CONCRETE-ABSTRACTIONS STAGE IN KINDERGARTEN CHILDREN'S PERCEPTION AND CONSTRUCTION OF ROBOTIC CONTROL RULES

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Knowledge Technology Lab - Research Report No. 70

ABSTRACT

Research concerning young children's perception and learning of technological systems is sparse. Today, controlled technological systems have become central to everyday life - hence, the importance of studying young children's perceptions of the structure and function of controlled systems. It is possible to represent control knowledge, using different representations such as scripts or rules. Developmentally, scripts are earliest to emerge. For example, children tend to categorize objects in space according to the features of particular events. However, rules or productions are powerful tools for representing control.

In the present study, we have examined the "rule-thinking" of young children and its development in a real-world constructive environment - a computer-controlled robot, traversing a modifiable terrain.

The overall research questions we pose are:

(1) What characterizes children's perception of control rules in technological systems?

(2) What characterizes the changes in perception as the children gain proficiency in controlling such systems?

The sample included six children, their ages spanned 5y4m- 6y0m. Two sets of instruments have been developed. One is a computerized control environment, scaffolding the children's learning process. This environment includes a computer interface, a physical robot and modifiable scenes for the robot's movement according to the various tasks. The second is a series of tasks using this learning environment to define the robot control rules.

The children's descriptions and definitions of the robot's behavior were analyzed using as a framework a conceptual model which discriminates between behavioral and technological definitions and maps out the relationships between them, as well as the condition and the action parts of the rule. Using this model, the children's performance was analyzed according to several criteria: (a) type of description (rules or scripts); (b) perception modality of the robot's functioning (behavioral or technological); (c) transition patterns between the various description-types and perception-modalities.

Initial results show: (1) With less experience, the rules start out as one condition-action pair. Some, but not all of the children, can provide more complex rules after gaining more experience in programming a robot with control rules. Unsupported by an adult's intervention, these rules are limited to one input and two output actions. (2) With an adult's support, the children can verbalize more advanced rule structures, but only one 'half' rule (single condition-action chain) more than that which they can provide on their own. (3) The behavioral description precedes the technological one in each of the sessions, regardless of their placement along the experimental timeline. (4) The use of script-like descriptions is transient and is exhibited during decomposition of the actions of confusing robot behavior. (5) Talking about the robot's actions along the borderline between the two input values usually marks the passage to more complex rules. (6) With support, the children could construct a robot's behavior at a higher complexity than that which they could describe in words. These results are discussed in terms of transitions one can tap onto as an observer or as a teacher.

Keywords: Technology education, design, controlled systems, learning.

Sub-theme: New media and teaching and learning processes

INTRODUCTION

Research concerning young children’s perception and learning of technological systems is sparse. Different studies show that children categorize artifacts by function, perceive causal relations in technological mechanisms, and are aware of the importance of the "insides" of artifacts for their functioning very early in their lives (e.g., Kemler Nelson et al, 1995; Simons & Keil, 1995). In attempting to explain this early understanding, researchers point out the large amount of knowledge already accumulated by young children (a) from the very fact they are immersed in a technology-saturated environment; (b) because of the many interactive encounters with such systems; (c) from the relatively greater attention children allocate to dynamic phenomena and processes, such as the functioning of artifacts. Today, controlled technological systems (e.g. remote-controlled television sets or automatic doors and faucets) have become central to everyday life - hence, the importance of studying young children’s perceptions of the structure and function of controlled systems (Ackerman, 1991; Papert, 1993).

It is possible to represent control knowledge, using different representations such as scripts or rules (Levin & Mioduser, 1996). Developmentally, scripts are earliest to emerge. For example, children tend to structure objects in space according to the features of particular events. However, rules or productions are powerful tools for representing control. Educational interfaces for the younger ages incorporate a ‘script’-like forms of programming, while only in the later ages do they include the more complex and abstract ‘rule’-type control. Research knowledge about young children’s perception and ability to design controlled systems using rules is yet weak and unstructured. It is suggested that in the domain of technology, children can operate at more mature levels of understanding (Piaget, 1956). Therefore, one purpose of this study is determining the children’s ability to program a robot, using the more abstract control rules, rather than the supposedly age-appropriate script type commands.

An important aspect of understanding how technological systems work is bridging two kinds of descriptions: (1) that of the behavior of the system, what it is doing in interacting with its environment. (2) the technological building blocks, whose interaction with each other, with the robot’s structure, and the environment, produce the particular behavior. It is suggested that the first type of description would be first to be used, and only after furthering the understanding of the system would support the shift to technological descriptions.

In the present study, we have examined the "rule-thinking" of young children and its development in a real-world constructive environment - a computer-controlled robot, traversing a modifiable terrain.

