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ABSTRACT

This study investigated a problem within the theoretical structure of cognitive development proposed by Jean Piaget, and used the concepts of classification and projective spatial relationships to investigate the nature of attainment and sequencing of three corresponding logical and infralogical groupings according to the models proposed by Piaget. Three classification and three logico-mathematically corresponding projective geometry (perspective) tasks were administered in a randomized order through individual interviews to 108 children born during the years 1962, 1963 and 1964. Subjects were chosen randomly to provide six equal groups of 18 according to birth year and sex. The oral presentations and responses were tape-recorded and transcribed. Silent responses were verbalized by the interviewer to facilitate transcription. Data were analyzed by using a test for scalibility; a chi-square one-sample test was used to test for differences in performance (age level, sex, between each age level on the projective spatial relationship tasks). The results indicate that cognitive processes undergo continuous development with growing differentiation and coordination until the processes become completely functional when the concrete operational period merges with the beginnings of formal operational thought at possibly thirteen or fourteen years of age: two or three years later than the transitional period suggested by Piaget. The reason for the age difference in performance on the upper level of the concrete operational tasks is not clear. (Author/BR)

A STUDY OF THE STRUCTURE OF PIAGETIAN LOGICAL AND INFRALOGICAL GROUPINGS WITHIN THE CONCRETE OPERATIONAL PERIOD

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INTRODUCTION

This study investigated a problem within the theoretical structure of cognitive development proposed by Jean Piaget. The research of Piaget and his colleagues suggests that parallel sequencing and hierarchical ordering of levels of reasoning may be found in certain fundamental logico-mathematical models of cognitive structures which bear upon the formation of concepts of space and classification in children (Piaget & Inhelder, 1967, p.450; Inhelder & Piaget, 1969, p.282). Piaget (1966, pp.139-140) has stated that gradual development of logical and infralogical operations proceeds through a series of stages "constructed parallel to and in synchronization with (Piaget & Inhelder, 1969, p.106)" each other. Since the logico-mathematical models of concrete operational thought are regarded as representing the fundamental cognitive processes in both of these domains, it was reasoned that these should show parallel development and that there should be an ordering of attainment according to their level of difficulty.

This study used the concepts of classification and projective spatial relationships to investigate the nature of attainment and sequencing of three corresponding logical and infralogical groupings according to the models proposed by Piaget.

REVIEW OF THE LITERATURE

Classification has been regarded as a major cognitive process for a long time. Spatial concepts have also been investigated for decades. However, this extensive literature on classification and space is not directly related to the present study. Other than the studies of Piaget and Inhelder (Piaget & Inhelder, 1967; Inhelder & Piaget, 1969) there appear to be few which have investigated the logical and infralogical groupings and their patterns of development. There seem to be no studies which have investigated the "synchronization" or "parallel" nature of corresponding logical and infralogical groupings. Studies investigating isolated aspects of the logical and infralogical have been reported. Replication of some of Piaget and Inhelder's spatial tasks have been carried out by Lovell (1959) and Laurendeau and Pinard (1970). These, as well as others related to the infralogical groupings concerned with spatial concepts by Kershner (1971), Kielgast (1971), Harris (1972), Davol and Hastings (1967), Towler and Nelson (1967), and Elkind (1961), have produced conclusions which have generally been supportive of Piaget and Inhelder's work. Garretson (1971), Dodwell (1962), Kofsky (1966), Raven (1967), Parker and Day (1971), Overton and Jordan (1971), Overton, Wagner and Dolinsky (1972), and Overton and Brodzinsky (1972) have investigated aspects of classification related to the logical groupings and the results of these studies are also generally supportive.

METHOD

Three classification and three logico-mathematically corresponding projective geometry (perspective) tasks were administered in a randomized order through individual interviews to 108 children born during the years 1962, 1963, and 1964. Subjects were chosen randomly to provide six equal groups of 18 according to birth year and sex. The oral presentations and responses were tape-recorded and transcribed. Silent responses were verbalized by the interviewer to facilitate transcription.

