DOCUMENT RESUME

ED 260 800 PS 015 267

AUTHOR Cuneo, Diane O.

TITLE Young Children and Turtle Graphics Programming: Understanding Turtle Commands.

PUB DATE Apr 85

NOTE 23p.; Paper presented at the Biennial Meeting of the Society for Research in Child Development (Toronto, Ontario, Canada, April 25-28, 1985).

PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.

DESCRIPTORS Age Differences; *Comprehension; Early Childhood Education; *Microcomputers; *Perspective Taking; *Programing Languages; *Spatial Ability; *Young Children

IDENTIFIERS *LOGO Programing Language; Piagetian Theory; Rule Application

ABSTRACT

The LOGO programing language developed for children includes a set of primitive graphics commands that control the displacement and rotation of a display screen cursor called a turtle. The purpose of this study was to examine 4- to 7-year-olds' understanding of single turtle commands as transformations that connect turtle states and to characterize the nature of their misunderstanding. Children were introduced to a highly simplified turtle graphics environment that included four possible turtle orientations and four legal commands. Children were then shown events consisting of an initial turtle state, a command transformation, and the resulting turtle state. They were asked to indicate the key/command involved in each event. Most children systematically misunderstood the commands. Younger ones associated each of the four commands with displacement in a particular direction and rotation to a particular orientation. Overall, most children performed much as Piaget's theory predicts. When the turtle rotated, they tended to focus on features of the final turtle state, ignoring both initial state and transformation information. When the turtle changed location, children seemed to attend to the transformation itself. Younger ones, however, tended to define the displacement from their own or the display screen's frame of reference rather than from the turtle's frame of reference. (Author/RH)

Meeting of the Society for Research in Child Development

Toronto, Canada, April 1985

Young Children and Turtle Graphics Programming:

Understanding Turtle Commands

Diane O. Cuneo

University of Massachussetts, Amherst

Author's address: Cognitive Development Project, Department of Physics, University of Massachussetts, Amherst, MA 01003

Abstract

Programming languages developed for children (e.g., LOGO) include a set of primitive graphics commands that control the displacement and rotation of a display screen cursor called a turtle. The purpose of this study was to examine 4- to 7-year-olds' understanding of single turtle commands as transformations that connect turtle states, and to characterize the nature of their misunderstanding.

Children were introduced to a highly simplified turtle graphics environment. There were four possible turtle orientations, 0-, 90-, 180-, and 270-degrees, and four legal commands, FORWARD (F), BACK (B), RIGHT (R), and LEFT (L). Following the introduction, children were shown events consisting of an initial turtle state, a command transformation, and the resulting turtle state. They were asked to indicate the key/command involved in each event.

Most children systematically misunderstood the commands. Younger ones associated each of the four commands with displacement in a particular direction and rotation to a particular orientation. If the turtle moved in a 0-degree direction or rotated to a 0-degree orientation, they thought that F had been executed; if the turtle moved in a 90-degree direction or rotated to 90-degree orientation, they thought that R had been executed; and so forth. Older children understood that only F and B displaced the turtle but, like younger children, thought that each of the four commands rotated it.

Overall, most children performed much as Piaget's theory predicts. When the turtle rotated, they tended to focus on features of the final turtle state (i.e., final orientation), ignoring both initial state and transformation information. When the turtle changed location, children seemed to attend to the transformation itself. Younger ones, however, tended to define the displacement from their own or the display screen's frame of reference rather than from the turtle's frame of reference.

YOUNG CHILDREN AND TURTLE GRAPHICS PROGRAMMING: UNDERSTANDING TURTLE COMMANDS

Turtle graphics programming is a popular vehicle for introducing children to computer programming. Children combine simple graphics commands to get a display screen cursor called a turtle (see Figure 1) to draw designs on the display screen. Even preschool-aged children jump right into creating their own turtle designs. Researchers and educators alike assume that children's instant use of turtle commands reflects relatively instant understanding of command definitions. However, this assumption is open to question in the case of preschool- and early school-aged children. The literature on early cognitive development suggests limitations of young children's thinking that should make it difficult if not impossible for them to understand the basic turtle commands.

