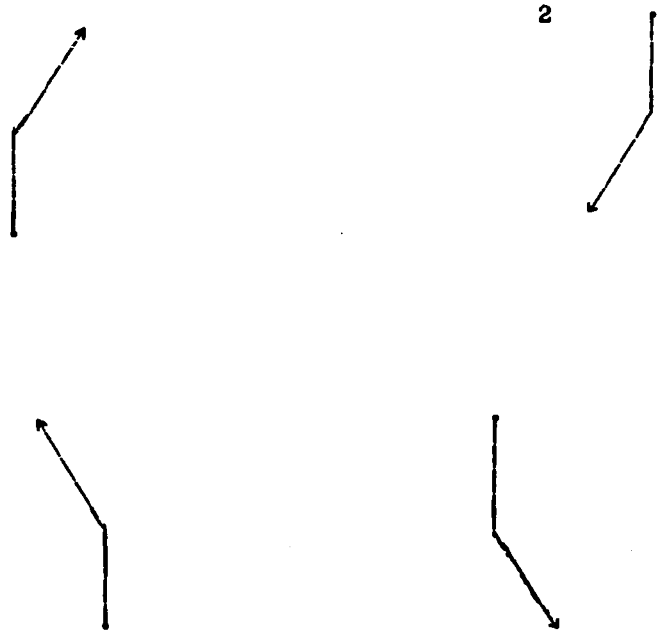
The children had completed a six month math/space curriculum study on April 7, 1988. They were taught the basic LOGO manipulations (FORWARD and BACK, RIGHT and LEFT, BIG and SMALL, clearing screen, hiding and showing turtle) also used in the faces study. Further training was not required. In the preceding study, the children had named

Figure 3. Introductory Training Task Card

Figure 4. Training Task Cards

1. 2

3.



Note: Dot indicates starting HOME position of "turtle" in center of screen. All angles represent 45° angles. Actual test cards had appropriate triangle, cross, or circle cursor instead of dot.

the triangular cursor "turtle" Tina Turtle. They had worked with Tina twice weekly.

The faces study began on Monday, May 9, 1988, four weeks after the curriculum study. The waiting period allowed all children to have a "wash-out" time. Otherwise, half the children would have proceeded directly from one study to the other while the other half would have been delayed two weeks without benefit of LOGO experiences.

Pretest

PEFT. Children were pre- and posttested before and after the prior curriculum study on the PEFT. The PEFT is a standardized perceptual disembedding test for measuring field dependent/independent learning strategies (Kogan, 1976, 1983; Saracho, 1984b; Watson et al., in preparation; Witkin, et al., 1977). PEFT scores range from 1-24. A median split divided scores into the two groups. The median split has one disadvantage: those children who scored just above or below the median might fall in the alternate category if tested with different children. Nevertheless, split-half and test-retest correlations (ranging from .74-.91 and .69-.75 respectively) have established acceptable reliability and stability for the PEFT (Coates, 1972; Kogen, 1983). The test also is accepted as having face, predictive, and construct validity (Coates, 1972; Saracho, 1984b; Kogan, 1983).

LOGO Expertise

As children were randomly assigned to treatment groups, covarying to control for initial individual differences was not necessary.

Observers

Two paid undergraduate students and the study coordinator served as observers. Because the students had worked as observers in the previous LOGO experiment, they were already thoroughly trained in setting up computers, LOGO use, and accurate scoring procedures. Observers were trained to load and start-up Sprite LOGO because several different commands were required. However, after start-up actual keyboard manipulations were the same as for LOGO. Each observer worked exclusively in one center.

Treatment Measure

A standard score sheet was used. On the score sheets, observers recorded a sketch of the child's chosen path for each separate task card, allowing for a detailed graphic review of precise mistakes, distance and direction manipulations, and an error count. A sequential log of all typed commands (correct and incorrect) served as a check on the pattern sketches. (Patterns could be reconstructed step by step from the log data.) Observers also recorded the following information for each task card in labeled columns: treatment level, card number, time, number of errors, and task completion (see Appendix A). Immediately following daily data collection, number of keystrokes, RIGHT and LEFT turns, BIG, SMALL, FORWARD, and BACK steps were tallied from the log data described above and recorded on the score sheet. This procedure kept actual observational scoring to a minimum of very precise information, reducing human error and ensuring higher data reliability.

Experimental Situation

The study was conducted in the regular classrooms. The necessary equipment was already an integral part of the class environment. Equipment included Apple IIe microcomputers (two with 64K memory and two with extended memory cards for 128K memory), dual disk drives, Amdec 12 inch color monitors, Apple LOGO software and Sprite LOGO interface card and software produced by Logo Computer Systems (1982, 1984). The children were acclimated to working with trained observer/teachers on various LOGO/CAI projects as a part of their daily schedule. Adding the Sprite LOGO board and software merely enhanced familiar LOGO capabilities. All other aspects computer interactions remained unchanged. Therefore, the faces study was merely a continuation of regular computer activities.

Procedures

Sampling procedure. The children were enrolled in the two four-year-old classes of the campus day care centers.

Letters describing the study and accompanying permission forms were sent to parents a few days before the target starting date of May 9, 1988 (see Appendix B). Completed forms were returned to the teachers and then collected by the experimenter.

Counterbalancing. All 38 children were divided into FDI categories by PEFT scores. As explained earlier, approximately half fell into each category. Children were randomly assigned by FDI to the three partially counterbalanced treatment orders. Counterbalancing reduced third variable effects and also guarded against testing and interaction of treatment effects (threats to internal validity).

Data collection. Training and testing were done individually. Training and treatment intervention occurred on four consecutive weekdays (Monday - Thursday). Friday served as a make-up day for children who had missed one day. Children missing more than one day were dropped. Data collection was done from 8:00 - 11:30 a.m. and 2:30 - 5:00 p.m. daily. Because only 10 children could be observed in one week (allowing for a half hour of turn-around time each morning), two weeks were required to complete data collection in each center. Half of the children were trained and observed the first week and the other half were trained and observed the following week.

