DOCUMENT RESUME

ED 032 112 PS 001 988

By-Parker, Ronald K.; Halbrook, Mary Carol

The Utilizations of Concrete, Functional, and Designative Concepts in Multiple Classification.

Florida State Univ., Tallahassee. Dept. of Psychology.

Pub Date 69
Note-62p.
EDRS Price MF-$0.50 HC Not Available from EDRS.
Descriptors-*Age Differences, *Classification, Cognitive Ability, *Cognitive Development, Cognitive Processes, Grade 1, Grade 2, Grade 3, Kindergarten, Learning Processes, Pictorial Stimuli, *Task Performance, Time Factors (Learning)

In order to investigate developmental changes in multiple classification, a matrix task was administered to 80 kindergarten first, second, and third grade children. Correct solution of the incomplete matrices, comprised of three pictures in a row and three pictures in a column meeting at a blank intersection, required identification and combination of the common attributes of the row and the column. Concrete, functional, and designative concepts were used in construction of the matrices. Results indicated performance improvement with grade level and a significant interaction between grade and type of matrix. This interaction means that development of the ability to classify the three types of concepts occurs in chronological order: first, concrete, then funcational, and finally, designative. In general, when errors were made, children seemed to choose the picture representing the type of concept (concrete, functional, or designative) shown by object-sorting studies to be the most frequent mode of categorization. The time required to respond decreased with practice and was negatively correlated with correct matrix solution. Further research should focus on developing a training program for the prerequisite skills necessary to solve the matrices. [Not available in hard copy due to marginal legibility of original document]. (MH)

The Utilizations of Concrete, Functional, and Designative Concepts in Multiple Classification

Ronald K. Parker

Mary Carol Halbrook

Department of Psychology
Florida State University

1969

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Studies of the changing manner in which children structure their experience have revealed three main changes with age: changes in the number and the organization of attributes used for classification, changes in the type of attributes used, and changes in the ability to define the common attributes of groupings.

In outlining the qualitative development of intellectual structures, Piaget has given the most detailed analysis of the steps by which a child acquires classificatory skills (Flavell, 1963). From ages two to seven, children are limited in their use of representation. They utilize perceptual attributes in categorization and are unable to consider more than one salient feature of an object. Momentary considerations of more than one attribute of an object begin to appear in the later years of this period of preoperational thought. During the subperiod of concrete operations (years seven to eleven), the child's representational processes become systematic and tightly integrated, thus forming what Piaget designates cognitive operations. Using logico-mathematical structures as models of the actual organization of cognitive structures, Piaget devised nine distinct "groupings" of logical classes and relations which appear during this period of middle childhood.

The combination of classes is described in Grouping III: Bi-Univocal Multiplication of Classes. This grouping involves defining a class which combines the relevant attributes of two or more classes. Piaget and Inhelder (1959) have conducted a series of studies which require finding an intersection or logical product of several classes. An example presented by Flavell (1963) requires determining a picture to be placed at the intersection of a row of pictures of differently colored leaves and a column of pictures of green objects. The correct intersect must contain both class attributes. Children at the level of concrete operations were able to solve this type of a matrix problem.

Both Kofsky (1966) and Lovell, Mitchell, and Everett (1962) designed a series of studies to replicate the findings of Piaget and Inhelder. Kofsky (1966) created 11 tasks to correspond to the 11 steps posited by Piaget and Inhelder to lead to the attainment of the concept of class inclusion. In the task dealing with multiple class membership, a set of triangles varying in size and color (large or small and red or green) were presented to children who were questioned to determine their understanding that the blocks could be classified in more than one way. Although only 10% of the four-year-olds passed this task, 60% of the six-year-olds and 90% of the seven-year-olds were successful. Lovell, Mitchell, and Everett (1962) asked children to partition 16 cards. Eight cards pictured rabbits running, four of which rabbits were white and four of which were black, and eight cards pictured rabbits sitting, four black and four white. Correct performance required recognition of the two dichotomies, black versus white and sitting versus running. Correct partition was achieved by two of ten six-year-olds, by five of ten seven-year-olds, and by all of the eight-year-olds.

