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ABSTRACT

Piaget and Inhelder, in The Child's Conception of Space (1956), described the coordination of viewpoints (CV) spatial operation as one of the prerequisites to the development of the rotation and development (RD) spatial operation. This study investigated this developmental dependency notion and also evaluated the effects of age and sex on the development of the CV and RD operations. Two 16-item instruments, one for each operation, were administered individually to 112 children, eight females and eight males at seven age levels, 7 through 13. In contrast to Piaget's and Inhelder's writings, the data revealed that some of the components of an RD operation seem to be among the major prerequisites to the development of the CV operation. Further analysis indicated that the capacity for CV and RD operational functioning appear to be greater in older children than in younger children and greater in males than in females. (Author)

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THE DEVELOPMENTAL DEPENDENCY BETWEEN TWO PIAGETIAN SPATIAL OPERATIONS*

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by

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The Developmental Dependency Between
Two Piagetian Spatial Operations

Abstract

Piaget and Inhelder, in The Child's Conception of Space (1956), described the coordination of viewpoints (CV) spatial operation as one of the prerequisites to the development of the rotation and development (RD) spatial operation. This study investigated this developmental dependency notion and also evaluated the effects of age and sex on the development of the CV and RD operations. Two sixteen-item instruments, one for each operation, were administered individually to 112 children, eight females and eight males at seven age levels, 7 through 13. In contrast to Piaget's and Inhelder's writings, the data revealed that some or all the components of an RD operation seem to be among the major prerequisites to the development of the CV operation. Further analysis indicated that the capacity for CV and RD operational functioning appear to be greater in older children than in younger children and greater in males than in females.

The Developmental Dependency Between
Two Piagetian Spatial Operations

This study sought information that would either support or refute the Piagetian notion that the development of mental operations depends on and is made up of operations that developed earlier. To evaluate this developmental dependency notion, this study investigated the growth of two Piagetian projective space operations in children: rotation and development (RD) and coordination of viewpoints (CV). RD is the mental anticipation of objects' surfaces being rotated and developed into one geometric plane. CV, on the other hand, is the mental linking into a single whole the various potential views of objects. This research sought to determine if the RD operation is one of the prerequisites to the development of the CV operation, or if the CV operation is one of the prerequisites to the growth of the RD operation.

The latter was the developmental dependency notion expressed by Piaget and Inhelder in The Child's Conception of Space (1956). Since no data was cited by the authors to support their claim, it appeared that the posited developmental dependency between the CV and RD operations stemmed from logical analysis rather than empirical analysis.

Except for the assertions of Piaget and Inhelder, no other reports substantiate the existence of a developmental

dependency between the CV and RD operations. The literature, however, is rich with studies (e.g., Larsen & Abravanel, 1972; Laurendeau & Pinard, 1970) investigating the developmental relationships between other pairs of spatial operations. Most of these studies provided only partial support for the sequences of spatial growth described by Piaget and Inhelder.

In this study two spatial aptitude tests were administered to obtain data concerning both possible directions of dependency between the CV and RD spatial operations. One test measured the CV operation, while the other measured the RD operation. Based on Piaget's and Inhelder's writings, it was expected that the data analysis would reveal that the RD operation is developmentally dependent on the CV operation.

To provide additional insight into the growth of the CV and RD spatial operations, and to fill the void of research which exists in this area, this study also sought to determine if children of various ages and sexes have different capacities for CV and RD operational functioning. To accomplish this task, females and males at a variety of age levels participated in this study. It was expected that the data would support previous related research (e.g., Piaget and Inhelder, 1956) indicating that older children make more correct responses on spatial tests than younger children. It was also hypothesized, based on related literature (e.g.,

Garai & Scheinfeld, 1968; Maccoby, 1966), that males would perform better than females, especially at the higher age levels.

Method

Subjects

Participating in this study were 112 predominantly white middle-class children from one parochial school located in Lafayette, Indiana. Eight females and eight males were randomly selected at each of seven age levels, from 7 to 13. Children having serious visual disorders were eliminated from the sampling pool.