Because the same Sprite LOGO interface board and software had to be shared by the two centers, data could not be collected concurrently. Instead, data collection at one center was completed and then the Sprite LOGO interface board and software were moved to the other center. Two computers (one for LOGO and one for Sprite LOGO) were used in each center.

Training was done on Mondays in 15 minute individual sessions. Each child was introduced to the three different "turtles" on the computer screen. Using an introductory training card, the observer then demonstrated manipulation of each of the "turtles" from their home (Point A) to the imaginary school (Point B) by the most efficient, direct route (see Figure 3). The child also performed the training task with each cursor. Treatment intervention (15 minutes per cursor) followed for three consecutive days (children worked with a different cursor each day according to the counterbalanced ordering). No children were forced to finish either a session or the study if they chose to withdraw.

Instructions to children. The children were asked to play a new game with Tina Turtle. Observers memorized and repeated the following script to each child before the daily session: "Tina wants to go from her home to her pretend school, but she needs your help. To make this game more interesting and fun for you, Tina is going to disguise or dress herself up in three different ways. On one of the days that we play the game, Tina will look just like the triangle she always has before. On another day, Tina will disguise herself as a cross. In the third disguise, Tina will look like a plain circle. Each day when Tina changes her disguise, you will have to help her find her way from home to school again by following a path like the one shown on the card propped up here on the computer. Remember that Tina wants you to show her the shortest path that she can take because she does not want to be late for school."

Treatment. The children completed the same four task cards (see Figure 4) for each of the three levels of the treatment (12 cards total). The task cards were 5 X 8 index cards with task patterns drawn on them. Cards were designed to achieve balance between the four screen quadrants (upper right, upper left, lower right, lower left), directions (FORWARD, BACK), and rotations (RIGHT, LEFT) (see Figure 4). A poster with written and graphic command reminders (i.e., RT accompanied by an arrow pointing right, FD accompanied by an arrow pointing forward) was positioned by the computer at the child's eye level to aid those children who needed help. The study purpose was not to test what children could remember about keying in commands nor to frustrate those who were insecure about it. The introductory task card was a direct route task. The other three task cards were slightly more difficult. Each of these required the child to reproduce a two-legged figure with one 45 degree angle (see Figure 4).

Task cards were propped above the keyboard and below the monitor in clear view. Cards were presented in the same order across all three treatment levels. Children worked individually on four cards per 15 minute session for each of the three treatment levels. Observers began timing as soon as they had positioned the task card and instructed the child to begin helping Tina find her way to the imaginary school. If a card was not completed in 3.5 minutes, the observer told the child that s/he had done a good job but it was time to try another card. Unfinished tasks were recorded as incomplete. If after two minutes a child had not even begun a task, the observer told the child that it was okay not to do that card. (It was expected that some children might not be able to manipulate the circle cursor.) The child then tried the next card. Each treatment level was completed (or terminated as described above) before moving to the next level the following day. It was important to keep intervention times brief due to the short attention span of four-year-olds (ensuring more reliable data unconfounded by fatigue and inattention).

Data Analysis

To test the hypotheses that no significant differences existed between FDI, treatment levels, and quadrants for total number of keystrokes, data were analyzed using a 2 (learning strategy) X 3 (treatment level) X 4 (quadrant) repeated measures ANOVA. The analysis tested for within-subject differences (treatment and quadrant levels) as well as between-subject differences (learning strategy) and interaction effects. Main effects and interactions from the unweighted means analysis (Type III) were evaluated (Keppel, 1982). Tukey's ad hoc comparison was performed to determine which means were significantly different for treatment and quadrant levels. A separate ANOVA was performed to test for significant differences on total number of errors.

The independent variables were learning strategy (field dependence and field independence), treatment level (triangle, cross, and circle cursors), and quadrant level (upper right and left, lower right and left). Dependent variables were task success, time, total number of keystrokes, errors, RIGHT and LEFT turns, BIG, SMALL, FORWARD, and BACK steps, and task closure.

A means comparison of the percentage of children who achieved success and task closure was used to compare quadrant, learning strategy, and treatment differences on these variables.

The ANOVAs and means analyses described above were sufficient to test the proposed hypotheses. It was hoped that results would provide empirical data supporting insightful explanations about the pointing behaviors of preschoolers during LOGO mastery.

CHAPTER IV

RESULTS

Description of Subjects

Of the original 40 subjects enrolled in the four-year-old classes at the two university centers, two did not participate in the study. One father objected to structured use of microcomputers with preschoolers. Another parent failed to return the signed permission form before the target starting date. During data collection, three subjects missed one day of treatment due to absences resulting in incomplete data. Another subject became distracted and frustrated, quitting on the final card of the last treatment level. Therefore, complete data were recorded for 34 subjects.

General Data Information

Preliminary univariate analyses of errors, time, and keystrokes showed an unanticipated problem for time. Number of errors and number of keystrokes were normally distributed variables and were included in ANOVAs. But due to a lack of variability, time scores showed extreme skewness.

Time ranged from 0-3.5 minutes. Examination of the histogram showed that subjects used the full 3.5 minutes of time on 236 of the 443 trials producing a ceiling effect.

From the experimenters' observations, providing extended time would not have benefited subjects who were not completing the tasks in the time allowed. In fact, observers reported that there was only one subject whom they felt confident would have completed the task if allowed a few more seconds.

It was decided that a simple summated score for RIGHT turns, FORWARD steps, and BIG steps would produce questionable data. For example, total number of RIGHT turns needed to be compared to total turns (RIGHT and LEFT) for clarity. Therefore, to evaluate the number of RIGHT versus LEFT turns a variable for percent of RIGHT turns was created (percent RIGHT turns = RIGHT turns/RIGHT turns + LEFT turns * 100). The same logic and formula was used to create percent variables for FORWARD steps and BIG steps.