Understanding Turtle Commands

The four basic turtle commands are FORWARD (F), BACK (B), RIGHT (R), and LEFT (L), and are illustrated in Figure 2. F (e.g., F 50) moves the turtle a specified number of units in the direction it is pointing, and B moves it in the opposite direction. R (e.g., R 90) rotates the turtle a specified number of units to its right (i.e., clockwise), and L rotates it to its left (i.e., anticlockwise).

The basic commands seem so simple and easy to learn. However, Gregg (1978) found that 4- and 5-year-olds had great difficulty using these commands to control the movement of a computer-controlled robot turtle. Indeed, at least some ability to relate states and transformations and some amount of spatial perspective-taking skill would seem to be prerequisites for entry into turtle graphics programming.

Relating states and transformations. At its most basic level, turtle graphics is a system of transformations. The states are defined by the orientation and location of the turtle. The transformations are the commands that result in changes in state. F and B change location, in reciprocal ways, and leave orientation invariant. R and L change orientation, in reciprocal ways and leave orientation invariant. A basic ability to relate states and transformations is thus central to understanding how the turtle "works".

Spatial perspective-taking. Turtle commands are defined relative to the turtle's perspective. For example, F displaces it in the direction it is pointing, and R rotates it to its right. Children must understand that the commands are defined relative to the turtle's intrinsic frame, and not to their own egocentric frame nor an external frame (e.g., the display screen). They must also be able to adopt the turtle's perspective and maintain it through imagined execution of a command or sequence of commands.

Young Children's Thinking

Do young children have the prerequisite abilities for understanding the basic turtle commands? According to Piaget's view of young children's thinking, they do not. First, according to Piaget's theory, children younger than about 6 or 7 years of age cannot relate states and transformations and, instead, are primarily state-oriented. For example, they fail to conserve a variety of different quantities across quantity-irrelevant transformations, thinking, for example, that pouring the liquid contents of a glass into a taller, thinner glass increases liquid amount (e.g., Piaget, 1952). According to the theory, young children fail to conserve quantity in part because they do not understand that successive states (e.g., liquid in the standard glass and that in the taller, thinner glass) are linked by a transformation (e.g., pouring). Similarly, in tasks of causal reasoning (e.g., Piaget 1930, 1974), young children attribute nonphysical causes (e.g., wishes, feelings) to physical events (e.g., the cycle of the moon). This is said to reflect their lack of concern about the specific nature of a transformation that might connect cause and effect.

Similarly, according to Piaget's theory, spatial perspective-taking does not occur before about 6 or 7 years of age (e.g., Piaget & Inhelder, 1956). The young child is characterized as egocentric and "rooted in his own viewpoint in the narrowest and most restricted fashion, so that he cannot imagine any perspective but his own" (p. 242). For example, when asked to indicate how a model of three mountains looks to a doll placed at various positions around the model, young children tend to choose a picture or small replica that depicts their own view rather than doll's view.

Piaget's characterization of young children as primarily state-oriented and egocentric suggests that they will not understand the basic turtle commands and, further, will systematically misunderstand them. That is, unable to understand how commands name turtle-referenced transformations, they may instead think that they name particular end-states, or self- or screen-referenced transformations. More recent work in early cognitive development (cf., Gelman & Baillargeon, 1983) is somewhat more positive but makes no specific predictions. In general, recent work suggests that young children have the basic capacities to understand transformations and adopt perspectives other than their own. However, their ability to perform such cognitive feats is said to be fragile and, thus, task specific.

Purpose

The purpose of this study was to examine young children's understanding of individual turtle commands as transformations that connect turtle states, and to characterize the nature of their misunderstanding. Children were shown display screen events, consisting of an initial turtle state (i.e., the turtle in a particular location and orientation), a command transformation (i.e., the turtle executes a command), and the resulting turtle state (i.e., the turtle in a new location or orientation). They were asked to indicate the command involved in each event. The ability to recognize when a given command has been executed seems basic to understanding that command.

Method

Subjects

Thirty-two 4- and 5-year-olds (mean age 5-1) and 32 6- and 7-year-olds (mean age 7-0) participated in the study. None of the children had previous experience with turtle graphics or computer programming although many had used computers to play games.