Other studies (Elkind, 1966; Goldman & Levine, 1963, Reichard, Schneider, & Rapaport, 1944; Thompson, 1941) tend to confirm Piaget's description, showing increased flexibility in thought and increased use of two or more dimensions simultaneously as a child becomes older.

Bruner (1966) emphasizes the necessity for an explanation of cognitive structures in terms of psychological processes and offers three modes of representation of reality used at different periods of development. These three types of representation--enactive, ikonic, and symbolic--emphasize common roles in action, common perceptual attributes, and common class relationships, respectively. Olver and Hornsby (1966) studied the changes in representation by tracing the manner in which children define objects as equivalent. They used both lists of words, in which each word was successively more different from the preceding word, and a group of pictures. Subjects were asked to tell how each word was "alike" and "different from" the preceding words and to group pictures which were "the same." Both stimuli yielded basically the same changes in attributes determining equivalence. Perceptual attributes were dominant at six years of age, but the use of functional attributes increased until the children reached age nine. The use of nominal grouping also increased steadily from 6% at six years of age to 32% at eleven years of age.

A great many studies have used object-sorting tasks in investigation of classificatory behavior (Goldman & Levine, 1963; Heald & Marzolf, 1953; Reichard, Schneider, & Rapaport, 1944; Sigel, 1953, 1954; Thompson, 1941). All have revealed a decrease in the use of perceptual or concrete categories and an increase in the use of nominal or designative categories with age. The majority also show the utilization of functional categories reaching a peak between the periods of perceptual and designative (ikonic and symbolic) representation.

In addition to finding changing modes of representation, Olver and Hornsby (1966) found an increase with age in the ability to correctly identify groupings. "Correct" identification requires recognition of a common feature characterizing all items in the group. Several other investigators (Lee, 1965; Reichard, Schneider, & Rapaport, 1944; Sigel, 1953) have also found an increasing ability to recognize relevant attributes with increasing age.

Much of the literature concerned with the equivalence of objects has tended to lead to the at least implicit assumption that a child groups by perceptual attributes because he is unable to use class or functional categories. Birch and Bortner (1966) used an object-matching task to test their hypothesis that "preferential responsiveness to stimulus factors and not the failure to possess class and functional categories underlies the failure of young children to make categorical choices." Children between three and ten years of age were asked to match one of three objects with an index object. In one condition matching on the basis of either stimulus similarity or function and class membership was possible, while in the other condition only functional or class properties could be used. In the former condition the usual increase with age was found in the use of class or functional categories, with asymptote being reached in the third grade. However, in the latter condition, even nursery school children matched correctly more frequently than chance, and asymptote was reached in the second grade. Thus although younger children seem to prefer to use perceptual cues as a basis for classification, they are capable of using functional and designative cues when perceptual cues are not available.

Two questions then arise from the findings that preferred bases of classification change with age and non-preferred bases can be used. (1) At certain ages are children able to combine certain combinations of perceptual, functional, and designative concepts and not others? (2) Will there be different errors caused by dominance of a particular type of attribute at different developmental levels? This problem can best be explored using an incomplete matrix task which requires the combination of two class attributes for the convergent production of one class. The simultaneous consideration of a combination of any two of perceptual (concrete), functional, and designative attributes can be investigated.

Correct solution of this type of matrix requires two processes: identification of the relevant attribute of the stimuli and convergent production of one class from two class attributes (requiring simultaneous consideration of both attributes) in selection of one picture. According to Guilford's factor analytic model of the "structure of the intellect," six factors are involved in this task--three in defining or naming the class and three in the convergent production of one class from two classes (Guilford, 1967). The three factors involved in naming classes are:

1. Cognition of figural classes: selection of figures which belong or do not belong with a class of figures.

2. Cognition of semantic classes: verbal classification, word classification, word group naming.

3. Convergent production of semantic units: naming of classes or relations; this naming factor causes variance in cognition of figural and semantic classes.

Involved in the convergent production of a class are:

1. Convergent production of semantic units: definition of formed classes.

2. Convergent production of figural classes: formation of classes.

3. Convergent production of semantic classes: production of classes of words or concepts.

of perceptual (concrete), functional, and designative attributes can be investigated.

