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ABSTRACT

This paper describes two experiments in which children in grades 1, 3, and 5 were given three kinds of spatial perspective-taking problems to solve as quickly as they could: (1) C problems, solvable only by computation (that is, noting which features of a particular object array were closest to another observer in order to estimate how the array appears from that observer's position); (2) R problems, solvable only by applying a rule (such as the generalization that two observers will have the same view of any object array if in the same viewing position and different views of it if in different viewing positions); and (3) RC problems, solvable either by computation or by rule. The task conditions were such that computation-based solutions ordinarily required several seconds to execute whereas rule-based solutions could be achieved with zero-order latencies. Older children proved likelier than younger ones to solve R problems correctly, solve them with zero-order latencies, and verbalize rule use in inquiry. Latency and inquiry data suggested that the children who used the rule to solve R problems also chose to solve RC problems by rule rather than by computation. It was concluded that a number of subjects possessed the rule, consciously and deliberately used it in solving concrete perspective-taking problems, and believed in its general veracity enough to rely on it when they did not have to (RC problems). (Author/SB)

Solving Spatial Perspective-Taking Problems by Rule vs. Computation: A Developmental Study

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Running head: Rules vs. Computation.

Abstract

A distinction was made between two aspects of spatial perspective-taking competence: (1) rules, such as the generalization that two observers will have the same view of any object array if in the same viewing position and different views of it if in different viewing positions; (2) computation, such as the cognitive process of noting which features of this object array are closest to another observer for the purpose of estimating how the array appears from that observer's position. Children of grades 1, 3, and 5 were given three kinds of problems to solve as quickly as they could: (1) C problems, solvable only by computation; (2) R problems, solvable only by applying the above rule; (3) RC problems, solvable either by computation or by rule. The task conditions were such that computation-based solutions ordinarily required several seconds to execute whereas rule-based solutions could be achieved with zero-order latencies. Older children proved likelier than younger ones to solve R problems correctly, solve them with zero-order latencies, and verbalize rule use in inquiry. Latency and inquiry data suggested that the children who used the rule to solve R problems also chose to solve RC problems by rule rather than by computation. It was concluded that a number of subjects possessed the rule, consciously and deliberately used it in solving concrete perspective-taking problems, and believed in its general veracity enough to rely on it when they did not have to (RC problems).

Solving Spatial Perspective-Taking Problems by Rule vs. Computation: A Developmental Study

A distinction can be made between rules and computation in the area of spatial perspective-taking and its development. Let S represent the subject, X an object array, and O another person who views X from a station point different from S's. Computation refers to the actual cognitive processes S uses to estimate ("compute") how X appears to O. S sees X, O, and the spatial relation between X and O, and from this visual information somehow constructs a representation (accurate or inaccurate) of how X looks from O's perspective. Several possible computation processes have recently been investigated (Huttenlocher & Presson, 1973; Marmor, 1975; Shantz, 1975). S might try to rotate X mentally until O's side of X is visualized as facing S; conversely, S might try to rotate him/herself imaginally into O's position. Another process would be to infer from the visual information that one object in the X array partly blocks O's view of another object, that this object appears right-rear of that one from O's point of view, etc. We know very little at present about the effects of developmental and individual differences in cognitive abilities on what computation processes are spontaneously applied with what results to what kinds of S-O-X problems.

Rules refer to general relationships among observer positions and observer visual experiences, relationships which are essentially invariant across Xs. The fact that these rules hold true regardless of the specific physical properties of X is one of the things that distinguishes them from computation. From example, if S is to determine how X looks to O by means of mental rotation or some other computation procedure, s/he obviously needs to be able to see X or otherwise obtain detailed information about its physical characteristics and orientation. Contrast this with the perspective-taking rule which asserts that X would appear to S as it does to O, if S were also to view X from O's station point (cf. Fishbein, Lewis, & Keiffer, 1972). An S who knows this rule obviously needs no specific information at all about a given X to be sure that the rule will hold true for that X. Like computation processes, general rules of this sort can play important roles in the solving of concrete perspective-taking problems. It is hard to see why an S would spontaneously try to rotate him/herself mentally into O's position, for instance, unless s/he "knew" the abovementioned rule in some sense. Conversely, like rules, computation processes can become general, across-tasks solution strategies--general "rules of procedure," in effect. The growing child could therefore come to believe that, say, rotation of self or array is a sensible solution procedure to try for any X, just as s/he could come to know the rule that, for any X, his/her view of X would be identical to O's if s/he were at O's station point.

A fairly sizable literature on the developmental aspects of spatial perspective-taking has accumulated since Piaget and Inhelder's (1956) pioneering work (see Shantz, 1975). However, the distinction between acquiring computation procedures and acquiring general rules about perspectives has not been made either clearly or often, even at the purely conceptual level (Fishbein et al., 1972; Flavell, 1974; Piaget & Inhelder, 1956). It does not appear to have been made at the experimental level at all, prior to a recent study by Salatas and Flavell (1976). They assessed 6- and 8-year-olds' (kindergarten and second grade children's) command of two rules: (1) one position - one view--an observer has one and only one view of X from any single viewing position; and (2) different positions - different views--a particular view cannot normally[1] be seen from more than one viewing position around X, and hence different observer positions normally imply different views. The X in this study consisted of three girl dolls seated diagonally on a square board. There were four "observers," one on each side of the board: S, the child subject (0°); a small Donald Duck doll (90° to S's right); Goofy (180°); and Mickey Mouse (270°). The child was first taken to each of these four viewing positions in turn and asked to select that picture (color photograph), from the set of four spread before him/her, which showed exactly how the dolls looked from that position. If the child chose the wrong picture his/her error was corrected and s/he was asked to choose again. Almost all children at both age levels were selecting the correct picture on the first try by the time they reached the third or fourth viewing position.

Understanding of rule 1 was then tested by asking the subject to evaluate, one at a time, each picture from a larger set by answering the question, "Does this picture show how the dolls look to ________ (e.g., Mickey)?" This serial-choice procedure allowed the child to end up having selected more than a single picture as representing that O's view. If the child did select more than one, s/he was first asked if the ones selected were all exactly the same (all children said they were not), and then asked if s/he still thought they all showed exactly how the dolls looked to that O. The child was credited with rule 1 if s/he consistently either chose only one picture initially, or else spontaneously reduced his/her selected set down to one following the second question. The child was next asked if the selected picture(s) could also show exactly how the dolls looked to another O in a different location (e.g., Goofy), then another, etc. The child was credited with rule 2 if s/he consistently said it or they could not.