The RIGHT, FORWARD, and BIG variables were by definition either/or forced choices. No variability was expected nor found in these univariate analyses. Because sample size was small (38 subjects) no other tests of significance were used to examine these variables. Very large numbers (hundreds) would be required for further analyses, and the nature of the study demanded the use of the available trained day care population.

Success was operationally defined as completing the task using less than the 3.5 minutes time allotment with zero errors. To control for those subjects who had zero errors on unsuccessfully completed tasks, those trials were coded as having one error. Task closure was operationally defined as a nominal, categorical variable: either children completed the task or they did not. A percentage of the success variable was created which grouped all subjects who had achieved success by the appropriate independent variable (learning strategy, cursor, quadrant) for the particular analysis in question. Percentage of task closure was computed similarly.

Analysis of Data

Hypothesis 1. It was hypothesized that there would be differences between treatment levels for total number of keystrokes.

A 2 X 3 X 4 repeated measures ANOVA (Keppel, 1982) was used to test for significant differences between learning strategies, treatment levels, and quadrants on keystrokes. The unweighted means analysis (Type III) showed no interaction effects. However, there was a significant main effect for treatment [F(2,2360=3.66, p=.0307]. The hypothesis was not rejected (see Table 2).

Tukey's post hoc comparison (alpha = .05) was used to determine which treatment means were significantly different from the others. The test showed that the triangular cursor was significantly different from those of

Table 2

<u>Repeated Measures Analysis of Variance Summary for Total Keystrokes (443) by Learning Strategy (2) by Treatment Level (3) by Quadrant (4)</u>

Source	df	SS	MS	F
FDI	1	11.2802	11.2802	0.67
Subject (FDI)	36	609.0899	16.9191	12.10
Quadrant	3	13.7933	4.5977	2.63*
Quadrant*FDI	3	0.9976	.3325	0.19
Subject*Quadrant (FDI)	108	188.8046	1.7481	1.25
Treatment	2	19.0257	9.5128	3.66**
FDI*Treatment	2	6.0000	3.0000	1.26
Subject*Treatment (FDI)	69	179.1104	2.5958	1.86
Quadrant*Treatment	6	8.7675	1.4612	1.04
Quadrant*FDI*Treatment	6	11.7617	1.9602	1.40
Quadrant*Treatment* Subject (FDI)	206	288.1586	1.3988	1.3988
Total	442	1336.7895		

Note: The table represents the unweighted means analysis (Type III).

*p=.0538

**p=.03

the cross and the circle (see Table 3). However, means of the cross and the circle cursors were not significantly different.

Hypothesis 2. There will be differences between treatment levels for total number of errors.

A 2 X 3 X 4 repeated measures ANOVA (Keppel, 1982) also was used to test for significant differences between learning strategies, treatment levels, and quadrants on number of errors. The unweighted means analysis (Type III) showed no interaction effects or main effect for treatment [$F(2,236)=1.14$, $p=.32621$] (see Table 4). The hypothesis was rejected.

Hypothesis 3. It was hypothesized that young children would use the heading of the "turtle" to point in the direction of the target destination.

a. Children would have the most success and a higher rate of task closure with the standard isosceles triangular "turtle" cursor.

A subject means examination (collapsed across cards and learning strategy) showed the triangular cursor tasks to be the most successful problem-solving category (18.61) (see Table 5). Subjects were familiar with this cursor from previous experience; therefore, they were expected to do better at this level. The triangular "turtle" cursor mean also showed a higher rate of task closure (25.00) for the triangular cursor (see Table 5). A means analysis

Table 3

Means for Keystrokes and Errors by Treatment (3)

Variable		Means	
Treatment Level	N	Keystrokes	Errors
Triangle Cursor	148	3.8815	2.0405
Cross Cursor	148	3.5202	2.0135
Circle Cursor	147	3.4013	2.2380

Table 4

Repeated Measures Analysis of Variance Summary for Total Errors (443) by Learning Strategy (2) by Treatment Level (3) by Quadrant (4)

Source	df	SS	MS	F
FDI	1	.0008	.0008	0.00
Subject (FDI)	36	366.0734	10.1687	6.69
Quadrant	3	57.3251	19.1083	8.39*
Quadrant*FDI	3	3.3556	1.1185	0.49
Subject*Quadrant (FDI)	108	246.0860	2.2786	1.50
Treatment	2	5.4958	2.7479	1.14
FDI*Treatment	2	6.9105	3.4553	1.43
Subject*Treatment (FDI)	69	166.5391	1.4136	1.59
Quadrant*Treatment	6	4.1157	0.6860	0.45
Quadrant*FDI*Treatment	6	7.3308	1.2218	0.80
Quadrant*Treatment*				
Subject (FDI)	206	312.9437	1.5191	1.5191
Total	442	1176.1765		

Note: The table represents the unweighted means analysis (Type III).

*$p \leq .0001$

Table 5

Means and Standard Deviations for Percentage of Subjects who Achieved Task Success and Task Closure by Treatment Level (3)

Variable	Mean	SD	N
Triangle Cursor			
Task Success	18.6111	16.7563	152
Task Closure	25.0000	19.8276	152
Cross Cursor			
Task Success	17.5000	16.3245	152
Task Closure	21.4181	10.2112	152
Circle Cursor			
Task Success	6.5972	8.2639	152
Task Closure	12.8289	12.6050	152

examination showed that both success and task closure was greatest for the triangular cursor, supporting the hypothesis.

b. Children would have moderate success and a lower rate of task closure with the cross-shaped "turtle" cursor.

A similar means examination (collapsed across cards and learning strategy) using the cross-shaped "turtle" cursor showed moderate success as predicted (17.50) (see Table 5). However, this mean was only one point lower than the mean for the triangular cursor. Moderate task closure also was shown with this cursor as predicted (21.42) (see Table 5). Therefore, results indicated that subjects were able to use this new cursor to point in the intended direction of movement. Children maintained almost as much control with the cross-shaped cursor as with the familiar triangular cursor. Again, a means comparison supported the hypothesis.

c. Children would have the least success and the lowest rate of task closure with the circular "turtle" cursor.