Correct solution of this type of matrix requires two processes: identification of the relevant attribute of the stimuli and convergent production of one class from two class attributes (requiring simultaneous consideration of both attributes) in selection of one picture. According to Guilford's factor analytic model of the "structure of the intellect," six factors are involved in this task--three in defining or naming the class and three in the convergent production of one class from two classes (Guilford, 1967). The three factors involved in naming classes are:

1. Cognition of figural classes: selection of figures which belong or do not belong with a class of figures.

2. Cognition of semantic classes: verbal classification, word classification, word group naming.

3. Convergent production of semantic units: naming of classes or relations; this naming factor causes variance in cognition of figural and semantic classes.

Involved in the convergent production of a class are:

1. Convergent production of semantic units: definition of formed classes.

2. Convergent production of figural classes: formation of classes.

3. Convergent production of semantic classes: production of classes of words or concepts.

Correct performance on both of these tasks has been found to increase with age.

In a pilot study an incomplete matrix task was used to investigate the development of multiple classification. Each of the 24 matrices consisted of three pictured objects in a row which had a common attribute and three pictured objects in a column which had a different common attribute. Of four choices, one pictured an object having both attributes and thus correctly filled the intersection of the row and the column. Ten children in each of the first, second, and third grades were administered the matrices, and a decreasing number of errors with increasing age was found. At the time of matrix construction, various concepts were considered only as a means of varying matrix difficulty.

The purpose of the present study was to investigate changes with age in the identification and combination of the common attributes of groups and to assess the influence of different attributes on this ability. An incomplete matrix requiring combination of two concepts to correctly fill a blank intersection was used. Six types of matrices were constructed from the various combinations of designative, functional, and perceptual concepts. The selection of one of three pictures to fill the intersection, one picture having both attributes and the other two having the attribute of the row alone and the column alone, allowed assessment of the type of error made.

The three main developmental trends previously discussed were expected to influence performance on this task. These three developmental changes are: an increasing ability to correctly identify the common attributes of groupings, an increasing ability to consider two attributes simultaneously, and changes in the type of attributes which determine equivalence groupings at different ages. The first two changes were expected to result in an increased number of correct completions with age. The changes in attributes used for grouping were expected to lead to errors caused by selection of "dominant" cues at certain ages with a failure to consider the less dominant cues when both are necessary for the correct solution of matrices.

METHOD

Subjects

The Ss were 80 children, 20 from kindergarten and 20 from each of Grades 1, 2, and 3, obtained from University School, an affiliate of Florida State University. Most Ss were within plus or minus four months of the mean age for their grade level. Two kindergarten children were one month below age, and two were two months below age. One first and one second grader were one month over age. The mean ages for kindergarten and Grades 1, 2, and 3 were 6 years 1 month, 7 years 1 month, 8 years 1 month, and 9 years, respectively.

Stimuli

The stimuli were a series of 42 incomplete matrices formed by three cards in a column and three cards in a row meeting at a blank intersection. The six 3 x 3 inch cards forming each matrix were pasted onto poster board. Three cards representing choices to fill the intersection were presented on a cardboard plaque below and to the right of the matrices. On each of the cards was a simple line drawing, except in the cases where color was a relevant attribute and the drawings were colored with crayon. The entire arrangement is diagrammed in Figure 1.

The three objects pictured in the row had a common attribute and the three objects pictured in the column had a different common attribute. Of the three choices, one pictured an object having the common attribute of the row alone, one the common attribute of the column alone, and the other the attributes of both the row and the column. Three types of attributes were used in construction of the matrices:

1. Concrete. Grouping is based on the perceptually dominant attributes of form, color, or identity. Identity involves a group of the same objects, such as three hats or three shells.

2. Functional. The objects all have a common use.

3. Designative. All objects belong to a common class and are subsumed under a common class name.

Combinations of these three types of concepts yielded six types of matrices: concrete x concrete (CC), functional x functional (FF), designative x designative (DD), concrete x functional (CF), concrete x designative (CD), and functional x designative (FD). The six matrices of each type and the practice matrices are presented in the Appendix.