TASKS

The six Piagetian-type task protocols were designed so that three (L_1, L_2, and L_4) would be associated with three of the four logical groupings which Piaget has used for models of cognitive processes underlying the various forms of classification (Piaget, 1953, pp.13-18, & 23-32) and three (I_1, I_2, and I_4) could be associated with the three corresponding infralogical groupings which Piaget (1967, pp.466-474) has used for models of cognitive processes underlying the operational conception of projective spatial relationships. The task pairings were as follows:

Grouping I

L_1 Primary addition of classes (Cows and Pigs Task)

I_1 Addition and subtraction of projective elements (Rod Task)

Grouping II

L_2 Secondary addition of classes (Collection of Model Objects Task)

I_2 Complementary perspective relations (Trees Task)

Grouping IV

L_4 One-to-one multiplication of classes (Four x Four Fields Task)

I_4 One-to-one multiplication of projective elements (Mountains Task)

Brief details of individual tasks are given below. The reader is referred to Dettrick (1974) for a complete statement of protocols, scoring criteria, and equipment.

TASK L_1

The child was given twelve cows (8 orange, 2 brown and white, and 2 black and white) and 7 pigs (5 pink and 2 black) and was asked (a) to form the animals into groups and give the groups a name, (2) whether the spotted ones would be fed if all the cows were to be fed, (3) whether there were more, same, or fewer orange cows than all the cows, (4) whether there were more cows or more animals, (5) whether there would be any animals left if (a) all the cows were taken away, and (b) all the pigs were taken away. Supporting reasons for answers to questions 2 to 5 were elicited.

TASK I_1

The child was shown a green painted dowel (20 cm long and 0.6 cm diam.) held by the observer and an answer card with drawings showing possible projective views of the rod. The child was asked to choose a drawing (or draw himself) and give a supporting reason for his choice for the rod (1) held vertically and observed from the child's viewpoint, (2) held vertically and viewed from an imaginary observer's chair equidistant from the rod but at right angles to the child's line of sight, (3) held horizontally and viewed (end on) from the imaginary observer's chair. Supporting reasons were elicited for answers to questions 2 and 3.

TASK L_2

The child was asked to use 15 model animals to form groups, name the groups, and supply a reason for the name. The animals were reformed into one group by the interviewer and the first process was repeated with subsequent regroupings to investigate whether the child would form secondary classes and whether a constant superordinate class would be maintained. Three additional model objects were then used to investigate the child's ability to form complementary classes.

TASK I_2

Four conical "trees" were mounted with their bases and vertical axes in line on a supporting green painted styrofoam board. The trees were different colours (red, yellow, orange, and ochre), heights (30 cm, 22.5 cm, 15 cm, and 11.5 cm), and had different base diameters (11 cm, 8.5 cm, 7 cm, and 5.5 cm). The trees were mounted at the child's eye level 2 metres distant at right angles to the child's line of sight so that the order, from left to right, was ochre, red, orange, and yellow.

The child was given coloured cardboard cut-outs which corresponded with a projected view of each tree and asked to construct a picture showing the view of the trees from his position. The interviewer then randomized the cut-outs and moved to a seat on the opposite side of the row of trees to the child. The child was asked to construct a picture using the cut-outs to show what his view of the trees would be from the interviewer's position. The interviewer repositioned himself accordingly for left and right end-on views of the trees. For these two positions the child selected (or opted to draw) the view from possible projected views drawn on a cardboard.

Supporting reasons were elicited. For scoring purposes, an acceptable reason was one which retained order of placement together with lateral (left-right) reversal for the rear view, or omissions by blocking or covering for the end-on views.

TASK L_4

The child was asked to choose and reason which model animals fitted four empty "fields" on a four by four multiplicative classification array based on the properties cow/calf, lying/standing, black spotted/brown spotted, and left/right facing. Scoring was based on choice and the properties which were elicited in support of the choice.

