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THE DEVELOPMENT OF LINEAR PATTERNING IN DISADVANTAGED CHILDREN OF THREE ETHNIC GROUPS

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The visual linear pattern task performance of a sample of Black, White and Hispanic children (N: 137) residing in economically disadvantaged urban areas was examined at three grade levels (prekindergarten, kindergarten and first grade) using a 72 pattern task instrument classified by cognitive process, mode of representation and pattern complexity. Statistical analyses revealed significant differences relating to grade-level and sex and to level of cognitive process and pattern complexity.

Between the ages of three and seven years children are considered to be developing the mental structures associated with the ability to classify and relate objects on the basis of their qualitative attributes and to conserve continuous and discontinuous quantities (8, 14). A related ability, also appearing during this period, is the ability to recognize visual linear patterns.† Recommended by many educationalists as basic to mathematical understanding (6, 10, 11), pattern recognition tasks are rapidly becoming an integral part of the curriculum in preschools and elementary schools in the area of pre-number skills. However, until recently, there has been a dearth of empirical evidence concerning the nature of the development of the ability to recognize visual patterns in young children and the variables associated with it.

The present study, attempted to provide some empirical evidence relating to the development of pattern recognition ability in children in the pre-operational years, a period characterized by the children's inability to perform mental operations to reverse actions on objects (14). Information

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† A pattern is defined as a finite sequence of elements that indicates the rule for the indefinite continuation of the sequence, e.g., ABCC ABCC . . . . , 101001000 . . . .
A linear pattern is defined as a pattern in which the rule for the indefinite continuation of the pattern is indicated by the repetend (repeating part) of the pattern, e.g., ABCC ABCC . . . . .

of this kind is required in order to facilitate the production of instructional materials and activities on patterning which are mathematically relevant and developmentally appropriate to young children of diverse backgrounds and personal characteristics, and the development of diagnostic and evaluative instruments for measuring children's pattern task performance This evidence also contributes to the general body of knowledge regarding the development of logical thinking and problem-solving ability in children in the pre-operational years

Following a pilot study (7), a co-ordinated series of investigations was initiated to provide information on the development of children's pattern task performance as it relates to instrument variables such as cognitive process, mode of presentation, pattern complexity, stimulus dimension, and to subject classification variables such as age, sex, race, socio-economic status, location, cultural background, and grade level Prior to the present study, a number of studies in the series had already been carried out (2, 3, 4, 12) All found significant differences in pattern task performance relating to grade level Cromie (4) investigated the pattern task performance of children of low socio-economic status and normal mental ability at three grade levels – prekindergarten, kindergarten and grade one He found a hierarchy in the cognitive processes involved in the pattern tasks – *reproduction*, *identification* and *extension* which was consistent within and across grade levels * This developmental hierarchy was also revealed in studies by Campbell (3) with children of low socio-economic status who were below average in mental ability and by Rustigian (12) with middle class children Burton (2) found the development of linear patterning to be strongly related to mental ability level but not to sex type Findings regarding the mode of presenting the task were inconclusive Campbell (3) found the ontogenetic hierarchy for mode to be symbolic, enactive, iconic, the other studies did not reveal any hierarchy for mode † Stimulus dimension (colour or form) and pattern complexity were not reported as significant variables in pattern task achievement in any of the studies

Since the need for more studies concerning the development of specific mental abilities in disadvantaged minority groups has been high-lighted by

* *Reproduction* tasks required the children to copy a pattern, *identification* tasks required them to select a specific pattern from among three patterns and *extension* tasks required them to continue a pattern

† The pattern tasks were presented to the children in three modes corresponding to Bruner's (1) three representation systems *enactive* presented with concrete materials, *iconic* - presented pictorially *symbolic* presented with symbols

numerous authors (e g , 5, 15), the present study continued the investigation into the development of pattern recognition in young children by examining its development in children of three ethnic groups, Blacks, Whites and Hispanics and by examining pattern task performance on a broader range of cognitive processes and pattern forms The process *reproduction* was replaced by the process *extravariable transfer* and the process *interpolation* introduced * To shed further light on the role of pattern complexity the number of pattern forms in the instrument was increased from four to six (AB, ABB, AABB, ABC, ABCC, ABCD)