Introduction to Turtle Graphics

Children were introduced to a highly simplified turtle graphics environment. There were four possible orientations, 0-, 90-, 180-, and 270-degrees (see Figure 3), and four legal commands, F, B, R, and L. Commands required a single key press and did not take arguments. F and B moved the turtle a fixed distance forward and back, respectively, and R and L rotated it 90-degrees clockwise and anti-clockwise, respectively. The introduction was brief but thorough, and included demonstration and explanation of each command beginning in each orientation. All children said that they understood "how the turtle worked."

Experimental Task

Children saw 16 state-command-state events constructed from a 4 x 4, begin orientation x command, factorial design. On each trial, two turtles, one red and the other green, appeared on the screen in identical orientations (see the top panel of Figure 4). The red turtle executed a command and then differed from the green one in either location or orientation (see the middle and bottom panels of Figure 4). Children were asked to indicate the command they would give and the key they would press to make the green turtle copy the red one. There was no screen feedback (i.e., the green turtle did not execute the given command).

Children completed two replications of the complete design. Events were randomly ordered separately for each child and each replication.

Results

Correct Performance

Table 1 shows percent correct performance by age group and trial (i.e., event) type. Turn trials involved execution of R or L, and move trials involved execution of F or B. As shown in Table 1, older children performed better than younger ones and, for both groups, performance was better on move trials than on turn trials. Overall, children were not very accurate at naming command executions, especially executions of R and L.

Correct performance by begin-orientation is not shown in Table 1 but deserves brief mention. For both age groups and both trial types, performance was better on 0-degree begin-orientation trials than on nonzero-degree trials which, in turn, did not differ from each other.

Rule Classification

Individual children's response patterns were analyzed for underlying rules using an approach similar to Siegler's (1976, 1981) rule assessment approach. Rules for turn events are shown in Figure 5, and rules for move events are shown in Figure 6.

Rules for turn events. Children's response patterns on turn trials were classified into one of four rule groups: Random (i.e., no apparent rule), End-state (i.e., if the turtle's end-orientation is 0-degrees, say F occurred; if 90-degrees, say R occurred; and so forth), Correct (i.e., always say R or L occurred), and Combination (i.e., combination of End-state and Correct rules).

Rules for move events. Response patterns on move trials were classified into one of four similar rule groups: Random, Direction (i.e., if the turtle moved in 0-degree direction, say F occurred; if in a 90-degree direction, say R occurred; and so forth), Correct (i.e., always say F or B occurred); and Combination (i.e., combination of Direction and Correct rules).

Note that the End-state rule for turn events and the Direction rule for move events are systematically incorrect, and consistent with Piaget's view of young children's cognitive limitations. Use of the End-state rule would indicate that children classified turn events by the final turtle state (i.e., oriented 0-, 90-, 180-, or 270-degrees) rather than by the transformation involved (i.e., rotated clockwise or anticlockwise). Use of the Direction rule would indicate that children classified move events by the displacement transformation involved, but that transformation was self- or screen-referenced (i.e., moved upward, rightward, downward, or leftward) rather than turtle-referenced (i.e., moved forward or backward). Note also that the Combination rules postulate a gradual transition from systematically incorrect to systematically correct rule.

Classification criteria. Response patterns were classified as End-state (or Direction) if 14 of 16 responses (2 replications of 8 events) conformed to the predictions of the rule; as Correct if 14 of 16 responses were correct, or 15 of 16 responses conformed to the predictions of the Correct rule; as Combination if all 16 responses were either correct or as predicted by the End-state (or Direction) rule; and as Random if not otherwise classifiable. These criteria allowed unambiguous classification of response patterns, and kept the probability of misclassifying a true Random as End-state (or Direction), Correct, or Combination low (binomial probability = .0000003, .0003, and .004, respectively).

Rule Usage

Tables 2 and 3 show rule usage by 4- and 5-year-olds and 6- and 7-year-olds, respectively. In each table, children are classified by both turn rule and move rule used.

Rules for turn events. As shown in the last column of Table 2, about one-third of the younger children responded randomly, and about two-thirds used the End-state rule. As shown in the last column of Table 3, one-half of the older children used the End-state rule, and about one-half used the Correct rule. There appears to be a developmental progression from Random to End-state to Correct rule. Although it seemed reasonable to expect a gradual transition from End-state to Correct rule, there was little evidence for the Combination rule.