TASK I_4

The child viewed from 2 metres a mountains model constructed according to a description by Piaget and Inhelder (1967, p.211). but mounted on a circular base. The child was asked to choose front, rear, and both side views from randomized sets of eight postcard size colour photographs mounted on four cardboards. Each set of eight photographs included the front, rear, and side views of the model together with "photographs" made by processing the four negatives of the preceding views in the reversed position (emulsion side down versus emulsion side up). The interviewer demonstrated viewing positions with the exception of the front view. A correct response required a correct choice of view and a reason expressing before-behind and left-right coordination. No reason was elicited following the choice of front view.

RESULTS

For the purposes of statistical analysis, the summarized scoring levels reported in Tables 1 and 2 were collapsed into pass-fail categories. Successful completion of all sections of a task was required for a pass.

A test for the scalibility of the six tasks produced a coefficient of reproducibility of .82 and a minimum marginal reproducibility of .65. Although this is close to the value recommended by Guttman (Edwards, 1957), it could not be concluded with any certainty that the tasks form an undimensional scale of increasing difficulty.

The chi-square one-sample test ($\alpha = .05$) was used to test for differences in performance (1) between each age leve. n the classification tasks, (2) between each age level on the projective spatial relationship tasks, and (3) according to sex of subjects on each of the six tasks. Two of the three calculated chi-square values used to test for differences between age levels on the classification tasks exceeded the critical chi-square at the .05 level (L_1:χ^2=5.77, df=1; L_2:χ^2= 4.87, df=1). The hypothesis that there was no difference at the three age levels for the three classification tasks was rejected for L_1 (primary addition of classes) and L_2 (secondary addition of classes) but the hypothesis was retained for task L_4(one-to-one multiplication of classes). None of the remaining chi-square tests exceeded the critical chi-square value at the .05 level. Results of the tests are reported in Tables 3, 4, and 5.

To obtain an indication of how performance on each of the three logical tasks was related to performance on the infralogical logico-mathematical counterpart, a simple correlation coefficient (Corr.) was calculated for each of the three pairs of two tasks L(a)-I(a) from pass-fail scores assigned to each of the subjects on each of the six tasks according to the formula:

$$\text{Corr.} = \frac{(\text{pass pass} + \text{fail fail}) - (\text{pass fail} + \text{fail pass})}{\text{number of subjects}}$$

The results of the calculations are presented in Table 6.

DISCUSSION

Scalibility and Task Difficulty

Although the test for scalibility did not provide conclusive evidence that the tasks formed an unidimensional scale, that is, a definite sequence in which individual children attained mastery of the cognitive processes measured by the six tasks, a comparison of the number passing each task successfully (see Tables 3 and 4) shows that both the logical and infralogical tasks increase in difficulty from Grouping I through Grouping II to Grouping IV, viz., the percentages passing the tasks are L_1: 41, L_2: 38, L_4: 20, I_1:51, I_2: 44, and I_4: 20.

The conclusion which appears to follow from this analysis is that the cognitive processes associated with performance on each of the three pairs of logico-mathematically related tasks develop together. However, this conclusion does not imply a parallel or simultaneous development, but rather a somewhat general correspondence in the ability of children to operate on a problem related to both the logical and infralogical grouping aspects of the logico-mathematical models of concrete operational cognitive processes. The order of difficulty of the tasks based on the percentage passing each task is not generalizable to the extent that it applies to the performance of individual subjects.

Performance According to Age

The significant difference according to age of subjects is restricted to tasks L_1 and L_2. Inspection of Table 3 shows that the youngest children (born in 1964) performed worst but that those born in 1962 performed worse than those born in 1963. Table 4 shows that the significant difference between age levels on L_2 was produced by the poor performance of the 1962 age group in relation to the other two age groups. A comparison of performances on the remaining four tasks shows little difference between the 1962 age group and the 1963 age group. The median I.T.B.S. grade equivalent for the composite test (C) was 5.9 for the 1962 age group, 5.8 for the 1963 age group, and 4.5 for the 1964 age group. This comparison of the I.T.B.S. composite grade equivalents indicates that although the 1962 age group is not performing much better than the 1963 age group, there is nothing to suggest that task performance would be significantly worse than either the 1963 or the 1964 age group for L_2. A review of task scores for individual subjects shows that more children in the 1962 age group resisted forming a dichotomy, more children did not reclassify, more children classified by iterating group membership, and more had difficulty maintaining a constant superordinate class than the 1963 age group. Although a review of the performance of the 1962 age group is interesting, this does not offer an explanation for the results obtained.