The results suggested that rule 1 may be acquired earlier in childhood than rule 2. Most subjects of both age levels seemed to recognize that no more than one depicted view could be seen from a single station point. In contrast, only about one-fourth of the 6-year-olds and about two-thirds of the 8-year-olds consistently denied that one O's depicted view could be seen by other Os at different station points. In addition, command of rule 2 did not appear to be as general and context-independent as we had expected, at least at this age level and in this task setting. A child could initially either (a) correctly identify an O's depicted view, (b) make a nonegocentric error (selecting neither O's view nor the child's own), or (c) make an egocentric error (selecting his/her own). Which of these s/he did seemed to have some influence on the child's subsequent adherence/nonadherence to rule 2. The child was likeliest to go on to say that the other observers could also see that same view, contra rule 2, if that view were egocentric (c), less likely if it were nonegocentric but incorrect (b), and least likely if it were correct (a). At the same time, the rule-computation distinction was clearly evident in the data. Individual subjects could and did make computation (view-selection) errors while still acting as if they fully understood rules 1 and 2, and correct view selections were sometimes followed by attributions of those same views to observers in other positions.

The purpose of the present study was to follow up and extend the research of Salatas and Flavell (1976). The knowledge about perspectives investigated was their rule 2 (different positions - different views) plus its corollary, namely, that two *O*s looking from the same station point will have the same view of *X* (same position - same view). The latter will be recognized as the rule mentioned at the beginning of this article, applied to two *O*s rather than to *S* and *O*. Children were presented with three types of problems: C, R, and RC. In C (computation) problems, the child saw Salatas and Flavell's three-object *X*, an *O* located to the child's left of *X*, and two pictures (photographs). One picture showed *O*'s view of *X* and the other showed the view of *X* from the opposite side of *X*, to the child's right. The child's task in this essentially conventional perspective-taking problem was to compute *O*'s view from the visual evidence and select the correct (*O*-view) picture. In R (rule) problems, the child again saw *O* and the two view pictures, but *X* was covered with a box so the child could not see it. *O* could see the array through an opening on his side of the box, however, and there was a similar opening on the opposite side from *O*. A second observer was also shown looking at *X*, either from *O*'s station point (on R_s problems) or from the opposite side (on R_d problems). The child was informed which of the two pictures showed the second observer's view, and was told that this information was a "hint" that would help him/her figure out which picture showed *O*'s view. It is apparent that, despite the impossibility of direct computation in either case, R_d problems can be solved by using rule 2 and R_s problems by applying its corollary. RC_s and RC_d (rule or computation) problems were identical to R_s and R_d problems, respectively, except that X was not covered by the box and hence was visible to the child as well as to the observers. A child could thus solve RC problems either by rule, by computation, or by some combination of the two methods. Subjects were urged on all three types of problems to indicate their picture choice just as soon as they were sure of it, and response latencies were recorded. The experimental set up and procedures were such that it normally took subjects a matter of seconds to solve problems by computation. In contrast, latencies for rule-based solutions could be zero-order, since the second observer's picture was known to the child before the signal to solve the R and RC problems was given.

Comparisons with the Salatas and Flavell (1976) study may be useful in highlighting special features of this study. Most important, that study sought primarily to assess rule knowledge; this study, both rule knowledge and rule use. In that study, the child could only show his/her knowledge of rule 2 by the answers s/he gave to explicit questions about whether other Os in other viewing positions could see X as this O does. In this study we also asked the child questions, but only in a posttest inquiry. We were primarily interested in when--or indeed, whether--the developing elementary school age child would nonverbally testify to the possession of rule knowledge by actually using that knowledge, "on line," to solve real if somewhat peculiar perspective-taking problems. A rule user could solve R problems at least as accurately and much more quickly than C problems, since computation processes obviously take time and are potentially subject to "performance errors" even in a skilled perspective-taker.

We also have the possibility, as Salatas and Flavell (1976) did not, of estimating how much the children trust the rules and how explicitly they understand them. Suppose a child solves all three types of problems quite accurately, the C problems in a few seconds and the R problems in a fraction of a second. How rapidly does s/he solve the RC problems? It might depend upon his/her developmental level. Older subjects, for whom the rules have perhaps become explicit, completely general, semi-necessary truths, might solve RC problems exactly like R problems, feeling sure that subsequent computation would always confirm picture selections based solely on rule use. Younger ones, for whom the rules may not yet have become as well articulated and as context-free, might elect to solve them like C problems, thereby showing an overall strategy of using rules when necessary but computing when possible. Still other, intermediate solution patterns are imaginable, such as computing on initial RC trials in order to verify the trustworthiness of the rules and later switching to a rule-only strategy in order to achieve the rapid solutions the experimenter wants. These experimental features, together with others to be described, should provide a richer picture than the Salatas and Flavell (1976) procedures could of the development of rule knowledge as well as rule use.

There were also other differences between the two studies. Preliminary instructions and familiarization with task requirements, procedures, and materials were more extensive in the present study. There were also more conventional (C type) view selection test trials on which to gain practice in computing; only one O to select a view picture for; and only two view pictures present to choose between, neither of which tempts egocentric responding by showing the child's own view. These and possibly other features seem to have resulted in a distinctly higher level of computation performance in the present study, especially in the second of our two experiments. This is a highly desirable outcome, because it provides added assurance that the children really understood the task demands--an everpresent problem in spatial perspective-taking tasks. Finally, we did not have to worry about the child's ability to use rule 2 being dependent on the correctness or certainty of the child's initial view computation: the child did not have to compute the second observer's view in R and RC problems at all, since that view was identified for him/her by the experimenter. In the three types of problems used in this study, then, the conceptual distinction between rules and computation seems clear, and the experimental unconfounding of the two seems complete.

Two experiments were done. Since the two were quite similar and their results will be repeatedly compared, they are reported together below.