Procedure

Two tests, entitled the "Coordination of Viewpoints Test" (CVT) and "Rotation and Development Test" (RDT), were administered individually during scheduled half-hour sessions. Half of the females and males at each age level were randomly assigned to take either the CVT before the RDT or the RDT before the CVT. The order (day and time) in which the children were examined was determined on a random basis.

The experimenter-developed CVT and RDT were refined in two pilot studies. Other than the difference in the cognitive tasks involved, the two tests were designed to be as similar as possible. The same eight simple three-dimensional geometric objects (see Figure 1) were employed as stimuli for the CVT and RDT. In addition, both tests utilized the

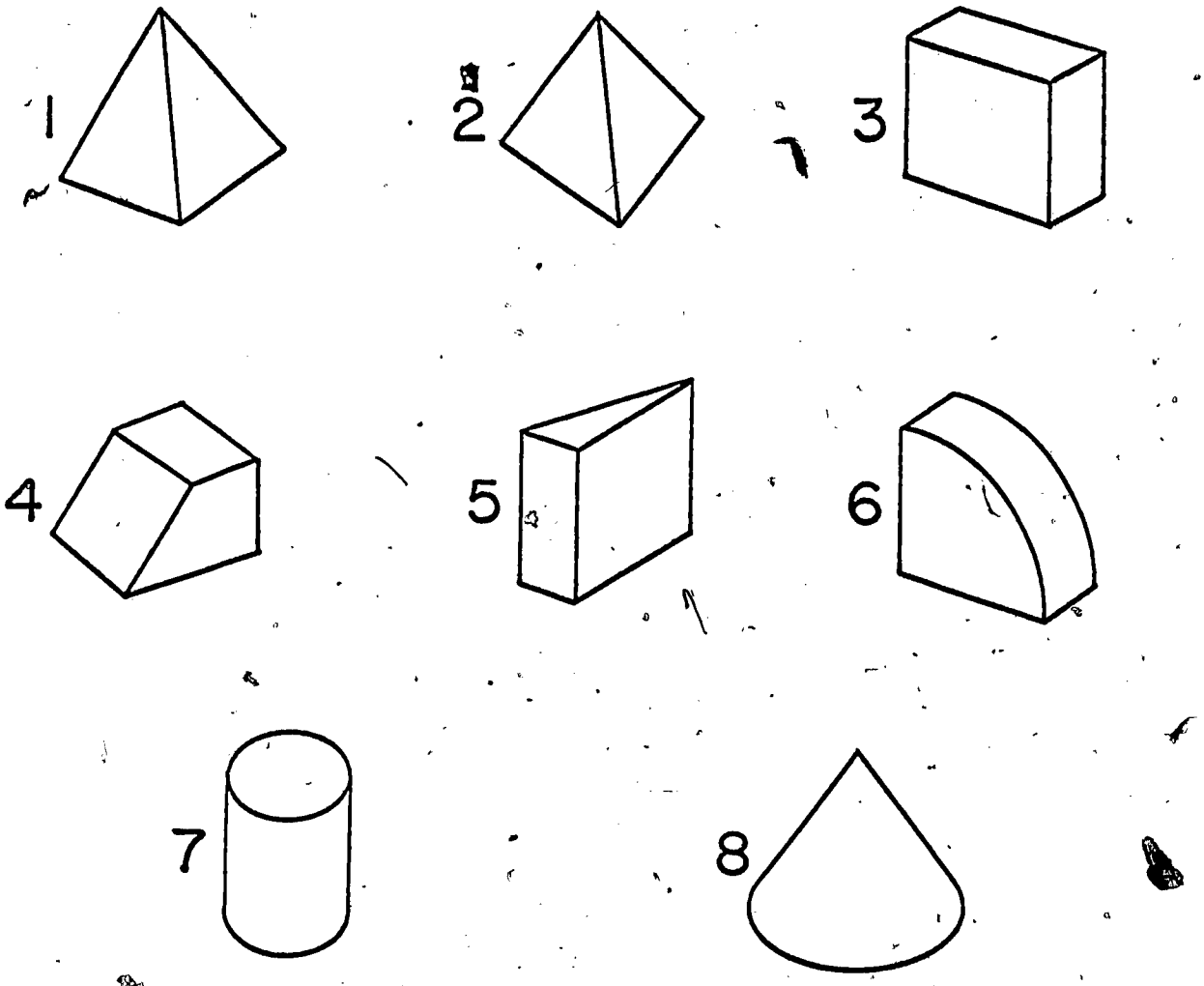

Figure 1. CVT and RDT Stimuli.

multiple-choice item format, three examples, and 16 test items (two for each stimulus) presented with black-and-white slides.