A subject means examination calculated for completed tasks when working with the circular cursor showed the lowest level of success (6.60) (see Table 5). The means analysis also showed that task closure was lowest for the circular cursor (12.83).

Hypothesis 4. It was hypothesized that children would use more RIGHT than LEFT turns.

An examination of the normal probability plot of the percent of RIGHT turns variable showed a ceiling effect due to lack of variability. An examination of the histogram clearly showed that the percent of RIGHT turns was greater than LEFT turns (167 to 111 respectively). Even though tasks were designed to address RIGHT and LEFT turns equally, children overwhelmingly chose RIGHT turns when confused or uncertain about how to perform the tasks. One of the interesting features of the LOGO software package is open-ended problem-solving potential: children who are uncertain about which direction to turn the cursor can choose RIGHT (or LEFT), and continue making RIGHT (or LEFT) turns until the cursor is manipulated (by circling) to point in the desired direction. For example, when the cursor heading is pointing straight up (HOME) and the desired goal is to point the heading 45 degrees to the LEFT, children have two choices. They can turn the cursor 45 degrees LEFT with one rotation, or instead they can turn the cursor 45 degrees RIGHT seven times. Either strategy will achieve the desired goal. Studies have shown that some children choose this longer alternative, especially when uncertain of most efficient manipulations. Data showed children in this study used some of the same problem-solving strategies, hence the greater percent of RIGHT turns; therefore, this hypothesis was supported.

Hypothesis 5. It was hypothesized that children would use more FORWARD than BACK steps.

A variable which examined the percent of FORWARD steps was created (percent FORWARD steps = FORWARD steps/FORWARD steps + BACK steps * 100). Again, the normal probability plot evidenced a ceiling effect due to lack of variability. The histogram showed extreme skewness, indicating that FORWARD steps greatly outnumbered BACK steps (215 to 69 respectively). It is important to refer to the strategies that children used to turn right to reach a goal on the left of the screen. A similar strategy also allowed them to move FORWARD in order to reach a destination on the bottom of the screen. Graphic data (an observer's recorded reproduction of the pattern drawn by the child) showed that subjects did not use this wrap-around strategy. Nevertheless, children were familiar with the reversible program features. Subjects seemed to prefer to go FORWARD when unsure about what to do; therefore, FORWARD steps outnumbered BACK as predicted in the hypothesis.

Hypothesis 6. It was hypothesized that children would use more BIG than SMALL steps.

Again, as in the above two hypotheses, it was decided that a variable that showed BIG steps in relation to total steps (BIG and SMALL) would be more meaningful than just a summation of total BIG steps; therefore, the percentage variable was created (percent BIG steps = BIG steps/BIG steps + SMALL steps * 100). Once more, the ceiling effect evidenced by the normal probability plot reflected lack of variability. The skewness of the histogram showed that very few SMALL steps were used at all (271 BIG to 41 SMALL). Most children seemed to realize that BIG steps were more efficient; therefore, the hypothesis was supported.

Hypothesis 7. It was hypothesized that there would be differences between learning strategies for total number of keystrokes.

The 2 X 3 X 4 repeated measures ANOVA (Keppel, 1982) testing significant differences between learning strategies, treatment levels, and quadrants on keystrokes was examined. Results did not support the hypothesis. Results from the unweighted means analysis (type III) showed no significant interaction effects or main effects for learning strategy [$F(1,236)=.67$, $p=.4196$] (see Table 2). Therefore, the hypothesis was rejected.

Hypothesis 8. It was hypothesized that there would be differences between learning strategies for total number of errors.

The 2 X 3 X 4 repeated measures ANOVA (Keppel, 1982) testing for significant error differences again was examined. The unweighted means analysis (Type III) showed no significant interaction or main effects for learning strategy [$F(1,236)=.00$, $p=.9932$] (see Table 4). Therefore, the hypothesis was not supported.

Hypothesis 9. It was hypothesized that there would be a difference in level of success and task closure between field dependent and field independent children.

a. Field independent children would be the most successful and complete the greatest number of the 12 problem-solving tasks.

An examination of the means of the success variable (collapsed across cards and treatment levels) by FDI showed a greater percent of field independent subjects had task success (14.58) (see Table 6). However, the difference between the two FDI groups was less than one point. Nevertheless, the actual means supported the hypothesis although the strength of a statistical difference was very doubtful.

A means analysis for percent of task closures (collapsed across cards and treatment levels) by FDI showed that field independent subjects completed the greatest percentage of the 12 tasks (23.37) (see Table 6). The means analysis supported the hypothesis.

b. Field dependent children would be the least successful and complete fewer of the 12 problem solving tasks.

Table 6

Means and Standard Deviations for Percentage of Subjects who Achieved Task Success and Task Closure by Treatment Level (2)

Variable	Mean	SD	N
Field Dependent			
Task Success	13.8888	14.8882	216
Task Closure	17.1296	17.3202	216
Field Independent			
Task Success	14.5833	15.2938	228
Task Closure	22.3684	18.7932	228

An examination of the same means table for the field dependent subjects showed that fewer in this group achieved task success (13.89) (see Table 6). Therefore, there was a visual examination difference in the task success levels of the field dependent and field independent subjects as predicted.

The same means analysis for percent of task closure (collapsed across cards and treatment levels) by FDI showed that field dependent children completed fewer of the 12 tasks than their FDI counterparts (17.13), supporting the hypothesis (see Table 6).

Hypothesis 10. It was hypothesized that there would be differences between quadrants for total number of keystrokes.

The 2 X 3 X 4 repeated measures ANOVA (Keppel, 1982) completed to test for significant differences between learning strategies, treatment levels, and quadrants on keystrokes supported this hypothesis. Again, examination of the unweighted means analysis (Type III) showed no significant interaction effects. There was a significant main effect for quadrant [$F(3,236)=2.63$, $p=.0538$)]; therefore, the hypothesis was supported (see Table 2).