Inhelder and Piaget (1969, p.124) report a simiiar case of regression in children 10 to 12 years of age for a task which corresponds to a part of task L_2. Inhelder and Piaget's brief comment (p.124) that the regression has nothing to do with the mechanism of classification and simply means that children tend to expect more complicated "puzzles" than the one set may offer some explanation, and it was the experience of the present investigator that in a fr [illegible] es subjects in the 1962 age group tended to look for more difficult problems than they were actually confronted with, but it seems that further investigation of primary and secondary classification with children near the end of the concrete operational period is necessary to clarify understanding of this regressive behaviour.

The homogeniety of performance of the remaining four tasks is also noteworthy and strongly supports the notion of "stage". It might be expected that a significant improvement in performance would occur from age group to age group, or more particularly between the youngest and the oldest age group, but such was not the case. The age range of the sample in this study fell within and extended beyond a stage of intellectual development commonly denoted as "stage III (Piaget & Inhelder, 1967, pp.184-193)." The age range reported for this stage is seven to nine years (Piaget & Inhelder, 1967, p.175). The behaviours reported by Piaget and Inhelder for the two substages within stage III (IIIA and IIIB) resemble the performance of subjects in the present sample with considerably more evidence of stage IIIA behaviour and a lower stage, IIB. Stage III projective spatial relationship behaviour is characterized by the child recognizing a distinction between different points of view without being able to draw or imagine the projective alterations which do occur with change of viewpoint. Piaget and Inhelder (1967, p.175) report this stage (by implication) as occurring about 7;6 to 8;6. In the present study, stage IIB and stage IIIA behaviours were observed throughout the three age levels (median ages 9;10, 10;9, and 11;10) as the most common forms of response with some evidence of stage IIA and stage IIIB behaviour, for example, 20 per cent of the sample reached stage IIIB in relation to task I_4. From the references cited above, it can be clearly established that Piaget and Inhelder regard the operations related to the various tasks used in this study as being firmly located within the logico-mathematical groupings of the concrete operational period. The general conclusion to be drawn from this analysis is that the pattern of development of the subjects in the sample used for this study corresponds with the nature and the sequence of behaviour established by Piaget and his colleagues but it seems however, that attainment of the various stages of development is occurring later in the sample investigated. The difference in the age of attainment appears to be at least two and possibly three years. A similar finding was reported by Laurendeau and Pinard (1970, pp.404-439).

On the basis of the findings in the present study, it is clear that the cognitive processes represented by the logico-mathematical grouping models examined in the six tasks undergo continuous development with growing differentiation and coordination until the processes become completely functional when the concrete operational period merges with the beginnings of formal operational thought at possibly thirteen or fourteen years of age: two or three years later than the transitional period suggested by Piaget. The reason for the age difference in performance on the upper level of the concrete operational tasks is not clear. Further research is necessary to establish whether there is definite cultural difference (incorporating Piaget's experience and social transmission factors) or whether the testing procedures were responsible for the difference.

Performance According to Sex

The finding that there was no significant difference in performance between males and females on each of the six tasks is congruent with the conclusions which follow from the assumption that the logico-mathematical groupings are models of the cognitive processes with which the child establishes the relationships leading to fully operational logical and infralogical concepts in the concrete operational period.

If differences were found between task performances on the basis of sex, this would suggest that the instruments or the method of administration measured processes which were not entirely dependent upon intellectual ability or which were so closely related to certain experiences which are generally socially exclusive on the basis of sex that the experience and social transmission factors, which Piaget considers to be important contributors to intellectual development, were responsible for the difference.