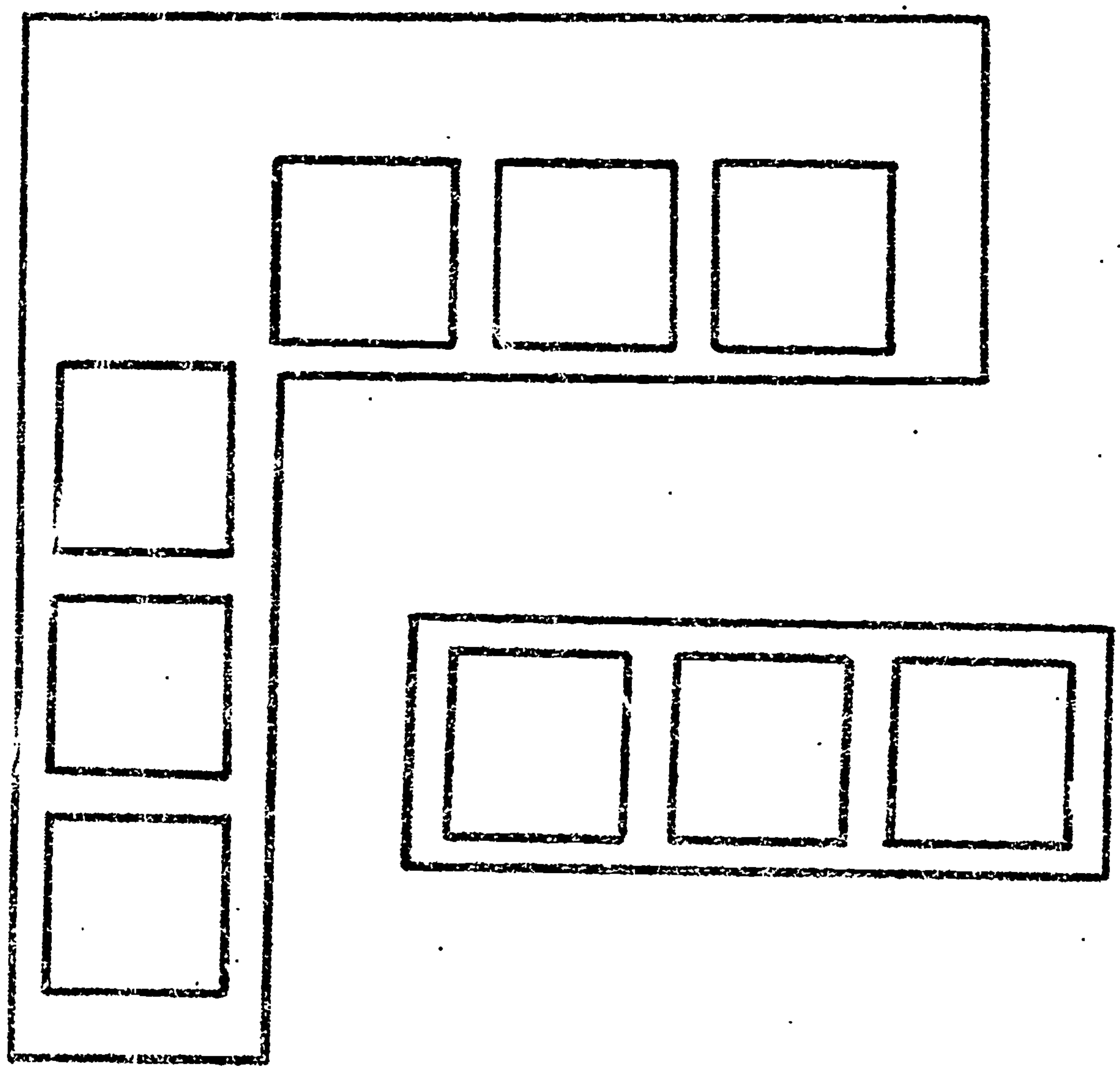

Fig. 1. Diagram of matrix and choices.

One each of concrete, functional, and designative concepts were used in practice matrices for instruction. A stopwatch was used to measure latency of response. Latencies and choices were recorded on mimeographed record forms.