Tukey's post hoc comparison (alpha = .05) was calculated to determine which quadrants were significantly different. Results showed a significant difference between upper and lower left quadrants (see Table 7). There were no significant differences between the other quadrants.

Hypothesis 11. It was hypothesized that there would be differences between quadrants for total number of errors.

The 2 X 3 X 4 repeated measures ANOVA (Keppel, 1982) was used to test for significant differences in number of errors between quadrants. Data supported the hypothesis. The unweighted means analysis (Type III) showed no significant interaction effects; however, there was a significant main effect for quadrant [$F(3,236)=8.39$, $p=.0001$)] (see Table 4).

Tukey's post hoc comparison (alpha = .05) was calculated to determine which quadrants were significantly different. Results indicated significant differences between the upper quadrants and the lower quadrants, but not between the upper right and left quadrants or between the lower right and left quadrants (see Table 7).

Hypothesis 12. It was hypothesized that there would be differences in levels of success and rate of task closure between quadrants.

a. Children would have the most success and a higher rate of task closure in the upper right quadrant.

The means analysis of the success variable (collapsed across FDI and treatment level) showed that subjects had the greatest level of success in the upper right quadrant (30.56) (see Table 8). Examination of means also showed

Table 7

<u>Means for Keystrokes and Errors by Quadrant</u>

Variable		Means	
Quadrant	N	Keystrokes	Errors
Upper Right	111	3.5225	1.8378
Upper Left	111	3.3963	1.6576
Lower Right	111	3.6090	2.5272
Lower Left	111	3.8828	2.3693

Table 8

Means and Standard Deviations for Percentage of Subjects who Achieved Task Success and Task Closure by Treatment Level (4)

Variable	Mean	SD	N
Upper Right Quadrant			
Task Success	30.5555	11.0442	111
Task Closure	35.9161	13.4355	111
Upper Left Quadrant			
Task Success	21.2037	12.3048	111
Task Closure	34.2105	10.3988	111
Lower Right Quadrant			
Task Success	2.5925	4.2552	114
Task Closure	4.4346	6.1623	114
Lower Left Quadrant			
Task Success	2.5925	2.8472	111
Task Closure	4.4346	3.9766	111

the highest rate of task closure in the upper right quadrant (35.92) (see Table 8). However the difference between upper right and upper left was less than two points, indicating very close levels of task closure. Nevertheless, the means analyses supported the hypothesis.

b. Children would have moderate success and rate of task closure in the upper left quadrant.

The means analysis showed subjects had a moderate level of success (21.20) and rate of task closure (34.21) in the upper left quadrant (see Table 8). Therefore, despite lack of a test for significance, a visual analysis of means supported the hypothesis.

c. Children would have next to the least success and rate of task closure in the lower right quadrant.

Identical means for success were shown for both lower right and lower left quadrants (2.60) (see Table 8). Task closure means also were identical in both right and left lower quadrants (4.43) (see Table 8); therefore, the hypothesis was not supported.

d. Children would have the least success and rate of task closure in the lower left quadrant.

Data cited in Hypothesis 12c. shown above also apply here; therefore, this hypothesis was not accepted.

CHAPTER V

DISCUSSION

General Findings

Papert (1980) introduced LOGO nine years ago, stating that it was a powerful, innovative educational tool. Debate about processing skills and strategies that young children employ in LOGO mastery has ensued. To date, there are few empirical studies found in the literature concerned with children's processing skills and strategies. This study was an effort to resolve some of these questions. Results supported Papert's prediction that children demonstrated syntonic behaviors (pointing) as a LOGO learning strategy. Research shows that young children use landmarks in their initial mastery of spatial development (Anooshian et al., 1984; Siegel, 1981; Siegel & White, 1975). Children proceeded from one familiar landmark to another, physically pointing their bodies in the direction of the next landmark in their progression. Problems arose when landmarks were obscure or absent as on the computer screen. Some researchers felt that this abstract feature would impede preoperational children's interactions with computers (Barnes & Hill, 1983; Brady & Hill, 1984). This study provided evidence that children simply adapted their egocentric spatial abilities to computer problem-solving tasks. The shape of the cursor and its position and/or heading on the screen determined the success of their syntonic problem-solving strategies.

Hypotheses 1 and 2.

Results showed a significant treatment effect for number of keystrokes ($p = .0307$). The triangular cursor produced significantly different child responses from the cross-shaped and circular cursors. However, there was no significant keystroke response difference between the cross-shaped and circular cursors. The familiarity of the triangular cursor is the most probable explanation for the significant difference. The cross and circular cursors required more trial and error explorations during problem-solving and hence more keystrokes. The lack of significant differences between the cross and the circle cursors is probably related to the quadrant effects discussed in Hypotheses 10, 11, and 12. Children were able to use the arm of the cross as a pointer to help them problem solve in the upper quadrants. However, problem-solving tasks in the lower quadrants were much more difficult even with the familiar triangular cursor. Any benefit from their egocentric spatial abilities was invalidated when children attempted to problem-solve in the lower quadrants. The success the children achieved pointing the cross-shaped cursor to problem-solve in the upper quadrants was diminished by the number of trial and error manipulations employed in the lower quadrant. Therefore, there was no overall evidence of a significant difference in the number of keystrokes between the cross and the circular cursors.

There were no significant differences between treatments for number of errors (p = .3262). When children made errors (both typographical and logistical distance/directional miscalculations), they realized their mistakes and recovered with correct moves more frequently with the triangular cursor. Errors made with the other cursors were more confusing to the children. Unsuccessful recovery attempts often involved a great deal of hit-and-miss manipulations resulting in significantly more keystrokes with the cross and circular cursors. In other words, it took fewer keystrokes to recover from errors made with the triangular cursor than from errors made with the cross-shaped and circular cursors. This explains why the triangular cursor showed a significant keystroke difference but not a significant error difference. The familiarity of the triangular cursor did not prevent errors, but it was an advantage in recognizing and correcting those errors.