The basic objectives of the study were

1 To examine the course of development of the ability to perform linear pattern tasks in economically disadvantaged Black, White and Hispanic children of below average mental ability aged between four and six years

2 To determine if the development of the ability to perform linear pattern tasks in the children was related to (i) grade level or (ii) ethnic group affiliation

3 To determine if the linear pattern task performance of the children was related to (i) the type of cognitive process involved in the task, (ii) the mode in which the task was presented, or (iii) the complexity of the pattern involved in the task

4 To examine the pattern task performance of children for evidence of difficulty hierarchies relating to process, mode or pattern

METHOD

Instrument

The instrument used to measure children's linear patterning performance was a modified version of the instrument used in previous studies (e g , 4) It consisted of 72 distinct linear pattern tasks classified along the dimensions of cognitive process, mode of representation, and pattern complexity A model of the 4 x 3 x 6 matrix of pattern tasks is shown in Table 1

* Tasks involving *extravariable transfer* required the children to reproduce a pattern with a form of the same stimulus dimension other than that on which the pattern was based e g *copying a pattern in coloured blocks with coloured houses* *interpolation* tasks required the children to put in missing elements in a pattern

TABLE 1

MODEL OF THE PATTERN TASK INSTRUMENT

MODE	COGNITIVE PROCESS: Extravariable Transfer	Identification	Extension	Interpolation
Enactive	AB ABC ABB ABCC AABB ABCD			
Iconic				
Symbolic				

Each of the 12 cells formed at the process mode intersections contained six pattern tasks graded in complexity according to the number of different elements and length of repetend as proposed by Simon (13) The children were presented with, at least, two complete repetends of each pattern in each pattern task (e g , ABAB) and required to execute the four processes in the three modes of presentation identification (selecting a matching pattern from three choice patterns), interpolation (putting in missing elements in a pattern), extension (extending a pattern) and extravariable transfer (copying a pattern in another form)

Pattern tasks in the enactive mode were presented with 1″ coloured wooden cubes glued to posterboard A reservoir of cubes was used by the children to respond to the tasks Tasks in the iconic mode were presented with 1″ coloured squares drawn on white paper and accompanied by a reservoir of coloured squares* on hard back paper Tasks in the symbolic mode were presented with alphabetic symbols (S, X, O and I) drawn on white paper and accompanied by a reservoir of symbols printed on hard back paper Table 2 contains a description of a sample of the tasks

* For tasks involving the process of extravariable transfer the reservoir contained coloured drawings of animals

TABLE 2

EXAMPLES OF LINEAR PATTERN TASKS

Process	Mode	Pattern	Task
Extravariable Transfer (Training Task)	Enactive	AA (Trivial pattern)	 B = blue cube □□□□ Tester reproduces trivial pattern with coloured houses then gets the child to do the same
Extravariable Transfer	Symbolic	ABB	XSSXSS □□□□□□ ' Look at this make this (pointing) here with these letters Reservoir contains similar letters printed on paper in different style (e g x i)
Identification	Iconic (Pictorial)	ABC	BRBORO OBROBR OORRBB O = orange square B = blue square OBROBR R = red square Look at this which one of these (pointing) is the same as this? (pointing)
Extension	Symbolic	ABCD	SXOISXOI□□□□ Look at this (pointing) what goes next (pointing)? (child can select appropriate letters from reservoir)
Interpolation	Iconic (Pictorial)	ABCC	ORBBORBB□□□B Look at this (pointing) what goes next? (reservoir contains orange, red and blue squares)

Sample

The population investigated was children served by the Title 1* preschool and school programme in the public school system of a large New England city (population 170,000) The children (c 1,200 in all) who resided in economically disadvantaged areas of the city, demonstrated below average achievement on the *Peabody Picture Vocabulary Test* and thus became eligible for Title 1 services

Three Title 1 elementary schools were chosen at random and from each of three grade levels, prekindergarten,† kindergarten and first grade, random samples of Black, Spanish surnamed and White children were drawn in proportion to the total number of each group in the school Altogether 137 children were selected, 47 at prekindergarten, 44 from kindergarten and 46 from first grade Of the total, 72 were boys and 65 were girls The mean age of the prekindergarten subjects was 4 8 years, that of the kindergarten subjects, 5 7, and that of the first grade subjects, 6 9 years