METHOD

Experiment 1

Subjects

Seventy-four children randomly selected from the first, third, and fifth grades of an elementary school in a largely middle-class suburb of Minneapolis-St. Paul participated in this experiment. Two third grade males were tested initially but excluded because they were suspicious of being tricked. The remaining 72 children were 12 boys and 12 girls at each of the three grade levels. The mean age of the first graders was 6 years 8 months, with a range of 6 years 3 months to 7 years 0 months. The mean age of the third graders was 8 years 7 months, with a range of 8 years 3 months to 9 years 0 months. The mean age of the fifth graders was 10 years 7 months, with a range of 10 years 3 months to 10 years 11 months.

Apparatus and Materials

Three dolls (12 cm x 14 cm x 19 cm) in different colored dresses were placed diagonally (see Figure 1, Salatas & Flavell, 1976) on a 49.5 cm x 49.5 cm board which rotated on a Lazy Susan. Each doll sat facing forward with a bottle in its right hand. Two dolls (7 cm x 5.5 cm x 14 cm), Mickey Mouse and Donald Duck, served as "observers." Donald was always situated at the side to the child's left. On R and RC trials only, Mickey was seated either on the same side as Donald (R_s and RC_s trials) or on the opposite side (R_d and RC_d trials). Four colored photographs (12.5 cm x 17.5 cm) depicted the four cardinal views of the array; one test pair consisted of the front and back views of the dolls, the other of the two side views of the dolls. For each trial, one test pair was placed in front of the child on a 35 cm x 40 cm x 5 cm response box. A 60 cm x 52 cm x 38 cm cardboard box covered the stimulus array at the beginning of every trial. Two 20 cm x 24 cm "windows" were cut in the middle of opposite sides of this box, permitting the observer dolls, but not the child, to "see" the stimulus array. A 25 cm x 40 cm x 2 cm lid covered the two photographs, leaving exposed two response buttons located to the right of the photographs. When this lid was removed, a micro-switch activated a timer (Industrial Timer, model C-100) and depression of either response button stopped it, thereby recording response latencies.

Procedure

Pretraining session. The child was seated behind Donald, both facing the dolls. For each of the four cardinal views of the dolls, the experimenter instructed the child to "point to the picture that shows how the dolls look to Donald" from among the four photographs. Incorrect responses were corrected by pointing out the view's distinctive features in a standardized manner and the child was subsequently retested on that view. Next the child was seated at the side to Donald's right. Beginning with the dolls facing the child, the experimenter presented the child with the photograph of Donald's view and asked, "When the dolls are turned like this, is this how they look to Donald?" This procedure was repeated for the remaining three views. An incorrect response was corrected in a standardized manner, as above, and the child was subsequently retested on that view in a forced choice situation using the other photograph of the test pair as the comparison picture.

Training session. The children were trained on the three types of problems in this fixed sequence of four trials: C, C, R_s, and R_d. The child was told to close his/her eyes while each task was being set up. The experimenter then set up the first C trial by covering the dolls with the box, placing the test pair of photographs which included Donald's view on the response box, and covering them with the lid. After reopening his/her eyes, the child was told that when the first experimenter said "Go," the second experimenter would simultaneously uncover the dolls and the pictures, and the child should then indicate which picture shows Donald's view by pushing the button next to it. Errors were corrected as in the pretraining. Additional information was presented on the second C trial: "There is always a right answer. One picture always shows you how the dolls look to Donald, and one doesn't. But sometimes that right answer will be down here, and sometimes it will be up here. Each time when Cindy sets it up, she turns the dolls around, so how it was before won't help you. You'll have to figure it out all over again each time. OK? Now you noticed that when we uncovered the pictures, this timer went around and when you pushed this button, it stopped. Because the timer is going, we want you to push the buttons as fast as you can, but not until you have figured out the r ht answer. So first you figure out which one Donald sees, then you push the button. Now, if you push the wrong button, tell us and we'll let you do it over again. (The trial was repeated later in the session when this happened.) Each time before you start we want you to put your hand up here (on the table) so you can get to the buttons. OK? Let's try it. Go."

Next, the child was presented with a R_s° trial. While the child's eyes were closed, the experimenter placed Mickey next to Donald and a tag with a picture of Mickey on it under the corresponding picture. The picture of Mickey on the tag was clearly visible while the pictures themselves were covered. The child was instructed: "Now we have Mickey with us. He is in the same place as Donald. He's looking through the same window. This tag tells you that this picture is how the dolls look to Mickey. Now we're still interested in how the dolls look to Donald. Mickey will be here a lot, and each time I'll tell you what he sees, but we never want to know what Mickey sees--only Donald. I'll never ask, 'How do the dolls look to Mickey?' but always, 'How do the dolls look to Donald?' This tag is a hint. If you know how the dolls look to Mickey, that can help you figure out how they look to Donald. Sometimes Donald will see the same thing as Mickey, so when I ask, 'How do the dolls look to Donald?' this (shakes tag) will be the right answer. But sometimes Donald won't see the same thing as Mickey, so when I ask, 'How do the dolls look to Donald?' this will be the right answer. Each time you'll have to figure out if the dolls look the same or different to Mickey and Donald. OK? Now, this time Cindy isn't going to uncover the dolls. And you'll still have to figure out, using the hint, how the dolls look to Donald. OK? Go." Errors were corrected in the following manner: "I liked the way you pushed the button, but this is the right answer. Remember when we said that sometimes Donald sees the same thing as Mickey? Well, this time the dolls look the same to Donald and Mickey. Donald and Mickey are in the same place. They are looking through the same window. This time they see the same thing. But maybe next time they won't. OK?"

Finally an RC_d trial was introduced. The experimenter placed Mickey on the side of the box opposite Donald's side, rotated the dolls, and placed the appropriate photographs on the response box, with Mickey's tag under the photograph of his view. "This time Mickey is over here. He's in a different place than Donald. He's looking through a different window. And this picture shows how the dolls look to Mickey, though we're still going to figure out how they look to Donald. This time Cindy is going to uncover the dolls. OK? Go." Errors were corrected in the following manner: "Good, only this is the right picture. You can figure this one out a couple of ways. Remember we said that sometimes Mickey sees the same thing and sometimes he sees something different.

Well, this time Mickey sees something different from Donald. He's in a different place. He's looking through a different window. So this is the right answer. Also, does Donald see the fronts or the backs? The backs? Which one of these is a picture of the backs. This one. That's right. So there are a couple ways you can do this. OK?"