The overall research questions we pose are:

(1) What characterizes children's perception of control rules in technological systems?

(2) What characterizes children's construction of control rules in technological systems?

METHOD

The sample included six children, 3 boys and 3 girls, selected randomly out of 60 children in a public school in the Israeli city of Rishon-LeZion. Their ages spanned 5y4m- 6y0m.

Two sets of instruments have been developed. One is a computerized control environment, scaffolded according to the children's learning process. This environment includes a computer interface, a physical robot and modifiable scenes for the robot's movement according to the various tasks. A key component of the environment is a visual iconic interface for defining the control rules in a simple and intuitive fashion (Figure 1).

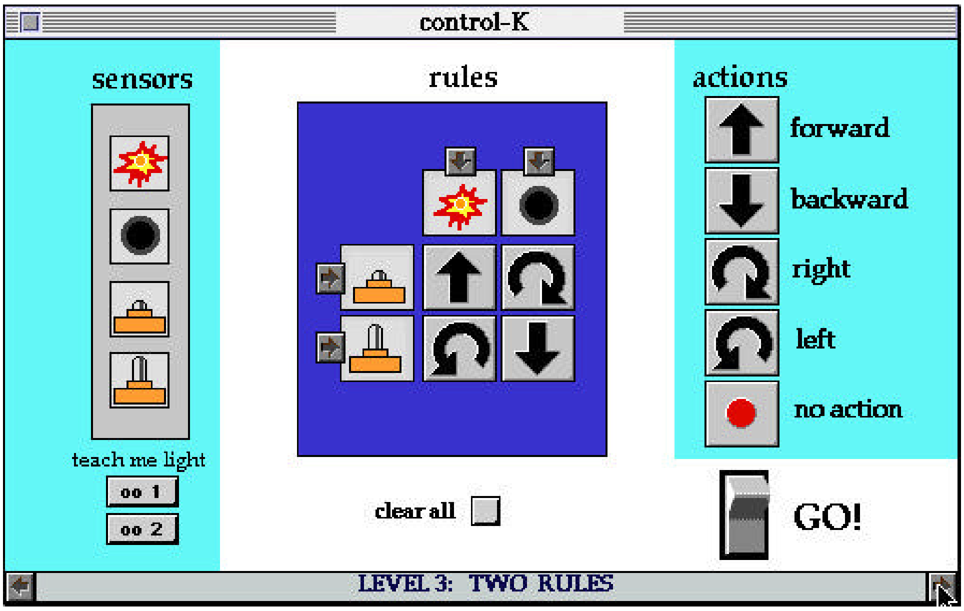

Figure 1: Sample screen of he computer control environment - configuration for level 3 tasks (two interrelated rules)

The second is a series of tasks using this learning environment to define the robot control rules. Examples of tasks are: “Teach the robot how to move freely in an obstacles field” or “Teach the robot to traverse a winding bridge, without falling off”.

Both environment and tasks were designed as a progression of increasing complexity. The operational definition of rule complexity is its number of condition-action pairs. Half a rule is one condition-action pair, i.e. ‘when the robot sees a light it turns away’ (the shy robot, if the sensor faces forward). One rule contains two pairs, i.e.: ‘when the touch sensor is pressed the robot turns, when the touch sensor is not pressed the robot moves forward in a straight line’ (the runaway top, if the touch sensor faces up). Two unrelated rules have 4 condition-action pairs, organized in two independent rules. For example, ‘When the light sensor sees black the robot turns, when the light sensor sees white the robot goes straight; when the touch sensor is pressed its buzzer goes on, when the touch sensor is not pressed, its buzzer is off’ (the screeching seeker of dark). The final level of complexity is that of two inter-related rules. For example: ‘when light sensor 1 sees white and light sensor 2 sees white stop; when light sensor 1 sees white and light sensor 2 sees black, turn to the left; when light sensor 1 sees black and light sensor 2 sees white, turn to the right; when light sensor1 sees black and light sensor 2 sees black, go forward’ (crossing a dark bridge, if the two sensors are pointing down).

PROCEDURE

The study lasted five 20-45 minute sessions, spaced one week apart. The children worked and were interviewed individually. A pre- and post-test were administered requiring the children to describe a 2-minute movie showing cars and people at a four-way stoplight intersection. Each session focused on one stage in the rule-complexity progression. A typical session included two parts: a description task, where the children were presented with a given robot behavior, and a construction task, where they were asked to program the robot with control rules to produce a particular behavior. Given the screen configuration for representing two interrelated rules as a 2X2 matrix (Figure 1) in the last stage of the study, the children were tested for understanding of this representation in two ways. One was used to probe their mastery of the matrix structure by asking them to place cards on a 2X2 matrix board. The second examined their understanding of the transformation from the matrix description to the actual robots’ behavior by asking the children to “behave like a robot” following control rules depicted on a matrix board. Data were collected by videotaping the sessions

PRELIMINARY RESULTS AND DISCUSSION

The children’s descriptions and definitions of the robot’s behavior are currently being analyzed using as a framework the conceptual model of the rule structure shown in Fig. 2.