For the CVT the subject was seated at a round table (100 cm diameter) facing a screen. Ten viewing positions

(every 36 degrees) were identified on the outer edge of the table by miniature lamps. The child was handed a stimulus and asked to study its shape. The object was then placed by the experimenter in the middle of the table. One of the lights, at least 108 degrees from the subject, was then illuminated, and a slide (see Figure 2) was projected on the screen. One of the three drawings on the slide depicted the stimulus viewed from the position of the illuminated lamp, while the other two represented the shapes of the

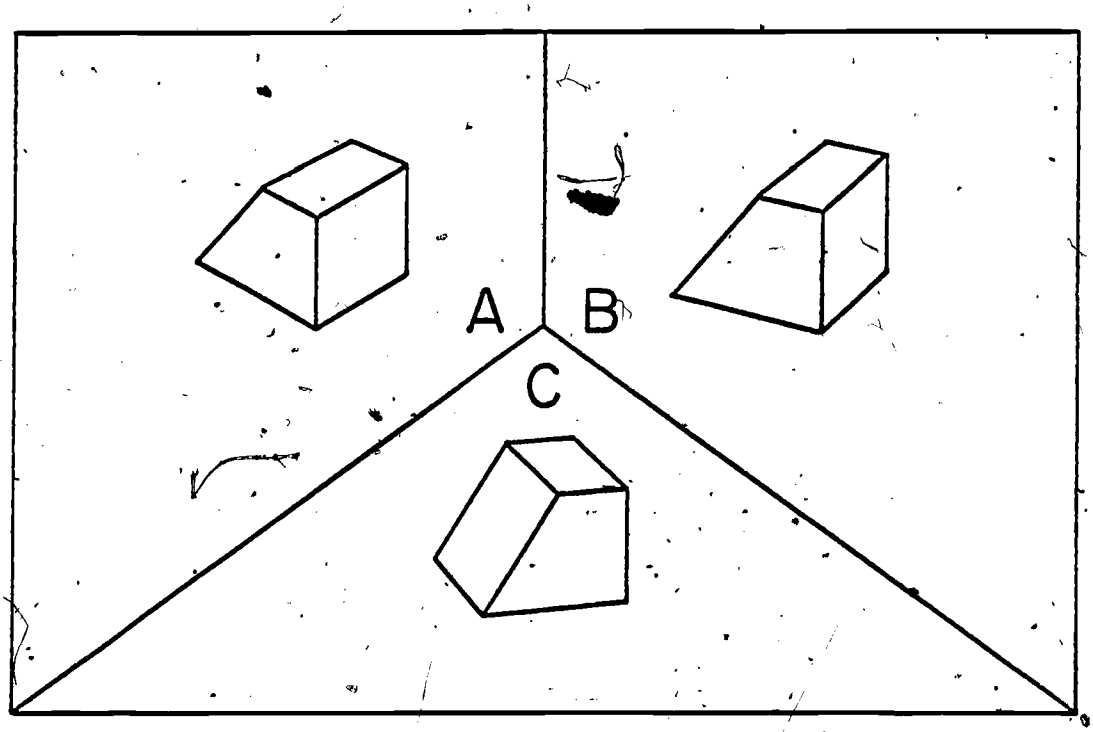

Figure 2. Illustration of a CVT Slide.

stimulus when viewed 36 degrees to either side of the light. The child was asked to identify orally the picture that best

represented the shape of the object when viewed from the light. The child then moved to another position located 108 degrees around the table and repeated the task.