All children received these four training trials in the same order. The nature of Donald's view and the location of the correct photograph on the response board was given in a fixed, random order over trials. All children successfully completed the training session.

Test trials. Each child received 24 test trials, 8 each of type R, C, and RC; within R, there were 4 trials each of subtype R_s and R_d, and within RC, 4 trials each of RC_s and RC_d. Trials were presented in four uninterrupted blocks of six trials. Each block contained two C trials, and one each of subtype R_d, R_s, RC_d and RC_s. Each subject received the three types of trials in a fixed alternating order so that no type of trial was experienced twice in a row. This order remained fixed over trial blocks. All six possible orders of R, C, and RC problems were used across subjects. The location of the R_s, R_d, RC_s, and RC_d trials and the two C trials within a block of six was such that each occupied a different ordinal position across the six orders. The location of the correct photograph on the response board on each trial was given in a fixed random order across all subjects. For each type of R, C, and RC trial each of the four cardinal views was Donald's view twice during the session.

Before each R or RC trial Mickey's location was pointed out by "He's in the same (a different) place than Donald," and the location of the tag by, "This is how the dolls look to Mickey." On C trials it was mentioned that Donald was all by himself. The child was also told on each trial whether or not the box was coming off.

Inquiry. After completion of the last test trial, the child was asked how s/he solved the R and C problems. Questions were asked in a standardized fashion and problems were reconstructed as memory aids whenever necessary. Unfortunately, the inquiry was not added to the procedure until 3 first graders and 5 fifth graders had been tested.

Experiment 2

It was decided to do an "improved" replication-with-variation for several reasons. First and foremost, an apparent inability on the part of some children to assimilate quickly the information describing the upcoming trial sometimes seemed to result in careless errors. Because the rapid, uninterrupted sequence of 24 test trials might have been responsible for this inability, a 5-second "think period" was inserted in between the description of each trial and the "Go" command in Experiment 2. It was hoped that this modification would help subjects perform at the highest level of which they were capable. Second, the experimenters noticed that children with low latencies often inched their fingers toward the correct response button on R and RC trials during the description of the trial; finger movements, therefore, were systematically recorded in Experiment 2. Third, children who made incorrect choices on trials during the training session received feedback about their performance that was not received by children who made correct choices. This feedback contained potentially useful information about solution strategies. Consequently, in Experiment 2 the experimenter gave the same feedback following correct and incorrect responses. Fourth, the training session exposed the children only to C, R_s, and RC_d trials prior to the test trials. In Experiment 2, therefore, they were also given practice R_d and RC_s trials after the training session. Since no feedback was given on these two trials, they were indistinguishable from test trials from the subject's point of view. Finally, the inquiry was unsystematic in its use of trial reconstruction to elicit reports of solving strategies. The inquiry in Experiment 2 therefore had the child complete the appropriate trial immediately before being asked how it was solved. In addition, the child was asked how an RC trial was solved as well as an R and a C trial; on all three types, the children were also asked what they did during the think period.

Subjects

Fifty-two children randomly selected from the first and third grades of another elementary school in a primarily middle-class suburb of Minneapolis-St. Paul served as subjects; the performance of the fifth graders in Experiment 1 was good enough to make it seem unnecessary to include subjects of this grade in Experiment 2. Four children were dropped from the analysis, one first-grade girl because 1/5 of her latencies were over 15 seconds, and two first-grade boys because of inattention during the session. The remaining 48 children were 12 boys and 12 girls at each of the two grade levels. The mean ages of the experimental samples were 6 years 10 months, with a range of 6 years 7 months to 7 years 2 months for the first grade and 8 years 11 months, with a range of 8 years 6 months to 9 years 3 months for the third grade.

Apparatus and Materials

The apparatus and materials were the same as in Experiment 1 with the following addition. A 5 cm x 8 cm x 4 cm box with a button and a light was connected to two timers (Hunter, Models 100-C and 111-C). After each trial had been described to the child, the experimenter pushed the button. After a four second interval the light came on, at which time the experimenter said "Ready"; one second later the light went off, at which time the experimenter said "Go." Both the timer box and the timers were placed under the table so that only the experimenter could see them.

Procedure

Pretraining session. The pretraining session followed the same procedure as in Experiment 1.

Training session. As in Experiment 1, children were trained on two C trials followed by an R_s and an RC_d trial. Training on C trials followed the same procedure as in Experiment 1 with these additions. The five-second think period was explained at the end of the first C trial's description with the instructions: "Each time I'll give you a couple of seconds to get ready and think about what you're going to do. Think about what you're going to do. (Experimenter pushes button on timer box.) Ready., Go." Toward the end of the second C trial's description the experimenter said, "Each time before you start we want you to put your hand up here (on table) so you can get to the buttons. If you know which picture Donald sees before we take the box off you can put your finger on the button" (experimenter demonstrates). After the child completed each of the C trials, the following feedback was given regardless of the correctness of the child's response. "That's right (or: I like the way you pushed the button, but this is the right answer). Donald can see the bottles and this is the picture with the bottles, isn't it?" Training on the R_s trial was the same as in Experiment 1 except for the addition of the think period instructions and the following feedback given independently of the correctness of the response: "That's right (or: I like the way you pushed the buttons, but this is the right answer). Mickey is here in the same place as Donald. This (points to Mickey's picture) is how the dolls look to Mickey and from that you can figure out which one Donald sees." Training on the RC_d trial had the same additions as the R_s trial. Feedback on this trial consisted of "That's right (or: I like the way you pushed the button, but this is the right answer). There are a couple of ways you could have figured this one out. First, Mickey is over there in a different place than Donald. This (points to Mickey's picture) is how the dolls look to Mickey and from that you can figure out which one Donald sees. Also Donald can't see the bottles, can he? And this is the picture without the bottles."

Practice trials. After the training session the children were given an R_d and an RC_s trial without feedback. After the first trial, the child was reminded: "Remember, push the buttons as fast as you can and if you know which picture Donald sees before we take the box off, you can put your finger on the button." With the exception of this addition the instructions before each of these trials was the same as in the training session.