Procedure

Eleven testers were trained to administer the pattern task instrument (all had had some classroom experience either as teachers or teacher aides) Testing was carried out in the largest space available in each school (either the hall or the cafeteria) The tasks were set out on tables in 12 groups of six tasks each, corresponding to the 12 process x mode cells of the instrument Each child was assigned to one tester who moved through the 72 tasks with the child in the order indicated in the response booklet To control for sequence effects the children were tested on the tasks in random order At the beginning of each group of six tasks children received training on a trivial pattern (e g , copy AAAA) to familiarize them with the process involved in those tasks Testing took place during normal school hours over a period of about four weeks in spring The average test length for each age level was 55 minutes for the four year olds, 47 minutes for the five year olds, and 38 minutes for the six year olds

RESULTS

Reliability The 72 pattern task instrument yielded a coefficient of internal consistency of 0 97 using the Kuder Richardson 20 formula For each of

* The Title 1 programs were designed to provide financial assistance to schools serving areas with large concentrations of children from low-income families

† There were prekindergarten classes in only 3 schools so all three of them were sampled

the four processes, identification, interpolation, extension and transfer (18 tasks in each), the reliability coefficients were 0 84, 0 92, 0 92 and 0 93 respectively

Grade level and ethnicity The mean scores and standard deviations of the three ethnic groups at each of the three grade levels on the pattern tasks are shown in Table 3 Two way factorial analysis of the variance

TABLE 3

MEAN RAW SCORES AND STANDARD DEVIATIONS CLASSIFIED BY GRADE AND ETHNICITY (MAXIMUM POSSIBLE SCORE IS 72)

		Black	White	Hispanic	Total
	Mean	16 54	15 12	14 72	15 36
Prekindergarten	SD	14 50	8 13	10 44	10 83
	Mean	31 73	36 78	29 46	32 57
Kindergarten	SD	18 55	21 83	19 87	19 85
	Mean	45 40	55 53	54 93	52 04
First grade	SD	14 91	14 65	15 80	15 48
	Mean	31 91	36 19	31 40	33 20
Total	SD	19 67	22 88	22 57	21 77

in the total scores of the 137 children yielded a highly significant positive relationship between grade level and pattern task performance ($F = 61\ 64$, $df = 2,\ 8$, $p <\ 001$) but no significant relationship was found between ethnicity and pattern task performance, although in first grade the White and Hispanic children performed somewhat better than the Black children Univariate analyses revealed that the strong relationship between grade level and pattern task performance was consistent across the three ethnic groups Further univariate analyses also revealed that performance in each of the three modes of presentation and on each of the four processes was strongly related to grade level

Cognitive Process The relationship between cognitive process and pattern task performance was examined using a three factor mixed design (9), with two between subjects dimensions (grade level and ethnicity) and one within subject dimension (process) Results of the analysis indicated that the type of process involved in the pattern task was a highly significant factor in the children's pattern task performance (F = 113 73, df = 3,27, p < 001) Weak interactions were also obtained between process and age and between process and ethnicity

Mean scores for the three grade levels on the four cognitive processes are given in Table 4 Tests for significant differences among the means

TABLE 4

MEAN SCORE ON THE FOUR COGNITIVE PROCESSES
(EIGHTEEN TASKS PER PROCESS)

	Transfer	Identifi cation	Extension	Interpol ation
Prekindergarten	6 02	7 19	0 98	1 36
Kindergarten	12 36	10 45	5 16	4 61
First grade	17 13	15 35	10 04	9 39
Total	11 79	10 98	5 36	5 10

showed that pattern tasks involving the interpolation and extension processes were more difficult than pattern tasks involving the identification and extravariable transfer processes A series of two way factorial analyses of variance indicated that the highly significant influence of cognitive process and the clustering of the processes into two difficulty levels was maintained in each grade level and ethnic group regardless of the mode in which the tasks were presented F ratios in these analyses ranged from 32 58 to 100 68, all were significant beyond the 001 level These analyses also indicated that the process x ethnicity and process x age interactions were attributable, in the main, to the fact that the Black first graders performed less well on interpolation and extension tasks than did the White or Hispanic first graders