For the RDT the subject was seated at a rectangular table facing a screen. The child was handed an object and asked to examine its shape. A slide was then projected on the screen (see Figure 3). Only one of the three drawings correctly

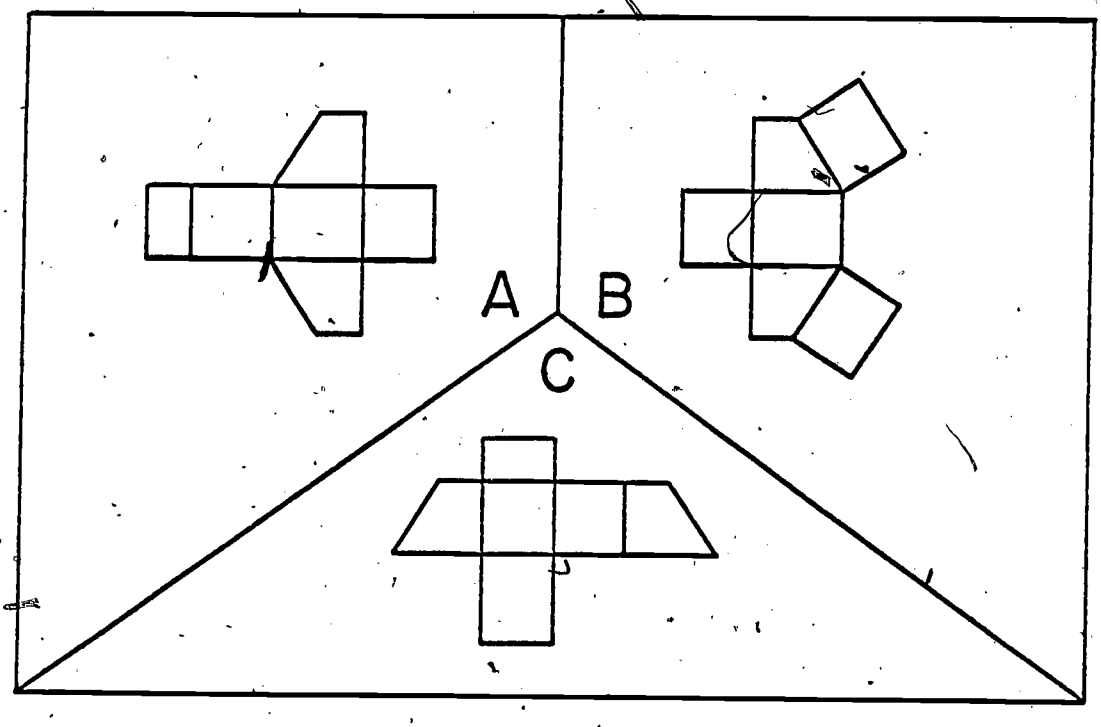

Figure 3. Illustration of a RDT Slide.

depicted the appearance of the stimulus if its surfaces were developed into one plane. The child was asked to indicate orally the correct drawing. A second RDT item dealing with

the same object was administered by repeating the process with another slide.

Results

A special chi-square analysis was used to evaluate the data for both directions of dependency between the CV and RD spatial operations. This approach was devised to eliminate the major deficiencies reported by White (1974) that exist in the statistical techniques (e.g., Guttman's coefficient of reproducibility and phi-correlation coefficient) generally employed to test for developmental dependencies.

The special approach used for this study involved the logical and sequential testing of two-way contingency tables. Item analyses of the CVT and RDT were employed to identify the most effective question from the two devised for each of the eight objects. A 2x2 contingency table was generated on each stimulus in terms of the performance of the 112 subjects on the one CVT and one RDT item selected for that object. These tables identified the number of children who got both items right, both items wrong, the CVT item right and the RDT item wrong, and the RDT item right and the CVT item wrong. The eight tables were first tested using standard chi-square procedures to determine if all subjects were guessing or if the CV and RD variables were independent for a particular stimulus. The six tables which led to the rejection of both the guessing and independence conditions

were then subjected to two versions of a special chi-square test for direction of dependency. One version determined if the CV operation is dependent on the RD operation, the other if the RD operation is dependent on the CV operation. Each version employed expected frequencies calculated from a mathematical model describing the distribution of the population expected if the hypothesized direction of dependency were true.