Test trials. The number of trials and order of their presentation were the same as in Experiment 1.[2] During the think period of each trial the two experimenters independently noted the position of the child's fingers relative to the response buttons. Finger movements were coded in terms whether the child's fingers were (1) on his/her lap, (2) on the table, (3) on the response board in between the buttons, (4) next to a button, or (5) on a button.

Inquiry. After completion of the test trials the child was questioned about how s/he solved the three types of trials. Before each type of trial the child was instructed, "After you finish this trial I'm going to ask how you figured it out. OK?" The child was then administered that type of trial and immediately asked in a standardized fashion what s/he thought about during the think period and how s/he chose his/her answer. The order of questioning was C, RC_d, and R_s for all children.

RESULTS

Response Correctness

The most important of the dependent measures examined in the two experiments was response correctness. It was first used to find out whether the subjects seemed to construe rule 2 and its corollary as two distinct and different rules or as two indissociable parts of the same rule. The former alternative would be supported by two possible findings. First, there might be little correlation, within subjects at each grade level, between the number of correct responses on the four R_d trials and the number of correct responses on the four R_s trials. Second, subjects might perform systematically better on one type of trial than on the other. A result of this second type would suggest that one rule is acquired earlier, or at least becomes available for use on R problems earlier, than the other. Product-moment correlations between R_d and R_s scores within grades 1, 3, and 5 of Experiment 1 and grades 1 and 3 of Experiment 2 were, respectively, -.05, .40, .69, .18, and .48. T-tests showed that the first graders performed significantly ($p < .01$) better on R_d than on R_s trials in Experiment 1 and near-significantly ($p < .06$) better in Experiment 2; there were no reliable differences in the three older groups. In the two experiments, a total of 10 first graders and 2 third graders chose the untagged picture on either 7 or 8 of the 8 R trials, thereby appearing to solve R_d problems better than R_s problems. Inquiry data were available on 10 of these 12 subjects. Of these 10, 8 reported some version of the simple, nonperspectival rule that, on R_d and R_s trials alike, if this (tagged) picture is Mickey's, then the other (untagged) one is Donald's, e.g., "This is for Mickey, so this is for Donald." Four subjects who did not meet this 7/8 response criterion also verbalized the same rule during inquiry. (In contrast, only two subjects chose the tagged picture on 7 out of 8 trials, and neither verbalized any sort of always-pick-the-tagged-picture rule in inquiry.) If we exclude from the analyses only the 3 first graders in Experiment 1 and the 4 in Experiment 2 who chose the untagged picture at least 7 times and also verbalized the above-mentioned nonperspectival rule in inquiry, the first grade correlations become .09 and .52, respectively, and the differences between R_d and R_s scores in these two groups are no longer statistically reliable. There appears, therefore, to be no compelling evidence that R_d and R_s problems were perceived by the children as being two different types of problems or that one rule develops earlier than the other.

Accordingly, in all subsequent analyses R_d and R_s trials and RC_d and RC_s trials have been collapsed into R and RC trials, respectively, and "rule 2" will henceforth refer undifferentiatedly to rule 2 and its corollary.

Since there were only two pictures to choose from on each trial, a subject could naturally be correct on 4 of the 8 trials of each type by chance alone. A criterion of at least 7 out of 8 trials correct was therefore adopted and taken to reflect good ability to use rule 2 on R problems and to compute on C problems. Which of these two abilities criterion performance on RC trials reflected could, of course, not be determined without additional evidence. Table 1 shows the number of children in each grade who met this criterion for each type of problem. In Experiment 1 performance on each type of problem

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Insert Table 1 about here

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improved with age: for R problems, $\chi^2(2) = 14.82$, $p < .001$; for C problems, $\chi^2(2) = 6.41$, $p < .05$; and for RC problems, $\chi^2(2) = 15.73$, $p < .001$. It is apparent that very few of the first graders did well on the R problems. In Experiment 2, none of the age differences were significant, although there was once again a tendency for the younger children to perform relatively more poorly on the R problems. Table 1 shows that the performance of the first and third graders in Experiment 2 was rather similar to that of the third and fifth graders in Experiment 1, respectively, both in absolute level and in profile across problems. No sex differences were apparent in either experiment.

A variety of analyses of variance were also carried out on the picture choice data, but they added no new information of interest. For example, a 3(Grade) X 2(Sex) X 3(Problem: R vs. C vs. RC) analysis of variance was computed on the number of correct responses in Experiment 1. Significant effects were found for Grade, $F\ (2, 66) = 18.41$, $p < .0005$, and Problem, $F\ (2, 132) = 5.36$, $p < .01$, and the Grade X Problem interaction, $F\ (4, 132) = 2.45$, $p < .05$. The comparable analysis of the Experiment 2 data yielded only a reliable effect for Problem, $F\ (2, 88) = 7.22$, $p < .005$.

The design of the R and C problems allowed the independent assessment of the ability to use rule 2 and the ability to infer perspectives in the normal fashion. The two abilities might, however, be correlated within subjects of the same age. Fourfold contingency tables were constructed showing the number of subjects in each of the five groups who did and did not meet the 7/8 criterion on each of the two types of problems. None of the five χ^2 values were significant, suggesting that there may be no age-independent association between the two abilities, at least in this task setting (these and all other chi-squares of $df = 1$ were Yates-corrected).

Response Latency

A critical difference between the R and C problems was that the information needed to solve R problems was available before the onset of the trial, while that needed to solve C problems was only available at the onset of the trial when array and pictures were exposed. C problems typically required several seconds to solve while R problems, being "pre-solvable," were often responded to in less than one second after trial onset. Solving our C problems in less than one second is possible but difficult. In the two experiments, a total of 960 C problems were administered; only three of these problems were solved in less than one second, and one of those three was solved incorrectly. Consequently, response latencies less than one second were considered a probable indication of rule use.