Mode When the results were analysed with mode as the within subjects factor in the three way factor mixed design, no significant differences relating to mode were found Performance patterns in the three modes of representing the pattern tasks were very similar

Pattern A three way factorial analysis with pattern as the within subjects factor revealed significant differences due to pattern ($F = 10\ 70, df = 5\ 45$, $p < \ 001$) The mean scores of the children on the six pattern forms are given in Table 5 Tests for significant differences among the means indicated that for the prekindergarten and kindergarten children patterns ABB, ABC, AABB, ABCC and ABCD were significantly more difficult than pattern AB It can also be seen from Table 5 that the rank order of difficulty in the six forms of pattern in the 72 pattern tasks was AB, ABB, AABB, ABC, ABCC, ABCD

TABLE 5

MEAN SCORES ON EACH PATTERN
(MAXIMUM SCORE IS 12)

Pattern No Pattern	P1 AB	P2 ABB	P3 AABB	P4 ABC	P5 ABCC	P6 ABCD
Prekindergarten	3 19	2 64	2 43	2 62	2 26	2 23
Kindergarten	6 27	5 50	5 30	5 16	4 89	5 45
First grade	8 96	8 54	8 65	8 76	8 43	8 57
Total	6 12	5 54	5 44	5 50	5 18	5 39

Sex (a post hoc analysis) Although not hypothesized as making a significant contribution to variance in the pattern task performance of the children, a three way factorial (post hoc) analysis revealed that sex was a significant factor in pattern task performance The means for boys and girls at the three grades levels and for each ethnic group were tested for significant differences If was found that the girls were superior to boys in pattern task performance in prekindergarten and kindergarten and in Whites and Hispanics but not in first grade or in Blacks

DISCUSSION

The most striking finding of the present study is the strong relationship between grade level and performance on linear pattern tasks The ability of young economically disadvantaged children of below average mental ability to respond to patterning tasks developed rapidly and uniformly between prekindergarten and first grade The prekindergarten children experienced much difficulty with pattern tasks, even ones requiring only a copying response, whereas the first graders performed very successfully on most of the tasks The transition period between the presence and absence of linear patterning ability in the sample occurred in kindergarten The nature of the development of patterning ability from prekindergarten to first grade appeared to be similar among the samples of lower class Black, White and Hispanic children with the possible exception of the Black first graders for whom the extension and interpolation tasks appeared to be more difficult than for White and Hispanic first graders These findings confirm the findings of Campbell (3), Cromie (4) and Rustigian (12) that grade level is closely related to the pattern task performance of disadvantaged children The unhypothesized finding that girls performed significantly better than boys is contrary to that of Burton (2), who found no sex differences in a study of patterning among disadvantaged children of high and low mental ability On the basis of informal observations made during the administration of the pattern task instrument, our finding related to sex differences could be attributed to the apparently greater attentiveness of the girls to the tasks than the boys, who appeared to be more restless and more easily distracted

Another clearcut finding of the study is the highly significant relation ship between linear pattern task performance and the type of cognitive process involved in the pattern task Two clusters of processes were obvious in the performance of the children on the four processes Tasks involving the interpolation and extension processes were of similar difficulty within each grade level but were much more difficult than tasks involving the identification and extravariable transfer processes which were also of similar difficulty This grouping of the processes into two difficulty levels suggests the likelihood that two factors or constructs relating to the degree of logical thinking involved in the tasks underlie the pattern task performance of the children Such a view is consistent with the nature of the four processes Extravariable transfer, which involved the reproduction of a colour pattern in a form other than that of the original pattern (e g , with coloured animals instead of coloured blocks), and identification, which involved matching a specified pattern with its equivalent among three choice patterns, could have been responded to correctly by a child using a form of 'one to one correspondence' strategy This strategy, which young children appear to apply widely in matching sets, does not necessarily require internalization of the pattern Interpolation and extension processes require some level of recognition of the relations among the elements of the pattern ('same as' and 'next to) and a decoding of the pattern for the child to respond appropriately by putting in missing elements in the pattern or continuing the pattern in such a way as to preserve these relations. It would be informative, in pursuing research on patterning, to examine the performance of children aged between four and six years on processes which are more likely to require complete abstraction of the pattern, e.g., reversal transfer, extradimensional transfer or intravariable transfer.