A common direction of dependency was indicated by the chi-square tests for direction of dependency. The chi-square values for these tests are presented in Table 1. Since the

Table 1. Chi-square Values for the Tests for Direction Dependency.

Stimulus number	Condition tested	
	CV dependent on RD	RD dependent on CV
1	.29	49.79*
2	_a	_a
3	28.33*	6.19*
4	3.84*	13.07*
5	25.41*	2.89*
6	.00	12.49*
7	2.45	60.96*
8	_a	_a

Note. $\chi^2_{.90}(1) = 2.7$

[a]Value not calculated since the CV and RD variables were not found to be independent for these stimuli.

*$p < .10$.

hypothesis of interest also served as the test hypothesis for the direction of dependency tests, the ten percent level was chosen over smaller alpha levels to increase the power of the tests. The hypothesis that the RD operation is dependent on the CV operation was rejected for all six contingency tables tested. However, when the same data were examined for the hypothesis that the CV operation is dependent on the RD operation, the hypothesis was accepted for the contingency tables generated on stimuli 1, 6, and 7. The statistical decision to accept implied that no sufficient evidence was found to indicate that the hypothesis was not true in these three instances.

To evaluate the effects of age, sex, and testing order on the development of the CV and RD operations, a 7x2x2 factorial analysis of variance was conducted on the subjects' CVT and RDT scores. The testing order variable was included in the analysis as a secondary source of information concerning the direction of dependency between the CV and RD operations. Testing order checked for the possibility that the growth of one spatial operation could be enhanced by providing preliminary experiences (testing) involving the other spatial operation. Taking the two tests in opposite orders represented two different treatment conditions for which the children were randomly assigned.

From the analysis of variance conducted on the CVT scores (see Table 2), it was found that the main effects of

age, sex, and testing order were statistically significant ($F[6,84] = 5.12$, $p < .01$; $F[1,84] = 5.94$, $p < .05$; $F[1,84] = 5.22$, $p < .05$, respectively), whereas all the interactions of these factors were nonsignificant. A Newman-Keuls probe of

Table 2. Mean Number of Correct Responses on the CVT by Children Taking the CVT and RDT in Opposite Orders.

Group	Age 7	8	9	10	11	12	13
Females							
CVT first	5.25	5.50	7.25	6.25	10.75	9.75	10.25
RDT first	6.50	7.50	8.50	9.25	9.50	9.25	11.00
Males							
CVT first	7.75	8.75	9.75	7.75	8.25	11.50	8.25
RDT first	7.50	8.00	9.75	11.75	9.75	12.00	11.50
Age marginals	6.75	7.44	8.81	8.75	9.56	10.56	10.25

Sex marginals	Females	Males
	8.30	9.45

Testing order marginals	CVT first	RDT first
	8.34	9.41

the age main effect revealed that the 11-, 12-, and 13-year-old groups scored significantly higher ($p < .05$, $p < .01$, and $p < .01$, respectively) on the CVT than the 7-year-old group, and the 12- and 13-year-old groups scored significantly higher ($p < .01$ and $p < .05$, respectively) than the 8-year-old group. With regard to the sex main effect, the result indicated that the group of males scored significantly higher on the CVT than

the female group. The finding concerning the main effect of testing order revealed that the group who took the RDT before the CVT scored significantly higher on the CVT than the group who took the CVT first.

Two statistically significant results were identified from the analysis of variance conducted on the RDT scores (see Table 3): the age main effect ($F[6,84] = 4.67$, $p < .01$) and the age by sex interaction effect ($F[6,84] = 2.32$, $p < .05$).

Table 3. Mean Number of Correct Responses on the RDT by Children Taking the CVT and RDT in Opposite Orders.