Logical-Infralogical Task Relationships

In the introduction it was pointed out that Piaget and Inhelder have stated quite clearly that the development of intellectual operations represented by each of the corresponding groupings proceeds concurrently in the logical and infralogical domains. In the analysis reported in Table 6 the results of this study were used to determine whether development of the logical and infralogical forms of the groupings examined by the six tasks in this study proceeded with the degree of precision implied by terms such as "parallel to", "in synchronization", and "exactly parallel". If Piaget and Inhelder's assertions about the progression of development of intellectual processes represented by the corresponding groupings were correct, the correlations produced in Table 6 would approach 1.00. Table 6 shows that, for the present sample and the tasks used, the correlations were L_1-I_1: .24, L_2-I_2: .35, and L_4-I_4: .56. The first two correlations are moderately low, while the third is moderately strong. On the basis of these results, it appears that, although there is a general correspondence in conceptual development between the logical and infralogical processes, development does not appear to be "simultaneous", nor does it appear to be "exactly parallel". The strength of this conclusion is predicated by the validity of the tasks used in this study to act as measures of the logical and infralogical grouping counterparts. However, it is the opinion of this researcher that it would be preferable to consider development of the groupings investigated as a gradual continuous process which exhibits a growing differentiation and coordination in the logical and infralogical domains, but that the development of these corresponding intellectual processes should not be regarded as synchronous.

EDUCATIONAL IMPLICATIONS

The results from the classification tasks indicate that, even by the age of twelve years, a child's classification abilities may be far from fully developed. The range of classification ability may serve as a partial reason why a wide range of ability to deal with mathematical and scientific concepts may be anticipated in both elementary and high school. While it may appear to be expedient to teach mathematical and scientific concepts through the rote application of algorithms or rules to those children who have not established the necessary processes (one of which is classification) a more beneficial and lasting effect may be anticipated by recognizing the concrete operational nature of a child's thought and the accompanying need for the child's continued personal use of a variety of relevant manipulable materials.

The results of the spatial relationship tasks indicate that children's ability to coordinate spatial relationship tasks by the age of twelve years is far from complete. This means that children at the end of their elementary school experience (with the proportion increasing with younger and younger children) are unable to imagine or reason using relationships using three dimensions formed from a two dimensional representation and vice versa. Such transformational abilities are usually assumed when teaching devices such as televised or filmed programmes are used, or when mathematical, scientific, or other concepts are presented visually through the use of overhead projection, charts, or blackboard drawings. On the basis of this study, it must be concluded that the use of these devices with elementary and junior high school students may be far less efficient as an aid to teaching than has been previously assumed and may, in fact, be responsible for a considerable amount of misinterpretation by students. Furthermore, illustrations in textbooks, particularly those illustrations which require the establishment of spatial relationships or those not congruent with the individual child's mental structure (especially formalized drawings or diagrams) may be interpreted in completely different, even divergent ways, by a child and an adult. This researcher also considers that the usefulness of classroom demonstrations is subject to limitations similar to those already outlined above. The results of the study also suggest that, where spatial relationships may be relevant to the formation of a concept, learning will be maximized and misunderstanding minimized by providing close physical or personal manipulative experience.

It seems clear that the period of concrete operational thought extends beyond the age range usually associated with the end of elementary schooling. This researcher has no doubt that the educational development of students, at least to the end of the concrete operational period, should be arranged to permit and encourage acquisition of knowledge and the formation of relationships to be established largely through hands-on experiences with a corresponding reduction of the verbal transmission of knowledge, particularly in mathematics and the sciences. As teaching strategies and curriculum programmes in mathematics and science move further and further away from concrete physical experiences to the more formal and symbolic the appropriateness of the teaching strategies and curriculum programmes decrease accordingly for most students up to the age of at least fourteen years. Such an approach to teaching and curriculum becomes even more urgent and important for elementary school children.