Table 2 shows the frequency distribution of the number of children in each grade of the two experiments classified according to the number of response latencies less than one second (zero-order) on the R problems. Children competent in using rule 2 might be expected to have

Insert Table 2 about here

zero-order response latencies on most of the R problems; children not competent in using rule 2 might be expected to have no zero-order response latencies on the R problems. As Table 2 shows, the distributions tend to be bimodal, with more than half of the subjects in each group showing either 0 or 7-8 zero-order latencies. Comparing the number of children in Experiment 1 who had no zero-order response latencies with the number who had 7 or 8 at each grade level revealed an interactional pattern. Half of the first and third graders but only 5 of the fifth graders had no zero-order latencies; in contrast, 1 first grader, 4 third graders, and 10 fifth graders had at least 7. A similar pattern appeared in the Experiment 2 data: 11 first graders vs. 5 fifth graders had no zero-order latencies whereas 6 first graders vs. 14 third graders had at least 7. Both of these comparison were reliable: $\chi^2(2) = 15.70$, $p < .001$ for Experiment 1 and $\chi^2(1) = 3.91$, $p < .05$ for Experiment 2. In addition, the number of first and third graders in Experiment 2 in these categories is again similar to the number of third and fifth graders in Experiment 1 in these categories, respectively. Latencies were also recorded on the two R and two RC training trials in Experiment 2; 3 first graders and 12 third graders showed a zero-order latency on at least one of these four trials.

RC problems allowed assessment of choosing to use rule 2 that was independent of the ability to use rule 2 as assessed by R problems. This allowed the identification of children who could use rule 2 but did not when given the opportunity to use computation instead. There proved to be very few such children, however. Of the 12 first graders and 18 third graders in Experiment 2 who could use rule 2 according to our 7/8 response correctness criterion on R trials, 10 and 17, respectively, reported solving the RC inquiry trial by rule rather than by computation. Moreover, the product-moment correlations between the number of zero-order response latencies on the R and the RC problems were: .86 for the first graders, .91 for the third graders, and .95 for the fifth graders in Experiment 1; .95 for the first graders and .89 for the third graders in Experiment 2. The two halves of each block of six test trials each contained one R, one C, and one RC trial. The set of 24 test trials therefore made up a succession of 8 of these half-blocks. There were 61 subjects in the two experiments who had both one or more zero-order latency R trials and also one or more zero-order latency RC trials. The first short-latency RC trial occurred in the same half-block as the first short-latency RC trial for 23 subjects, in the just previous half-block for 9 subjects, and one, two, three, four, and five half-blocks later for, respectively, 14, 8, 4, 2, and 1 subjects. There was no tendency for these latter 29 subjects to be younger than the other 31. Thus, although virtually all subjects who solved R problems via rule 2 also solved RC problems the same way, some of them may have also or instead computed on one or more additional RC trials after beginning to use rule 2 on R trials. That is, some children did appear to show the intermediate solution pattern mentioned in the introduction.

Thus far we have discussed two indicators of rule 2 use: response correctness and response latency. As the interpretation of subjects' behavior on RC problems relies exclusively on response latency, it is necessary to examine the relationship between the two. Product moment correlations between the number of correct responses and the number of zero-order response latencies on the R problems were .49 for the first graders, .46 for the third graders, and .33 for the fifth graders in Experiment 1; .55 for the first graders and .62 for the third graders in Experiment 2.

Inquiry

Answers given to questions during the inquiry provided further evidence of ability to use rule 2. In both experiments, the answers were categorized as stating rule 2, stating an inappropriate rule (in all but one case the nonperspectival rule that Donald always sees the untagged picture), stating no rule, and contradictory. Interrater reliability for these four categories $\left(\frac{\text{number of agreements}}{\text{number of agreements+number of disagreements}}\right)$ computed on all subjects was .91 for the first graders, .95 for the third graders, and 1.00 for the fifth graders in Experiment 1; .96 for the first graders and .96 for the third graders in Experiment 2. Since few children were categorized as stating an inappropriate or contradictory rule, these categories were subsequently combined with stating no rule. In Experiment 1, the number of children who stated the rule significantly increased with age. Of the 21 first graders, 19 third graders, and 24 fifth graders who received the inquiry in that experiment, 5 first graders, 13 third graders, and 23 fifth graders stated rule 2, $\chi^2(2) = 25.44$, $p < .001$. In Experiment 2, however, the number of children who stated the rule did not reliably vary with age; 15 first graders and 18 third graders did so.

Finger Movements

The child's finger movements during the think period of each trial were independently coded according to the five categories described in the procedure section. Interrater reliability computed on all trials for 45 children was .99. Since the information needed to solve R problems was available before the onset of the trial, children able to use rule 2 could get ready to respond rapidly by placing their fingers either next to or on the appropriate button. A chi-square analysis was performed on the number of children in each grade who did this on at least 4 of the 8 rule problems, provided that they did not do the same on computation problems; 4 first graders and 11 third graders met this criterion, $\chi^2(1) = 3.49$, $p < .10$.

Response Patterns

Meeting any of the following three response criteria should reflect at least some understanding of rule 2 in most subjects: (1) 7 or 8 R trials correct; (2) stating rule 2 during inquiry; (3) 2 or more R trials with zero-order latencies, provided there was also no evidence from inquiry or pattern of picture choices that the subject was probably following the nonperspectival, untagged-picture strategy (this latter restriction actually excluded only three subjects from meeting criterion 3). Finger movements did not prove to be a sufficiently sensitive measure of rule knowledge to be included as a fourth criterion, and were in any case only recorded in Experiment 2. Table 3 shows the number of subjects in each grade and experiment who met none, any one, any two, or all three of these criteria; the eight subjects in Experiment 1 who had no inquiry are of course excluded. It is evident that the

Insert Table 3 about here

tendency to meet all three criteria increases with age and the tendency to meet none decreases with age, especially in Experiment 1: in Experiment 1, $\chi^2(6) = 22.16$, $p < .005$; in Experiment 2, $\chi^2(3) = 6.34$, $p < .10$. Table 4 shows the patterns of co-occurrence among the three criteria. These three contingency tables indicate that the criteria

Insert Table 4 about here

are highly correlated with one another over the total sample of 112 subjects; the correlations within each grade also tend to be moderate to high (recall, for example, the .33-.62 within-grade *r*s between correct R trials and zero-order latency R trials reported earlier).