The model discriminates between behavioral and technological definitions and maps out the relationships between them. A first discrimination is made between the condition and the action parts of the rule. Both components may be perceived and referred to in behavioral as well as in technological terms. For example, a given situation to which the robot should respond (condition part) may be described as "a bridge " (a behavioral condition), or as "when its light sensor senses the bridge’s color” (a technological description). We assume similar modalities for the action component of the rule. Moreover, we assume a mapping process among behavioral/technological perceptions of both the rule components, as well as the whole set of rules, determining the device's overall functioning. This mapping parallels the bridging discussed above between the types of description.

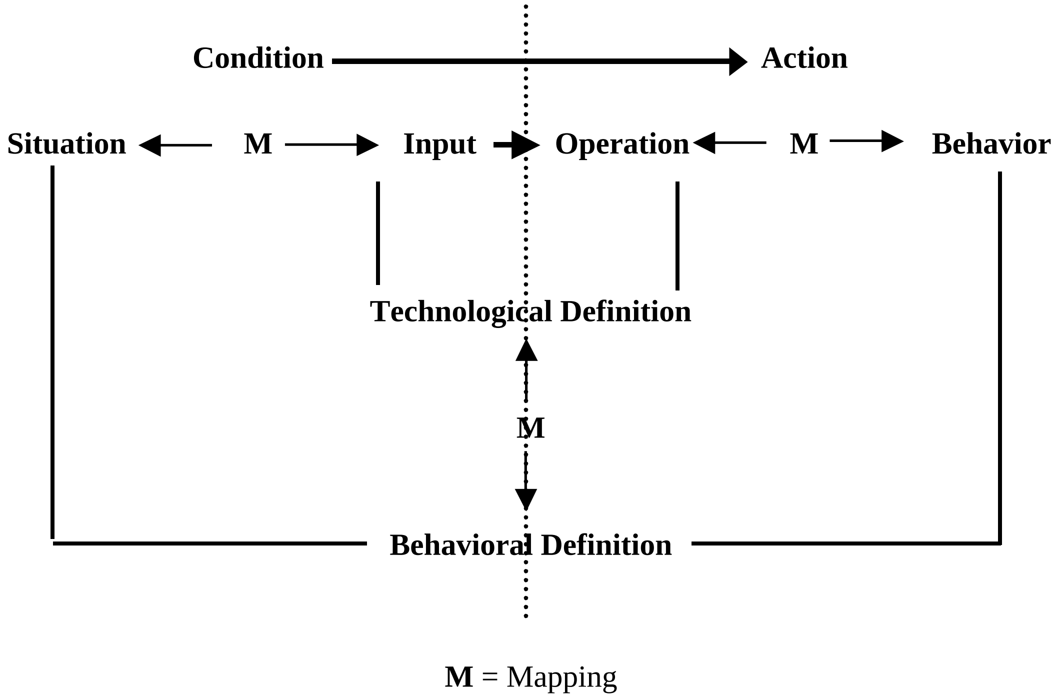

Figure 2: Framework for the analysis of the children's perceptions and definitions of rules in behavioral and technological terms, and the mapping (M) scheme among their components.

Using this model, the children’s performance was analyzed according to several criteria: (a) type of description (rules or scripts); (b) perception modality of the robot’s functioning (behavioral or technological); (c) transition patterns between the various description-types and perception-modalities.

The whole set of results is currently undergoing analysis.

The iconic notation in the computer-control environment appears to be an appropriate intuitive tool for the young children participating in the study. It seems to represent an appropriate "tool to think with" about describing and generating rules of functioning of the technological devices. This role of the notation was evident in the last task of the study. This task focused in the configuration of two interrelated rules, based on the simultaneous consideration of two input signals from two sensors for generating four possible actions. The representational scheme adopted in the iconic interface was of a 2x2 matrix (Figure 1). Understanding of the matrix representational structure is not well established for some of the children. While they could program the robot’s behavior with guidance, they could not actually use the matrix independently as a representation. The children's difficulties in resolving the whole configuration of the rules matrix, was overcome by progressively filling each cell (namely a given combination of inputs and outputs) on the screen's matrix, running the partial solution to evaluate the robot's behavior in that given state of the rules, until completing all options (cells) in a way that satisfies the task's goals. The iconic interface was used to think-by-doing and progressively adjusting the solution.