Hypotheses 3a., 3b., and 3c.

As was predicted, children used the heading of the "turtle" to point toward the target destination. Children had the highest level of success (mean = 18.61) and rate of task closure (mean = 25.00) with the familiar triangular cursor, moderate success and rate of task closure (mean = 21.42) with the cross-shaped cursor, and the least success (mean = 6.60) and rate of task closure (mean = 12.83) with the circular cursor. However, differences in levels of success and rate of task closure for the triangular and cross-shaped cursors were very slight. Although the cross did not have as clear a heading as the triangle, there was an artificial heading in its pointing arms. Children adopted an arm as the heading and manipulated the cross by pointing. The children turned the designated arm (artificial heading) toward the target destination and then moved FORWARD as with the triangle. The circle by definition had no heading. As expected, the children had great difficulty manipulating the circular cursor. Without a heading to point and guide them, children became very confused and frustrated with the task.

It is very difficult for a young child to adopt the turtle's perspective, i.e., to understand that a RIGHT command refers to the turtle's right which is not necessarily the child's right (Cuneo, 1985). Even children who do not know left from right know that they can problem-solve by pointing with their body and then manipulating the "turtle" in that direction. It is when the heading of the "turtle" is not congruent with their own egocentric perspective (i.e., lower quadrants) that these pointing behaviors failed them as an effective problem-solving strategy. This pointing behavior is a clear and conventional form of communication for children and they use it to great advantage (Herman, Shiraki, & Miller, 1985). Instead, relying on pointing behaviors in the lower quadrants confused and frustrated their problem-solving efforts. Fay and Mayer (1987) argued that these egocentric conceptions and confusions about spatial reference that children bring to LOGO conflict with the requirements of LOGO mastery. The pointing behaviors demonstrated in the faces study supported this argument.

Campbell et al., (1986) hypothesized that children are more successful and flexible when taught to perceive the computer screen as concentric circles instead of a grid with quadrants. However, evidence from this study supports the argument that the pointing strategy is a first stage in a developmental sequence of young children's processing skills (Watson, in preparation). The fact that children were much less successful with the circular cursor than the familiar triangle or the new cross-shaped cursor with its clear heading is strong support for the pointing strategy as an early processing skill in LOGO mastery. Problems arose when children's egocentric spatial skills were inappropriate (i.e., lower quadrants) or nonadaptable (i.e., circular cursor with no heading).

Hypotheses 4, 5, and 6.

Univariate analyses showed that children used FORWARD (N = 215), RIGHT (N = 167), and BIG (N = 271) more frequently than BACK (N = 69), LEFT (N = 111), and SMALL (N = 41) commands collaborating past research findings (Campbell et al., 1986; Fay & Mayer, 1987; Mayer & Fay, 1987; Gallini, 1987; Watson et al., in preparation). FORWARD required less cognitive skill for a child to understand. The FORWARD command moved the "turtle" straight ahead regardless of its initial angle of rotation or starting position of the screen. FORWARD required no mental calculations to understand resulting consequences. Fay and Mayer (1987) found that even fourth to eighth grade children continue to perceive FORWARD to be easier than all other commands.

Past research has shown that direction commands are more difficult than distance commands (Campbell et al., 1986; Fay & Mayer, 1987; Gallini, 1987; Mayer & Fay, 1987; Watson et al., in preparation). Preschooler's spatial relationship abilities are not well developed in either small- or large-scale environments (Hazen, Lockman, & Pick, 1978; Herman et al., 1985). Children relied on their egocentric perspective to compensate for their deficiencies in spatial ability. RIGHT rotations were probably used more because we live in a right-handed world. RIGHT moves logically should have been easier with which to identify. Observations indicated that when children were uncertain about correct directional rotation, they were more likely to choose RIGHT than LEFT moves. In fact, studies have shown that children often choose to use multiple RIGHT rotations as the method for achieving a destination that could be achieved more efficiently with a single LEFT rotation (Watson et al., in preparation).

Observers reported that BIG steps were used more frequently than SMALL steps. Children quickly realized that BIG steps required less time and fewer keystrokes. Children often tried SMALL steps only once and then never used them again. The exception was children who were very uncertain about the appropriate problem-solving strategies. Those children were observed to try all commands in a random hit-and-miss fashion. Nevertheless, those children who had an understanding of the problem-solving task focused on using more efficient BIG steps.

In summary, FORWARD, RIGHT, and BIG are directly tied to a child's ability to understand the problem-solving task. Children found FORWARD to be the easiest command to understand. RIGHT rotations were used more because children were more familiar with right manipulations in the real world. BIG was quickly understood to be the most efficient distance command. Perceived task ambiguity often resulted in the child using these better understood manipulations more frequently regardless of appropriateness or efficiency.

Hypotheses 7, 8, 9a., and 9b.

Analyses showed no significant differences in number of keystrokes ($p = .4196$) or errors ($p = .9932$) between learning strategies. Field dependent children are person-oriented and are more dependent on external sources of information for self-direction. Field independent children are task-oriented and are better at restructuring skills (Barnes, 1981; Kogan, 1983; Saracho, 1983, 1985; Witkin et al., 1977). Therefore, field dependent children should not be as competent as their field independent counterparts on abstract computer activities which have no landmarks and few external cues. FDI has been shown to be a stable, consistent characteristic over extended periods of time in school-age children (Saracho, 1983; Witkin, Goodenough, and Karp, 1967). However, FDI differences in preschoolers might be a less stable and less polar construct by definition (Kogan, 1983; Saracho, 1983). This would explain the lack of clearly distinct characteristics typifying each group. This instability or lack of polar clarity between field dependent and field independent children probably explains the lack of significant differences between the two groups.

As predicted, field independent children were the most successful (mean = 14.58) and showed the highest rate of task closure (mean = 22.37) for the 12 tasks. However, the differences between the two groups were very close. The instability of FDI in preschoolers discussed above probably explains why the difference was not greater.