Group	Age 7	8	9	10	11	12	13
Females	7.00	5.88	6.75	8.12	10.12	10.12	9.75
CVT first	8.25	5.00	5.75	9.00	9.00	10.00	10.50
RDT first	5.75	6.75	7.75	7.25	11.25	10.25	9.00
Males	6.62	8.62	10.25	8.12	8.50	12.38	8.38
CVT first	7.50	9.00	10.50	7.75	8.00	11.00	6.50
RDT first	5.75	8.25	10.00	8.50	9.00	13.75	10.25
Age marginals	6.81	7.25	8.50	8.12	9.31	11.25	9.06

Sex marginals	Females 8.25	Males 8.98
Testing order marginals	RDT first 8.82	CVT first 8.41

A Newman-Keuls analysis of the age main effect revealed that the 12-year-old group scored significantly higher on the RDT

than the 7- ($p < .01$), 8- ($p < .01$), 9- ($p < .05$), and 10-year-old ($p < .05$) groups. An analysis of variance for simple effects was conducted to evaluate the age by sex interaction effect. The results indicated that the 8-year-old group of males scored significantly higher ($p < .05$) on the RDT than the 8-year-old group of females, and the 9-year-old group of males scored significantly higher ($p < .05$) than the 9-year-old group of females.

Discussion

Developmental Dependency

The results provided some support for the notion that a developmental dependency exists between the CV and RD spatial operations. Data from this study indicated that some or all the components of a mature RD operation seem to be among the major prerequisites to the development of the CV operation. However, this conclusion was not in agreement with Piaget and Inhelder (1956), who proposed that the developmental dependency exists in the opposite direction.

Evidence for the notion that the CV operation is structurally dependent on components of the RD operation (CV → RD) was provided two ways. First, three chi-square tests for direction of dependency led to the acceptance of the CV → RD hypothesis, while none of the tests led to the acceptance of the hypothesis that the RD operation was dependent on the CV operation. In fact, the .29 and especially the .00 chi-square

values (see Table 1) indicated strong support for the CV → RD dependency hypothesis, since these small values meant that the distribution of children within their respective contingency tables was almost identical to the distribution expected if the hypothesis were true. And secondly, taking the CVT before the RDT did not cause an improvement in the RDT scores, whereas taking the RDT before the CVT did cause a significant improvement in the CVT scores. The significant testing order effect implied that the growth of the CV operation was significantly enhanced by the preliminary development in the RD operation, which occurred when the RDT was taken first. This positive effect of the RD operation on the growth of the CV operation was expected if the CV → RD dependency hypothesis were true.

Effects of Age and Sex

The findings provided support for the notion that children between the ages of 7 and 13 differ in their capacities for CV and RD operational functioning. Data from this research revealed a trend toward more efficient CV and RD operational functioning with an increase in chronological age. This trend was consistent with the findings in most areas of cognitive development.

The results also provided support for the notion that the majority of males and females between the ages of 7 and 13 differ in their capacities for CV and RD operational functioning. Analysis of the data indicated a tendency

toward more efficient CV and RD operational functioning in males than in females. The observed sex difference was consistent with many reviews of literature (e.g., Garai & Scheinfeld, 1968; Maccoby, 1966) suggesting that males usually perform better than females on spatial tests. The present study, however, did not support reviews of literature (Anastasi, 1958; Terman & Tyler, 1954) suggesting that sex differences generally become more apparent with an increase in age. The significant sex difference for the CVT data was not found to be a function of any variation of age. In addition, the significant difference between female and male RDT scores was found to exist only for 8- and 9-year-olds, and not for the older children, which would have been predicted from the reviews of literature.

Implications for Education

This research revealed that it is possible to stimulate the growth of a spatial operation by providing appropriate instruction. Spatial operations are undoubtedly important components in the cognitive repertoire of people. It would seem reasonable to make an effort to develop the spatial thinking abilities of school children. In general, females more so than males need spatial instruction. Data from this study suggests two guidelines in designing an efficient schedule of educational experiences involving the CV and RD operational functioning: (1) activities requiring the RD spatial

operation should be introduced before activities demanding the CV operation; (2) activities requiring the RD operation should be introduced no earlier than the beginning of the sixth grade.

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