More interesting are the numbers of subjects in the off-cells of these three tables. As the left and center tables show, if a subject correctly solved 7 or 8 R problems and/or had 2 or more short-latency R trials, s/he was extremely likely to go on to verbalize rule 2 knowledge in the inquiry. In fact, a few subjects spontanaously verbalized this knowledge during the training or test trials. These findings suggest that those rapid, correct responses were mediated by rule 2 knowledge rather than by something else. They also suggest that rule use during R trials was a conscious, deliberate affair, at least for many subjects; the finger movement data also supports this interpretation. On the other hand, the entries in the lower left quadrants of the left and center tables and the upper right quadrant of the right table indicate that consciousness of the rule came late rather than soon for a number of subjects, that is, not until the last few trials or even the inquiry. Of the 13 subjects who met only one of the three criteria (Table 3), that one criterion was Inquiry in 10 cases. Finally, the right table in Table 4 shows that 13 subjects responded correctly but slowly to R problems; moreover, 12 of these children verbalized the rule during inquiry. We can think of several possible explanations for this curious response pattern but have no basis in the available evidence for favoring any one or combination of them over others.

DISCUSSION

These two experiments have suggested some interesting conclusions about both the psychological nature and the ontogenetic development of rule 2 (different positions--different views) and its corollary (same position--same view). We shall discuss first their nature and subsequently their development. In contrast to rule 2 and rule 1 (Salatas & Flavell, 1976), there is little positive evidence that rule 2 and its corollary function psychologically as two distinct rules, at least in this age range and task setting. Neither seemed accessible to children more easily or at an earlier age than the other, and their use/nonuse in solving R problems was at least moderately correlated in all but the Experiment 1 first grade group. This finding is less predictable and self-evident than it may seem. In the first place, rule 2 does not logically imply its corollary or vice versa. Moreover, one can imagine rule or task variations that might differentiate the two. For instance, if S and O played the roles that O_1 and O_2 did in our task, young children might accept the S-O variant of the corollary (i.e., S would consistently attribute S's view to O when both are in the same position) but not the S-O variant of rule 2 (i.e., S would not consistently attribute a different, non-S view to O when they are in different positions, perhaps because of egocentric lapses). In fact, it would be interesting to find out if there is any systematic developmental ordering among these four acquisitions, that is, among the O_1- O_2 and S-O variants of both rule 2 and its corollary. Even in the present, O_1-O_2 case, children might prove less steadfast in their adherence to rule 2 in comparison to the corollary if the two Os' positions were less clearly different from one another than the 180° separation used in the present experiments. It should not be difficult to explore such possibilities experimentally.

There was also a variety of evidence for the psychological reality and salience of rule 2 (hereafter taken to include its corollary) in the thought and behavior of many of our child subjects. The older ones, especially, appear to have (1) deliberately used it, (2) consciously represented it, and (3) strongly believed in it.

As to use, these subjects correctly solved perspective-taking problems which required the application of the rule (R problems). Their very short response latencies on these problems also suggested the deliberate, planful use of rule 2. Similarly, when asked in inquiry to explain how they solved R problems, their verbal reports suggested that they had indeed solved them by using rule 2. In some cases the evidence for rule use was particularly strong. Examples include unbroken strings of zero-order latencies and correct responses that began with the first R or RC training trial, spontaneous rule descriptions given prior to inquiry, and exclusive references on the RC inquiry trial to tag and observer locations rather than to equally visible observer-array relations. Salatas and Flavell (1976) showed that many middle-childhood subjects have knowledge of rule 2. Our study shows that they will also spontaneously use that knowledge in problem-solving situations that only tacitly call for it.

Much of the evidence for deliberate rule use is also evidence for its conscious representation, e.g., short latencies and descriptions of rule-based solution procedures. Particularly striking were the frequently seen abrupt and irreversible changes from computation-length latencies to zero-order ones on the <u>n</u>th R trial. Such children acted for all the world as if they had suddenly caught on to how R problems could be solved ("I know the trick", exclaimed one third grader). In view of the fact that children of this age are not generally credited with particularly good introspective skills, it also seemed noteworthy that more subjects met the verbal Inquiry criterion than either of the two nonverbal ones (Table 4).

Subjects' behavior on RC problems clearly showed that those who understood and thought of using rule 2 on R problems usually placed a great deal of credence and trust in it. Within-grade correlations between the number of R and RC short-latency trials ranged from .86 to .95, and rule-based solutions to RC problems were frequently reported in inquiry. The children obviously could have aolved RC problems by direct computation rather than by applying the rule. We had expected that many would, but very few in fact did. Moat began applying the rule to RC problems about the same time they began applying it to R problems; a few waited for one or more trials before also solving RC problems that way, possibly to check rule-based picture choices against computation-based ones. One fifth grader who solved RC problems by rule complained in inquiry that "sometimes it slowed me down when you take the box off 'cause aometimea I'll look at the dolls just because you took the cover off". Further research would be necessary to determine just how much faith aubjects of different ages place in the rule. One might teat this faith by seeing how they would respond to false (counter-rule) empirical feedback about what each obaerver sees, similar to what has been done in the ao-called Piagetian "extinction" studies (Miller, 1971). The data from the present study suggests that rule 2 may for many children have the cognitive status of a consciously-known, well-rationalized fact of life, the aort of knowledge that should be hard to extinguish.

In retrospect, our evidence even for rule knowledge seems more unambiguous than that obtained by Salatas and Flavell (1976). The child could see the array as well as the obaervera when anewering their rule 2 questions, as in our RC problems. It was therefore at least poasible for a subject in their atudy to conclude that O_1's picture could not show O_2'a view by simply looking at O_2 and the array and determining by computation that it does not. In the present study, on the other hand, we know that a subject could not have solved R problems by computation rather than by rule and also, if RC latencies were zero-order, that s/he did not solve RC problems that way either.

As to the developmental aspects of the study, we face the usual problems of cognitive-developmental diagnosis (Flavell, 1977, ch. 7): how to make valid inferences about developmental differences in the nature, extent, stability, accessibility, utilizability, etc., of the cognitive entity under study--differences between what younger and older children "have," cognitively, and/or how they "have" it. We might begin by trying to bracket the probable range of knowledge of rule 2 present in our two child samples. Is it possible that none of the subjects tested had rule 2? Conversely, is it possible that all of them possessed it?