The sensitivity of PEFT scoring methodology was another influential factor contributing to the lack of clearly defined differences between the two learning strategies. The PEFT requires a median split scoring to classify the two groups on the FDI dimension (Coates, 1972). From a potential range of 0-24, faces study PEFT scores ranged from 10-23. Therefore, a median split divided children with very close scores into two conceptually bipolar categories. From an ideal statistical perspective, scores should have a broader range with more variability. Ideally, scores should be divided into thirds instead of halves. Those subjects scoring in the middle third should be discounted leaving two groups with more discrepancy between scores. In actuality, distinct differences could not be expected when the actual scores between field dependent and field independent children were so close.

Despite these limitations, the study results indicated that there were FDI performance differences in problem-solving strategies. However, further research is needed to establish whether effects are as clearly demonstrable at the preoperational level as at the concrete operational and formal operational levels. Investigations should also address whether such FDI performance differences are situation specific (Kogan, 1983).

Hypotheses 10, 11, 12a, 12b., 12c., and 12d.

There was a significant difference between quadrants for number of keystrokes and errors. The difference was between the upper and lower left quadrants for keystrokes and between upper (right and left) and lower (right and left) quadrants for errors. There was also a slight ranking difference in level of success and rate of task closure. Children were most successful in the upper right quadrant, next in the upper left, and lastly in the lower quadrants. However,the predicted difference between lower right and left quadrants was not found. As discussed in Hypotheses 4, 5, and 6, children use FORWARD more frequently than any other move and RIGHT more than BACK and LEFT manipulations. Because HOME position for the "turtle" cursor is in the middle of the screen, the predominant use of FORWARD and RIGHT moves means that children chose to begin manipulations in the upper right quadrant more frequently than any other (see Figure 2). The HOME position also maintains the cursor's heading as identical to that of the children, i.e., the "turtle's" right is the same as the child's right, etc. However, no one had previously addressed the logic that FORWARD, RIGHT moves place children in the upper right quadrant of the computer screen. Following this logic, children have had more practice in the upper right quadrant. It is also easier for them to benefit from their egocentric spatial perspective in the upper right quadrant.

Children were almost as successful with upper left quadrant manipulations again because their egocentric spatial perspective can be maintained as a legitimate crutch for their pointing behaviors in problem-solving tasks. It is when the "turtle" must be rotated and moved in the lower quadrants that their egocentric cueing becomes a hindrance instead of an advantage. Relying on egocentric spatial perspectives in the lower quadrant does not enable children to determine correct strategies. The fact that children who are uncertain of distance/directional moves have been shown to continue to rely on their egocentric spatial perspective as late as eighth grade also implies that there should be quadrant effects on their understanding and success (Fay & Mayer, 1987; Mayer & Fay, 1987; Watson et al., in preparation).

This study provided sufficient evidence to suggest that this FORWARD, RIGHT behavior support this upper quadrant logic. Quadrant effects can be explained by children's dependence on egocentric spatial abilities and pointing strategies to problem-solve. In summary, the egocentric pointing behaviors that children relied on to problem-solve helped them to perform better on upper quadrant tasks. These same pointing behaviors were a disadvantage in lower quadrant problem-solving paradigms.

CHAPTER VI

CONCLUSIONS

This study empirically investigated the processing skills and strategies that preoperational children use during LOGO mastery. Thirty-eight four- and five-year-old pretrained children were included in an observational study designed to compare differences in FDI learning strategies, treatment levels, and quadrants on number of keystrokes, errors, RIGHT and LEFT turns, FORWARD, BACK, BIG, and SMALL steps, level of success, and rate of task closure. Children worked with three different cursors (triangular, cross-shaped, and circular) on three consecutive days. They were required to complete the same four problem-solving tasks with each cursor.

Pointing Behaviors

Results showed a significant treatment effect for keystrokes but not for errors. For number of keystrokes used, the triangular cursor was significantly different from the cross-shaped and circular cursors. The familiarity and the pointing capability of the triangular cursor ensured that children could recognize and correct their errors with fewer keystrokes than necessary for the other cursors. Children had greater success with the triangular and cross-shaped cursors. The children were unable to point with the circular cursor which made those problem-solving tasks very difficult. These results presented evidence to demonstrate that children were using syntonic learning to point the cursor toward the targeted destination.

FORWARD, RIGHT, and BIG Commands

Children used FORWARD, RIGHT, and BIG commands more frequently than others. The FORWARD command was easier to identify with and required less cognitive problem-solving skill than the directional commands. Children relied on familiar RIGHT rotations when they were uncertain of appropriate problem-solving manipulations, providing further evidence that they were using syntonic strategies from the real world to help them.

FDI Differences

There were no learning strategy differences found for number of keystrokes or errors. However, there were slight learning strategy differences for level of success and rate of task closure: field independent children were more efficient than field dependent children as predicted. The lack of clear distinctions between field dependent and field independent children was probably due to potential instability of the FDI construct in preoperational children. The limitations imposed by the PEFT scoring methodology (median split) were also a problem. Further research is needed to address these problems and resolve the learning strategy issue.

Quadrant Differences

There were significant quadrant differences between upper and lower quadrants. Children used small-scale landmark cues in the local computer environment and syntonic learning strategies to help them successfully problem-solve in the upper quadrants. However, these same egocentric spatial strategies were of no benefit to their problem-solving attempts in the lower quadrants. In fact, observations indicated that efforts to use their syntonic spatial abilities in the lower quadrants confused and frustrated them.

Summary

In summary, the study provided evidence that young children used egocentric spatial abilities in LOGO mastery. Preschool children may not have the precise spatial or cognitive skills that LOGO mastery actually requires. However, without understanding right and left per se they are able to use small-scale landmarks and Papert's syntonic body cueing and referencing to point the cursor toward the targeted destination and achieve success with the task. This study supports speculation that a microcomputer screen pointing strategy is the initial level in a developmental problem-solving sequence. The pointing behaviors evidenced in this study were limited to a four- and five-year-old university day care population: it has not been tested to determine the age range for this developmental behavior. Further research is also needed to determine if this strategy is typical of preoperational children in the general population. It is important for studies to continue to address the developmental sequence of problem-solving processes and strategies of young children as they master microcomputer skills. Results can be used to establish realistic, appropriate educational guidelines and boundaries for optimal use of the technology as an innovative learning tool.