Procedure

E accompanied S from the classroom to the testing room, where both were seated before a table at right angles to each other, and talked with him briefly to establish rapport. A practice task was presented to each S for instructional purposes.

First, three pictures of objects perceptually alike were placed before S. S was asked to name each picture and then to tell how the pictures were alike. "All of these pictures are alike in some way. How are they alike?" If S was incorrect or did not know, E told him. E then said: "Here are three other pictures. One of these is like these three. Choose the one like these three and put it with them." Only one of the three pictures presented had the same perceptual attribute as the three like pictures. If S was incorrect, E pointed out the correct picture and explained why it was correct. This entire procedure was employed next using three pictures of objects with a common function and three choices, and, finally, using three pictures of objects subsumed under a common class name and three choices.

The three pictures with the same perceptual attribute were then arranged in a row and the three pictures of objects with a common function in a column. The row and the column met at a blank intersection. E said: "I'm going to put these three pictures which are alike in a line here and these three pictures which are alike in a line here. I'm going to put three choices down here." Three pictures were placed below and to the right of the matrix. Two of the choices were those two pictures previously placed with the two groups of like pictures; thus one picture had the attribute of the row alone and the other the attribute of the column alone. The third choice combined both attributes and correctly filled the intersection. E said: "I want you to pick the picture that goes with both groups and put it in this blank space. There is one picture that goes with both groups. Which one is it?" If S was incorrect or did not make a choice, E asked him the common attributes of both the row and the column and again asked which picture had both attributes. E then pointed out the answer and explained carefully the reason if S still could not choose the correct intersect. The stimuli were then arranged in the two remaining types of matrices (FD and CD), and the same procedure was followed.

The experimental matrices were presented one at a time, with the matrix and choices presented simultaneously. E named each picture. The choices were randomly arranged for each S to avoid bias by position preference. The matrices were randomized daily with the following restriction. There were six groups of matrices, and each group contained one of each of the six types of matrices. Both the matrices within each group and the order of presentation of the groups were randomized each day.

The Ss were instructed to "find the picture that goes with both groups, and place it in the blank space." Both choice of picture and latency of response were recorded for each matrix. After 12 and 24 matrices had been completed, one of the practice matrices was presented again, and E said: "Now we're going to review what you are supposed to do. Each picture in this line is alike in some way, and each picture in this line is alike in some way. I want you to find the picture which is like both groups and place it up here." After each S had completed the set of matrices, E accompanied him back to his classroom.

RESULTS

For all analyses of variance, responses on the first half and responses on the second half of the 36 matrix items were totaled separately. Thus there were two response measures for each S on each type of matrix, and the effect of stage of practice could be assessed. The score of each S on each type of matrix indicated the number of correct responses made on three matrices, providing a possible range of scores from 0 to 3. Analyses of variance were used to test for differences in number of matrices correct, for differences in types of errors made on CF, CD, and FD matrices, and for differences in latencies of responses. Pearson product-moment correlation coefficients were computed using CA, MA (when available), number of correct responses, and latencies. The Duncan multiple range test was used to test for significant differences between means in all analyses.