An initial examination compares the children’s description of robot behavior in the second and fourth sessions. In the second session, the robot is ‘guarding an island’. The island is a white sheet of paper, which is placed upon a dark rug. The robot has a light sensor facing downwards. On the paper, the robot goes forward and on the rug, it turns. The combination of the robot structure, its program and the surrounding environment produce a border-following behavior.   In the fourth session, the robot is passing over a ‘checkerboard’ terrain, of black and white squares. The light sensor is facing down and a touch sensor is facing up. One can place a hat upon the robot, thus pressing the touch sensor. With no hat, the robot moves around the board hopping between black squares. When he reaches a square, he stays there for a moment and then goes off searching for the next black square. With a hat, the robot moves forward in a straight line, ignoring colors on the floor. The program for each is that a white reading by the light sensor produces a straight motion forward, while a dark reading produces a turning motion. In the fourth session, this set of rules defines the behavior when the touch sensor is not pressed. When it is pressed, the robot goes straight forward, both on white and dark parts on the floor.

The children were asked to describe the robot's behavior. Two types of questioning followed. One type is 'jump-starting': the same question is asked in different forms, encouraging description and re-description, which usually enrich the initial version. The second type is a 'decomposing' intervention. When differentiation is not made - in the robot's actions or its relevant environment conditions - different questions aimed at separating them out are asked. The latter kind of questioning is termed as the 'supported' situation, while the first kind is the 'un-supported' situation.

For five children (one child was dropped out because of faulty data collection), comparison of the descriptions of the robots behavior leads to the following conclusions:

(1) With less experience, the rules start out as one condition-action pair. Some, but not all of the children, can provide more complex rules after gaining experience in programming a robot with control rules (2 out of 5 advanced, 1 was advanced from the start). Unsupported by an adult's intervention, these rules are limited to one input and two output actions. Most (4 out of 5) of the children started out with "half rules" - one condition, one action. Three ended up with a whole rule - two conditions, two actions.

(2) With an adult's support, the children can verbalize more advanced rule structures, but at the most one 'half' rule (single condition-action chain) more than that which they can provide on their own.

(3) The behavioral description precedes the technological one in each of the sessions, regardless of their placement along the experimental timeline. This is true for all children but one, who in the later session started out with a technological description. Most of the children (4 out of 5) moved to a technological description with more ease in the later session.

(4) The use of script-like descriptions is transient. It is exhibited during decomposition of the actions of confusing robot behavior (4 out of 5 children). When a child cannot construct a suitable rule/s, he may focus for a while only on the robot's actions, following them from moment to moment. The conditions are ignored and incorporated later on.

(5) Talking about the robot's actions along the borderline between the two input values usually marks the passage to more complex rules. Between 'half rules' and 'whole rules', 4 out of 5 children referred to the edge, or side, dividing the dark from the light colors, and the robot's actions with respect to it (i.e. "turns.. when corners", "but how does he come to the side?")

(6) With support, the children could construct a robot's behavior at the same, or higher complexity than that which they could describe in words, but not lower. All the children succeeded in all the robot programming tasks, in some cases, with the interviewer's support.

What bridges are built?

A gradual shift can be seen from behavioral rule descriptions to technological rule descriptions within each task. As a particular task evolves, description moves from focusing on simple behaviors (one condition-action pair) to the consideration of a compound of a number of behaviors (functional chunks), as well as of relevant contextual information. This process does not happen to a child independent of interaction with an adult. For most of the children, more complex descriptions were provided when an adult intervened and helped them decompose the situation at hand. After the behavioral description has been sufficiently defined, the technological description arises, while preserving the original target behaviors. With experience in the learning environment, the technological description is easier to achieve. As the tasks are more advanced and complex, technological descriptions are more frequent.

Two kinds of transitions are seen when behavioral and technological descriptions are being bridged. One is a decomposition of the actions, while disregarding conditions, seen in the temporary script-type descriptions. Another is a shift in focus of attention on the conditions - from attending to only one environment input value, to the focus on the system's 'fluctuating' behavior along the borderline between two input values. Both of these reflect transitional stages between alternative cognitive models of the robot's behavior (Mioduser, Venezky and Gong, 1996).

Scripts and rules: can children make concrete abstractions of robot control rules?

Initial results show a rule-type description from the outset. Therefore, rule-type thinking dominates children's thinking about such technologies even without learning about them at school. This may be associated with 'thinking in functions', a characteristic of human thought regarding artifacts. This kind of thinking is early to emerge (Kemler-Nelson et al, 1995) and may guide construction of generalizations or abstractions with respect to the robot's behavior. The complexity, or the number of rules the children can combine into a compound behavior, is limited to one rule (2 conditions, 2 actions), but can go beyond that limit with an adult's support.

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