As to the first question, an argument might be made that children who appeared to be using rule 2 could actually have been using some type of wholly nonperspectival rule that yields the same picture choices. For example, they might simply match position descriptors with picture descriptors, that is, same picture "goes with" same position, and different picture "goes with" different position. While some children who responded as though they had used rule 2 may have actually been using some such nonperspectival rule, it is certain that not all did. Inquiry responses like "If Mickey sees the back (of the dolls) then Donald will have to see the front" were not uncommon, and surely attest to a genuinely rule 2 solution procedure. In short, the answer to the first question is "no." Actually, it seems prima facie unlikely that many subjects would have used the somewhat complex and difficult to rationalize nonperspectival rule just mentioned. A more attractive, sensible-seeming alternative, especially to a young child, would probably be the simple nonperspectival rule mentioned in the Response Correctness section, which was indeed used by some of the younger subjects.

The second question is more difficult to answer. It is certainly possible that some children may have known rule 2 at some level but not have shown this knowledge in our task situation. The initial emphasis on view computation during training, the strangeness and lack of ecological validity of R problems, or other task factors may have prevented them from bringing to consciousness and/or using perspectival knowledge they actually possessed. The greater frequency of rule use in Experiment 2 than in Experiment 1, especially at the first grade level, shows that task factors can make a difference here. We believe that the introduction of the think period in Experiment 2 may have been especially facilitative: it seemed to help refocus the child's attention on the task at the onset of each new trial, and may also, as intended, have gotten the child to do more thinking about how R problems might be solved. On the other hand, one would think that even a child who had only a passable command of rule 2 would give evidence of it somewhere in our extended and heterogeneous testing procedure. In both experiments, but particularly the second, the lengthy pretraining and training, the explicit, almost coaching-like instructions and post-response explanations provided on the initial R and RC practice trials, the numerous test trials, and the careful inquiry -- all of these combine to provide what seems to us to have been an extremely hospitable setting for the expression of rule 2 knowledge. Although we obviously cannot prove it, these considerations lead us to believe that at least the 8 first graders and 5 third graders in Experiment 2 who met none of the three criteria of rule 2 knowledge (Table 3) had little if any potentially conscious understanding of this rule.

The data suggest that there is some development during the middle childhood period with respect to the "having" of rule 2, although the evidence for age changes is stronger in Experiment 1 than in Experiment

2. As just indicated, some children showed no evidence at all of knowing the rule, even according to what should be a diagnostically sensitive procedure. Other children appeared to know it about as clearly and completely as this assessment procedure could show -- possibly as well and fully as an adult would. Still others fell at various hard to order points between these poles. Their rule 2 knowledge seems to have been less readily accessible, usable, or verbalizable than that of the second group. They did not use the rule in the early trials, did not use it to mediate quick responding, or did not articulate it in inquiry.

In summary, a number of our elementary school subjects seem to have deliberately used the perspective-taking rule studied here in solving both R and RC problems, to have been consciously aware of its use, and to have believed it to be a wholly trustworthy guide to problem solution. There also appear to have been developmental and individual differences in awareness and use of the rule: some children gave no evidence of either, others gave ample evidence of both, and still others showed various intermediate levels of performance.

References

Fishbein, H. D., Lewis, S., & Keiffer, K. Children's understanding of spatial relations: Coordination of perspectives. Developmental Psychology, 1972, 7, 21-33.

Flavell, J. H. The development of inferences about others. In T. Mischel (Ed.), Understanding other persons. Oxford, England: Blackwell, Basil & Mott, 1974.

Flavell, J. H. Cognitive development. Englewood Cliffs, N.J.: Prentice-Hall, 1977.

Huttenlocher, J., & Presson, C. L. Mental rotation and the perspective problem. Cognitive Psychology, 1973, 4, 277-299.

Marmor, G. S. Development of kinetic images: When does the child first represent movement in mental images? Cognitive Psychology, 1975, 7, 548-559.

Miller, S. A. Extinction of conservation: A methodological and theoretical analysis. Merrill-Palmer Quarterly, 1971, 17, 319-334.

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

Salatas, H., & Flavell, J. H. Perspective-taking: The development of two components of knowledge. Child Development, 1976, 47, 103-109.

Shantz, C. U. The development of social cognition. In E. M. Hetherington (Ed.), Review of child development research (Vol. 5). Chicago: University of Chicago Press, 1975.

Footnotes

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[1]While rule 1 has no exceptions, rule 2 could, especially with one-object X_s. An extreme case would be X = a sphere, uniformly illuminated from all sides: an observer's visual experience of it is the same from all station points.

[2]Through inadvertence, the six possible orders of presenting the three types of problems were not equally distributed across grade and sex in either experiment. Possible order effects were most likely to be caused by the children obtaining the correct answer for the R problem from a[illegible]mediately preceding RC problem, which was possible on three of the six orders. However, the distribution of correct R responses within each grade on these three orders proved to be almost identical to the distribution of correct responses within each grade on the other three orders. In addition, a one-way analysis of variance among the six orders (collapsing across grade and sex) did not reach an acceptable level of significance.

Table 1

Number of Children in Each Grade
Who Met the 7 out of 8 Criterion
For Each Problem Type

		Problem Type		
Grade	n	R	C	RC
		Experiment 1		
1	24	4	13	10
3	24	13	16	22
5	24	17	21	19
		Experiment 2		
1	24	12	19	20
3	24	18	18	18

Table 2

Number of Children in Each Grade

Classified According to the Number

of Zero-Order Response Latencies on R Problems

			Number of Zero-Order Response Latencies								
Experiment	Grade	*n*	0	1	2	3	4	5	6	7	8
	1	24	12	3	2	2	3	1	0	1	0
1	3	24	12	2	1	1	0	3	1	0	4
	5	24	5	3	3	1	0	0	2	4	6
2	1	24	11	2	0	1	0	2	2	0	6
	3	24	5	2	0	0	2	1	0	3	11

Table 3

Number of Children in Each Grade Meeting

Various Numbers of Criteria of Rule 2 Knowledge

			Number of Criteria Met			
Experiment	Grade	n	0	1	2	3
	1	21	14	3	2	2
1	3	19	6	2	4	7
	5	24	1	4	5	14
2	1	24	8	4	3	9
	3	24	5	0	4	15

Table 4

Number of Children Meeting (+) and Not Meeting (-)

Pairwise Combinations of the Three Rule 2 Criteria

		Inquiry +	Inquiry -
Correct	+	59	2
Correct	-	15	36

		Inquiry +	Inquiry -
Latency	+	52	3
Latency	-	22	35

		Correct +	Correct -
Latency	+	48	7
Latency	-	13	44