A somewhat less important, but significant, factor in the pattern task performance of the children was the complexity of the pattern involved in the task. The fact that AB type pattern tasks were significantly easier than the other five types, and the fact that the rank order in the pattern types was AB, ABB, ABC, AABB, ABCD, ABCC suggest that the length of the repetend and the number of different elements in the pattern contribute strongly to the complexity of the pattern. However, further research on this issue is desirable, possibly including patterns with repetends of five symbols and simple non linear patterns (e.g., AB, ABB, AAAB ...). The pattern forms were presented to the children in three different modes – enactive, iconic and symbolic – but no differences in the performance of the children relating to mode were found. The implications of this finding are that the differences in perceptual support provided by the three modes were insufficient to make a significant contribution to the difficulty level of the pattern tasks. Previous related studies (2, 3, 12) support this finding.

Some educational implications can be drawn from the findings of the present study. As growth in children's logical thinking is considered to be proceeding rapidly during these early years, it is desirable that young children be provided with learning and problem-solving experiences appropriate to their developmental level. Linear pattern tasks, on the basis of the present findings, provide challenging cognitive tasks to precede activities on number patterns and relations, in particular for children residing in low socio-economic inner city environments. For four-year olds, pattern tasks should be confined to those involving reproduction and identification processes and, for five and six year olds, they could be extended to include higher level processes such as interpolation and extension. Simple AB type pattern tasks should precede the more complex types in an instructional sequence on patterning. The findings of this study, combined with findings of the related studies, indicate the suitability of linear pattern tasks for young children of different abilities and backgrounds. In addition to further studies of a developmental nature it would also be informative to determine the effects, if any, of instruction on linear patterning to young children.

REFERENCES

1 BRUNER, J S and KENNEY H J On relational concepts In Bruner, J S Olver R , and Greenfield, P (Eds), *Studies in cognitive growth* New York Wiley 1966

2 BURTON G M Variations in the ontogeny of linear patterns among young children Unpublished doctoral dissertation University of Connecticut 1973

3 CAMPBELL, C E The ontogeny of linear patterns among young children of below normal mental ability in an economically disadvantaged area Unpublished doctoral dissertation University of Connecicut 1974

4 CROMIE R G The ontogeny of linear patterns among normal children in an economically disadvantaged area Unpublished doctoral dissertation, University of Connecticut, 1971

5 DEUTSCH C P Environment and perception In Deutsch, M , Katz I and Jensen, A R (Eds), *Social class, race, and psychological development* New York Holt, Rinehart and Winston 1968

6 GIBB G E and CASTANEDA A M Experiences for young children In Payne, J.N (Eds) *Mathematics learning in early childhood* Reston Virginia National Council of Teachers of Mathematics, 1975

7 GLENNON, V J , and ALDERMAN D The ontogeny of linear tesselations in one variable among young children Mimeo Storrs Conn University of Connecticut 1970

8 INHELDER B , and PIAGET J *The early growth of logic in the child Classification and seriation* (Translated by E.A Lunzer) London Routledge and Kegan Paul 1964

9 LINDQUIST E F *Design and analysis of experiments in psychology and education* Boston Houghton Mifflin 1953

10 LOVELL K Intellectual growth and understanding mathematics *Journal for Research in Mathematics Education* 1972 *3* 164 182

11 McKILLIP, W D Patterns A mathematics unit for three and four year-olds *Arithmetic Teacher* 1970, *17* 15 18

12 RUSTIGIAN A The ontogeny of pattern recognition Significance of color and form in linear pattern recognition among young children Unpublished doctoral dissertation University of Connecticut 1976

13 SIMON H.A Complexity and the representation of patterned sequences of symbols *Psychological Review* 1972 *79*, 369 382

14 SINCLAIR, H Piaget s theory of development The main stages In Rosskopf, M F , Steffe L P , and Taback, S (Eds), *Piagetian cognitive development research and mathematics education* Reston Virginia National Council of Teachers of Mathematics, 1971

15 STODOLSKY, S , and LESSER, G Learning patterns in the disadvantaged *Harvard Educational Review*, 1967, *37*, 546 593