Rules for move events. As shown in the bottom row of Table 2, about one-third of the younger children used the Direction rule, about one-third the Combination rule, and about one-third the Correct rule. As shown in the bottom row of Table 3, about one-third of the older children used the Direction rule, and about two-thirds the Correct rule. These data suggest a progression from Direction to Combination to Correct rule.

The rule classification data capture the trends present in the accuracy data (i.e., main effects of age and trial type) and, further, capture and characterize the systematic nature of children's errors.

Joint rules. The End-state/Direction, End-state/Combination and, End-state/Correct cells in Table 2 account for 91 percent of the younger children using systematic turn and move rules, and 63 percent of the total group. The End-state/Direction, End-state/Correct, and Correct/Correct cells in Table 3 account for 100 percent of the older children using systematic turn and move rules, and 94 percent of the total group. These cells form a progression of levels of overall command understanding, as indicated in Tables 2 and 3 and illustrated in Figure 7.

Level 1 describes children who used the End-state rule for turn events and the Direction rule for move events (7 younger and 7 older children). As shown in Figure 7, these children associated each command name with a particular rotation end-state and a particular displacement direction. What they did not do was associate R and L with turn events only, and F and B with move events only.

Level 2 describes children who used the End-state rule for turn events and the Combination rule for move events (5 younger children). These children sometimes classified move events by displacement direction and sometimes by "turtle direction" (i.e., forward or backward movement). This level captures the transition from the Direction to the Correct rule for move events.

Level 3 describes children who used the End-state rule for turn events and the Correct rule for move events (8 younger and 9 older children). Like children at Levels 1 and 2, these children associated F, B, R, and L with particular rotation events. However, they seemed to understand that move events involved only F and B.

Level 4 describes one older child who used the Combination rule for turn events and the Correct rule for move events. This level postulates a transition from the End-state to the Correct rule for turn events, analogous to the transition from the Direction to the Correct rule for move events in Level 2. Although little evidence for Level 4 was found in this study, it seems reasonable to retain it in the present developmental formulation of command understanding.

Finally, Level 5 describes children who used the Correct rules for turn and move events (1 younger and 12 older children). These children understood that turn events involved R or L, and move events F or B.

Conclusions

In summary, most children misunderstood some or all of the basic turtle commands. And their initial misconceptions were pretty much as Piaget's theory predicts. When the turtle rotated, children tended to focus on the final turtle state (i.e., final orientation), and not on the rotation transformation. Even children who seemed to know that F and B produced displacement transformations thought these commands were involved in events that provided clear evidence for an intervening rotation transformation. When the turtle changed location children seemed to attend to the displacement transformation itself. Younger ones, however, often viewed the displacement with reference to themselves or the screen, and not with reference to the turtle.

The results suggest that young children's entry into turtle graphics programming will not be as spontaneous as suggested by anecdotal evidence (e.g., Papert, 1980). At the very least, careful attention should be given to their initial introduction to single primitive graphics commands. At worst, it may be unreasonable to expect young children go beyond the level of the single command to the more complex programming aspects of turtle graphics.

References

Gelman, R., & Baillargeon, R. (1983). A review of some Piagetian concepts. In J. H. Flavell, & E. M. Markman (Eds.), Handbook of child psychology (Vol. 3). New York: Wiley.

Gregg, L. W. (1978). Spatial concepts, spatial names, and the development of exocentric representations. In R. S. Siegler (Ed.), Children's thinking: What develops? Hillsdale, N. J.: Erlbaum.

Papert, S. (1980). Mindstorms. New York: Basic Books.

Piaget, J. (1930). The child's conception of physical causality. London: Routledge & Kegan Paul.

Piaget, J. (1952). The child's conception of number. London: Routledge & Kegan Paul.

Piaget, J. (1974). Understanding causality. New York: W. W. Norton.

Piaget, J., & Inhelder, B. (1956). The child's conception of space. London: Routledge & Kegan Paul.

Siegler, R. S. (1976). Three aspects of cognitive development. Cognitive Psychology, 8, 481-520.

Siegler, R. S. (1981). Developmental sequences within and between concepts. Monographs of the Society for Research in Child Development, 46, 1-84.