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APPENDIX A

SCORE SHEET

SCORE SHEET

Name________________ Date________________ Center ____________________________

ID# ________________ Sex ________________ Observer ____________________________

Log Data	Card #	Time	# Errors	Task Complete	# Keyst.	# Rt T.	# Lt T.	# FDS	# B Step	# Big Steps	# Small Steps

APPENDIX B

PARENT PERMISSION LETTER

PARENT CONSENT FORM

PARENT PERMISSION LETTER

April 11, 1988

Dear Parent:

As you know, your child just completed participation in a pre-math and spatial development research study at the child care center on Thursday, April 7, 1988. You will remember that it was a study which combined age-appropriate microcomputer applications, individualized instruction, and ordinary objects from the regular classroom. Half of the microcomputer experience was with LOGO software, and I am interested in looking at what the children were thinking as they managed their LOGO success. Therefore, it is very important that I work with these children who are already trained and succeeding with LOGO,and I am requesting your permission for your child to participate in a brief four day follow-up study beginning on Monday, May 9, 1988.

The primary purpose of this research study will be to examine closely the process that children use to figure out the necessary "turtle" manipulations when they are working with LOGO. ("Turtle" is simply the LOGO terminology for the cursor used in the LOGO software package: the cursor really looks like an isosceles triangle instead of a turtle.) In order to gain an understanding of their strategies, the children will be closely observed as they perform simple problem-solving tasks by moving the "turtle" from one place to another on the microcomputer screen.

Researchers have known for several years that LOGO is an excellent age-appropriate software package for a broad age range of children (preschoolers included). They have not, however, been able to isolate the thought processes used by these young children as they master LOGO manipulations, and this is the area that I want to explore. I will use a combination of LOGO, Sprite LOGO, and LOGO Writer (other LOGO-based software packages that have the additional feature of allowing the "turtle" cursor to take on different shapes) to help me answer my question.

The children will not be pretested at all. They will continue to work individually with one trained observer on simple LOGO tasks very similar to those in the preceding study: they will use the three different pieces of LOGO software to reproduce on the computer screen the four different, simple, three-legged figures that are drawn on 5 X 8 cards and propped above the keyboard. The children will work for four 15 minute sessions on Monday through Thursday. On Mondays, all the different cursors (the LOGO triangle and the Sprite LOGO and LOGO Writer cross and circle) will be introduced and demonstrated with a sample card task to the children who are scheduled for that week. For the next three days, they will work on tasks with each of the three different cursors (a different cursor each day) for the 15 minute daily session. I want to emphasize that the nature of the required tasks will be familiar to them at this point. In fact, it is this very familiarity that the children have with LOGO that will allow me to examine my question. After four days, the children will be finished with their participation in the study. There will be no posttesting. Because children will be observed only in the mornings, all of them cannot be observed in one week. Rather, half of the children will be involved the first week of the study, and the other half will participate the following week. However, all children will receive the same experience with the computer and all three different pieces of LOGO software.

Please feel free to talk with me further about the study if you have any question. I will even try to arrange to show you the features of LOGO, Sprite LOGO, and LOGO Writer after the research is completed if you are interested. However, please do not discuss the study with your child until after May 23, 1988, when the project has been totally completed by everyone. It is critical that the information that we gain from observing the children not be influenced by their talking with anyone before or during the research.

Please complete the attached consent form today and return it to your child's teacher tomorrow. Timing is a very crucial factor in this follow-up study, and any delays must be avoided. If you want to receive a group summary of the results, please check the appropriate box on the consent form.

Thank you again for your continued support of the child lab programs and child research and development.

Sincerely yours,

Vickie M. Brinkley, M.S.
Research Assistant
Children and Technology Project
Department of Child Development
and Family Relations
University of North Carolina at
Greensboro
334-5307

PARENT CONSENT FORM

CHILDREN AND TECHNOLOGY PROJECT

My child ______________________________ ________ May

________ May not

participate in the computer study, "Pointing behaviors of preschoolers during LOGO mastery". Your child can withdraw from the study at any point in time without penalty. Non-participation in the study will in no way affect the status of your child in the Center. Data will be numerically coded, kept confidential and secure, and destroyed at the conclusion of the study.

____

(signed)

____

(date)

_____ I would like to receive a group summary of the results of the above study. Please send the summary to me at the name and address given below:

____

____

____

(city, state, zip code)

APPENDIX C

GLOSSARY

GLOSSARY

CAT - CAT is the acronym for the Children and Technology Project.

Concentric circles - Concentric circles refer to oblique angles rotating from the "turtle's" screen position through continuing units, 0-360.

Curriculum Study - The Curriculum Study refers to the research study by Watson, Brinkley, Sheets, Wheatley-Heckman, Ingles, and Howard.

Focus Study - The Focus Study refers to the research study discussed in this dissertation.

Heading - Heading refers to the direction in which the "turtle" is pointing. In its HOME position, the heading is always pointing north.

HOME - HOME refers to the normal starting position of the "turtle" cursor in the center of the screen. The heading is always north in this position.

Interface card - Interface card refers to a board inserted into a computer which allows auxiliary functions to take place.

Oblique angles - Oblique angles refer to non-perpendicular (90) angles.

Quadrant - Quadrant refers to the four areas of the computer screen formed by imaginary perpendicular lines cutting through the center of the computer screen.

Syntonic learning - Syntonic learning refers to learning which is related to children's sense and knowledge about their own bodies.

"Turtle" - "Turtle" refers to the standard triangular-shaped cursor in the LOGO programming language.