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TABLE 1

SCORING LEVEL PERFORMANCE OF SUBJECTS IN EACH AGE LEVEL FOR THE THREE CLASSIFICATION TASKS

Year of Birth	Task	Scoring Level 0	1	2	3	4	5	n
1964	L_1	0	1	13	14	8	*	36
1963	L_1	0	0	4	11	21	*	36
1962	L_1	0	3	7	11	15	*	36
Total		0	4	24	36	44	*	108
1964	L_2	4	5	6	3	1	17	36
1963	L_2	1	2	9	5	2	17	36
1962	L_2	2	4	11	7	5	7	36
Total		7	11	26	15	8	41	108
1964	L_4	9	10	7	5	5	*	36
1963	L_4	5	8	7	7	9	*	36
1962	L_4	4	7	8	9	8	*	36
Total		18	25	22	21	22	*	108

* This level does not apply to this task.

TABLE 2

SCORING LEVEL PERFORMANCE OF SUBJECTS IN EACH AGE LEVEL FOR THE THREE PROJECTIVE SPATIAL RELATIONSHIP TASKS

Year of Birth	Task	Scoring Level 0	1	2	3	4	n
1964	I_1	1	4	13	18	*	36
1963	I_1	0	6	10	20	*	36
1962	I_1	1	6	12	17	*	36
Total		2	16	35	55	*	108
1964	I_2	0	8	8	6	14	36
1963	I_2	0	13	2	6	15	36
1962	I_2	0	6	5	6	19	36
Total		0	27	15	18	48	108
1964	I_4	1	20	5	4	6	36
1963	I_4	0	16	7	5	8	36
1962	I_4	0	14	9	5	8	36
Total		1	50	21	14	22	108

* This level does not apply to this task.

TABLE 3

RESULTS OF THE CHI-SQUARE TEST FOR SIGNIFICANT DIFFERENCE BETWEEN PERFORMANCE AT THE THREE AGE LEVELS FOR EACH OF THE THREE CLASSIFICATION TASKS

Year of Birth	Number of Passing Scores on Each Task			n
	L_1	L_2	L_4	
1964	8	17	5	36
1963	21	17	9	36
1962	15	7	8	36
Total	44	41	22	108
Chi-Square	5.77*	4.87*	1.18	
df	1	1	1	

* significant at the .05 level
alpha level = .05

TABLE 4

RESULTS OF THE CHI-SQUARE TEST FOR SIGNIFICANT DIFFERENCE BETWEEN PERFORMANCE AT THE THREE AGE LEVELS FOR EACH OF THE THREE PROJECTIVE SPATIAL RELATIONSHIP TASKS

Year of Birth	Number of Passing Scores on Each Task			n
	I_1	I_2	I_4	
1964	18	14	6	36
1963	20	15	8	36
1962	17	19	8	36
Total	55	48	22	108
Chi-Square	.25	.88	.36	
df	1	1	1	

TABLE 5

RESULT OF THE CHI-SQUARE TEST FOR SIGNIFICANT DIFFERENCE BETWEEN PERFORMANCE ON EACH OF THE SIX TASKS ACCORDING TO SEX OF SUBJECT

Sex	Number of Passing Scores on Each Task						n
	L_1	L_2	L_4	I_1	I_2	I_4	
Male	20	20	13	41	25	15	54
Female	24	21	9	32	23	7	54
Total	44	41	22	73	7	22	108
Chi-square	.36	.24	.72	1.02	.082	2.90	
df	1	1	1	1	1	1	

TABLE 6

CORRELATIONS BETWEEN PERFORMANCE ON THE LOGICAL TASKS AND PERFORMANCE ON THEIR LOGICO-MATHEMATICAL INFRALOGICAL TASK COUNTERPARTS

Performance	Tasks L_1-I_1	% of n	Tasks L_2-I_2	% of n	Tasks L_4-I_4	% of n
Pass L(a) - Pass I(a)	29	28	27	25	11	10
Pass L(a) - Fail I(a)	15	14	14	13	12	11
Fail L(a) - Pass I(a)	26	24	21	19	12	11
Fail L(a) - Fail I(a)	38	35	46	43	73	68
Total	108	100	108	100	108	100
Correlations	.24		.35		56	