Table 1

Study 1A: Percent Correct

	Trial Type	
Age	Turn[a]	Move[b]
4-5	27	53
6-7	40	73

[a]R or L was executed.

[b]F or B was executed.

Table 2

Study 1A: Rule Usage by 4- and 5-year-olds

Turn	Move Rule				
Rule	Random	Direction	Combination	Correct	Total
Random	-	3	4	2	9
End-State	1	7[a]	5[b]	8[c]	21
Combination	-	1	-	-[d]	1
Correct	-	-	-	1[e]	1
Total	1	11	9	11	

[a]Understanding level 1.

[b]Understanding level 2.

[c]Understanding level 3.

[d]Understanding level 4.

[e]Understanding level 5.

Table 3

Study 1A: Rule Usage by 6- and 7-year-olds

Turn Rule	Move Rule: Random	Direction	Combination	Correct	Total
Random	-	-	-	1	1
End-State	-	7[a]	-[b]	9[c]	16
Combination	-	-	1	1[d]	2
Correct	1	-	-	12[e]	13
Total	1	7	1	23	

[a]Understanding level 1.

[b]Understanding level 2.

[c]Understanding level 3.

[d]Understanding level 4.

[e]Understanding level 5.

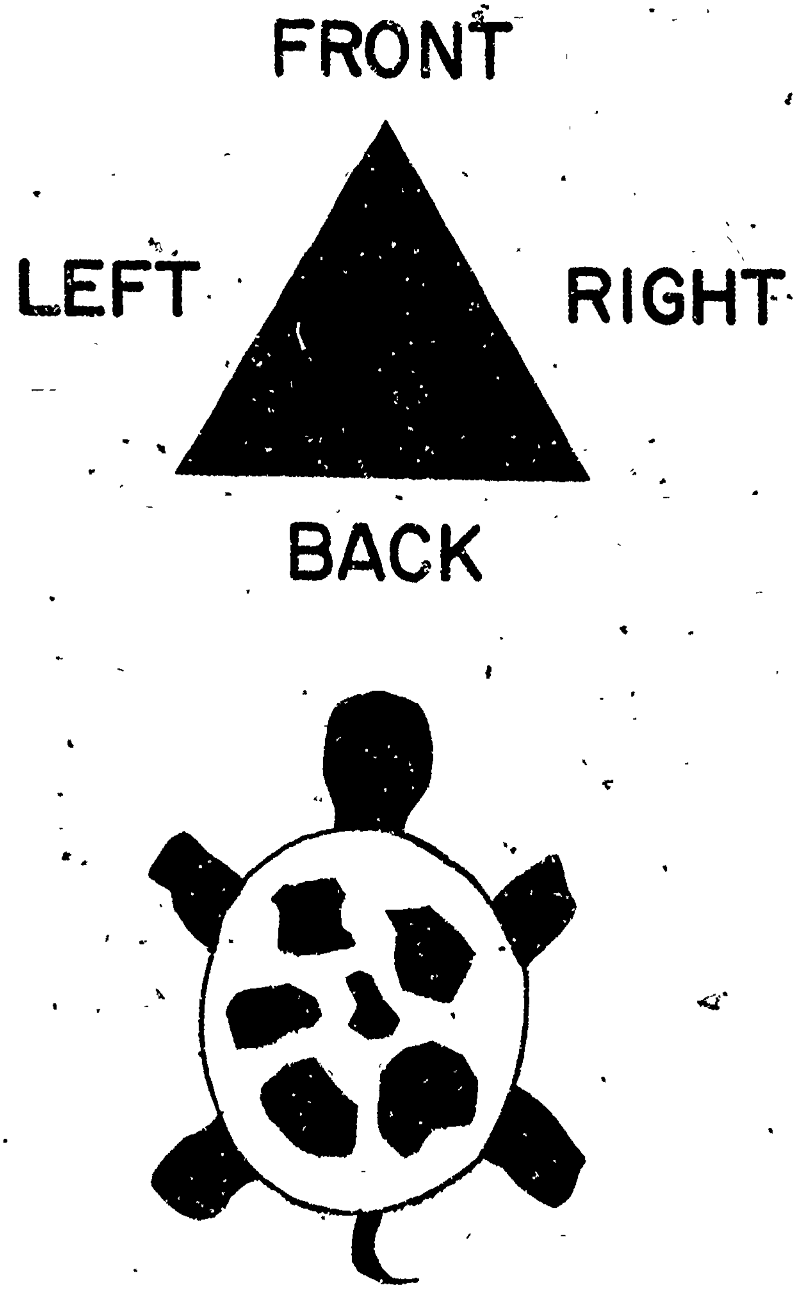

Figure 1

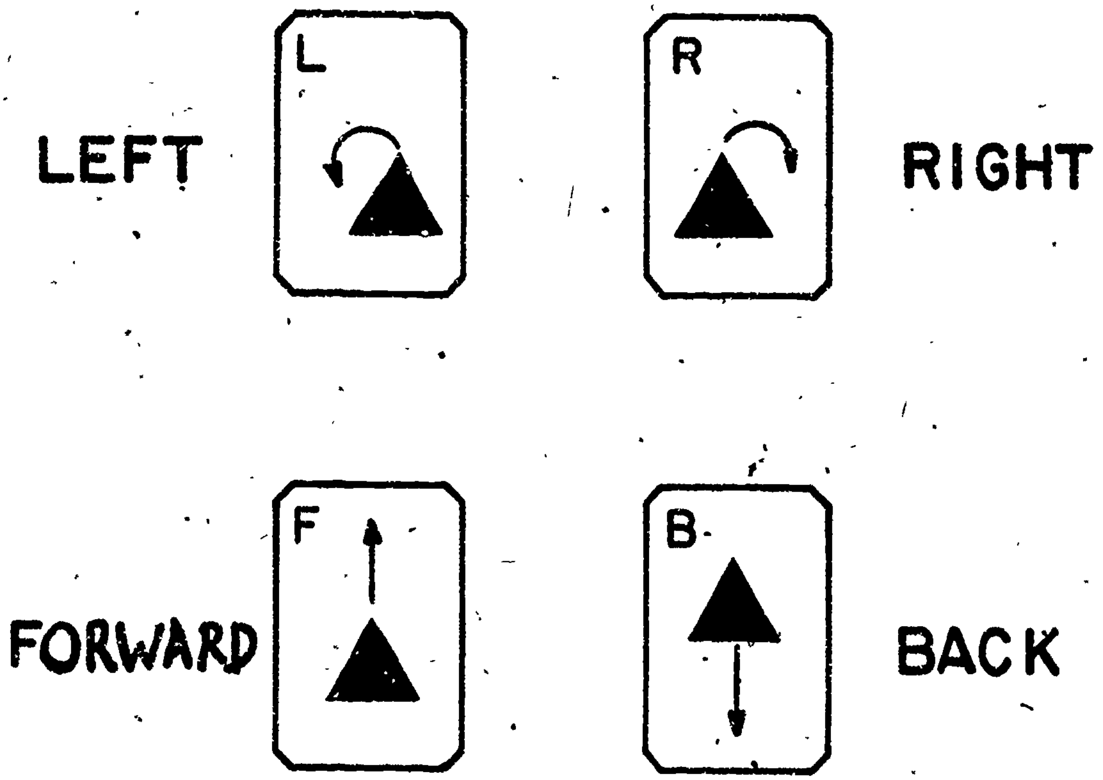

Figure 2

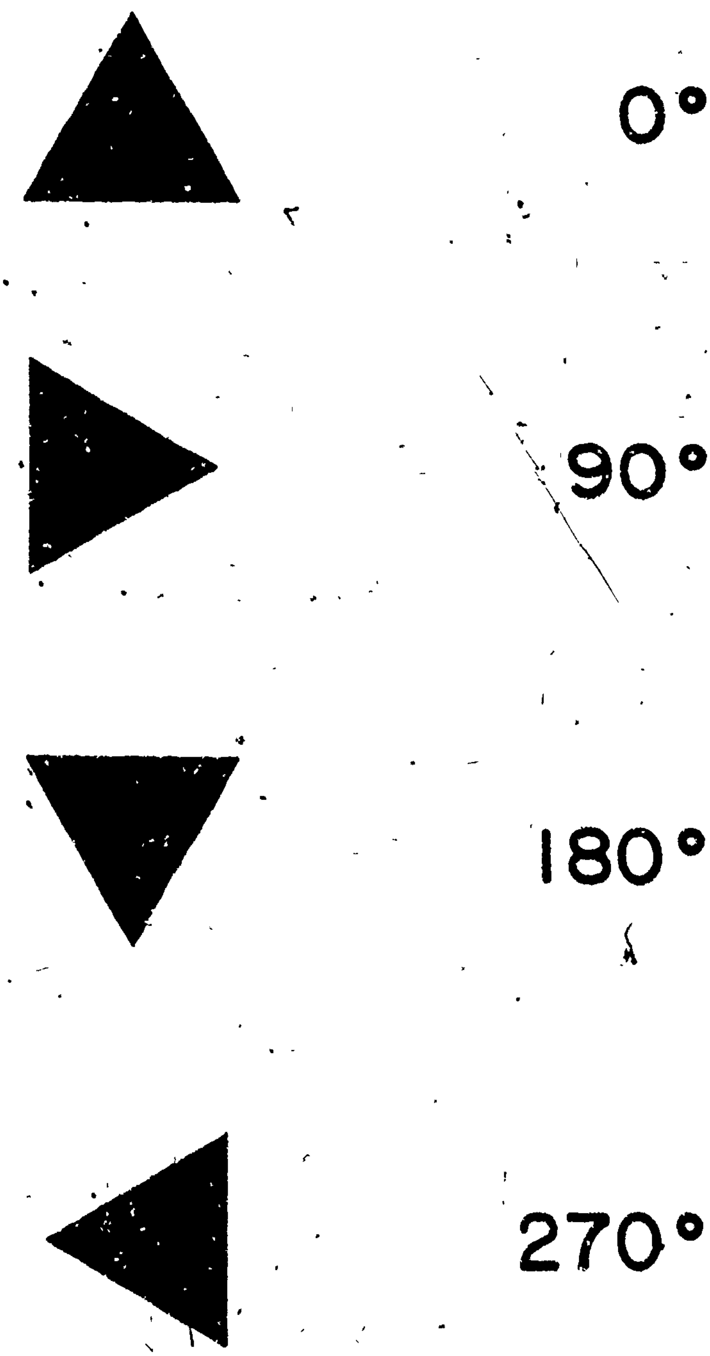

Figure 3

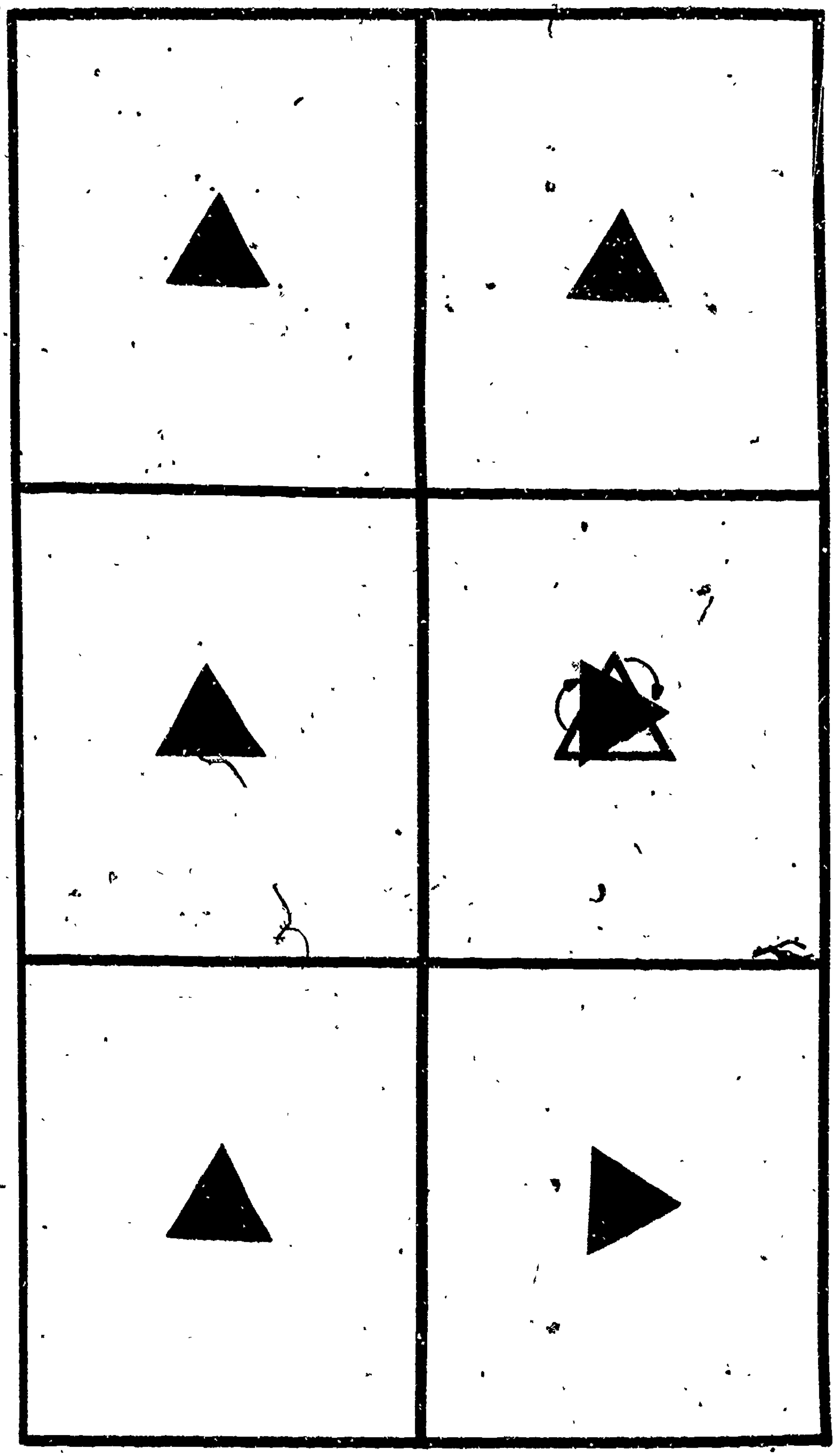

Figure 4

Rules for Mapping Turn Events onto Commands

Rule	Turtle End-State	Turtle Transformation	Key
0. Random	Facing 0		F
	" 180		B
	" 90		R
	" 270		L
1. End-State	Facing 0	⟶	F
	" 180	⟶	B
	" 90	⟶	R
	" 270	⟶	L
2. Combination	Facing 0	⟶	F
	" 180	⟶	B
	" 90	⟶	R
		Clockwise ⟶	R
	" 270	⟶	L
		Anticlockwise ⟶	L
3. Correct			F
			B
		Clockwise ⟶	R
		Anticlockwise ⟶	L

Figure 5

Rules for Mapping Move Events onto Commands

Rule	Screen Direction	Turtle Transformation	Key
0. Random	Moved 0		F
	" 180		B
	" 90		R
	" 270		L
1. Direction	Moved 0 →		F
	" 180 →		B
	" 90 →		R
	" 270 →		L
2. Combination	Moved 0 →	Moved Forward →	F
	" 180 →	Moved Backward →	B
	" 90 →		R
	" 270 →		L
3. Correct		Moved Forward →	F
		Moved Backward →	B
			R
			L

Figure 6

Levels of Command Understanding

	Turn Events: Turtle End-State	Turn Events: Turtle Transformation	Key	Move Events: Turtle Transformation	Move Events: Screen Direction
1.	Facing 0	→	F	←	Moved 0
	" 180	→	B	←	" 180
	" 90	→	R	←	" 90
	" 270	→	L	←	" 270
2.	Facing 0	→	F	← Moved Forward	← Moved 0
	" 180	→	B	← Moved Backward	← " 180
	" 90	→	R	←	" 90
	" 270	→	L	←	" 270
3.	Facing 0	→	F	← Moved Forward	
	" 180	→	B	← Moved Backward	
	" 90	→	R		
	" 270	→	L		
4.	Facing 0	→	F	← Moved Forward	
	" 180	→	B	← Moved Backward	
	" 90	→ ; Clockwise →	R		
	" 270	→ ; Anticlockwise →	L		
5.			F	← Moved Forward	
			B	← Moved Backward	
		Clockwise →	R		
		Anticlockwise →	L		

Figure 7