Correct responses

As Figure 2 shows, correct performance increased as

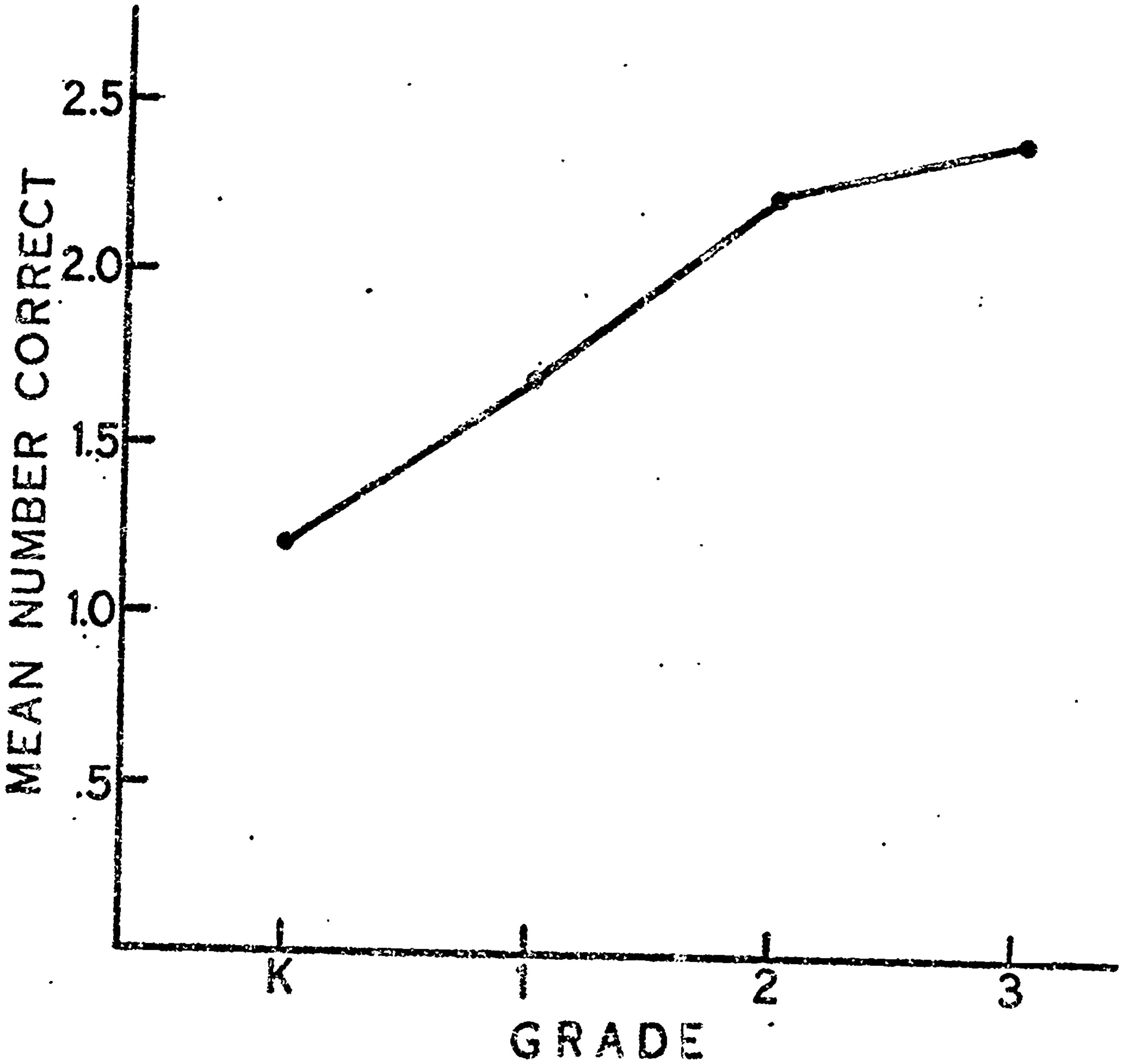

Fig. 2. Mean number of correct responses on three matrices as a function of grade.

grade level increased. An overall analysis of variance, summarized in Table 1, indicated significant main effects of grade and type of matrix ($p < .01$), as well as a significant interaction between grade and type of matrix ($p < .05$). Differences between kindergarten (K) and the first (G1), second (G2), and third (G3) grades were significant beyond the .001 level. Performances of G2 and G3 were not significantly different.

TABLE 1

ANALYSIS OF VARIANCE FOR CORRECT RESPONSES

Source	df	MS	F
Grades (A)	3	68.168	47.837**
Error	76	1.425	
Practice (B)	1	.051	1.000
A x B	3	.101	1.000
Error	76	.500	
Matrices (C)	5	8.743	14.101**
A x C	15	1.067	1.720*
Error	380	.620	
B x C	5	.978	1.466
A x B x C	15	.585	1.000
Error	380	.667	

*Indicates significance at the .05 level.

**Indicates significance at the .01 level.

The mean number of correct responses on three exemplars of each type of matrix is presented graphically in

Figure 3. Those matrices which did not differ significantly in number of correct responses are underscored by the same line in Table 2. It is evident that there were significantly more correct responses to CC matrices than there were to FF matrices, and significantly more correct responses to FF than to DD matrices. Statistically significant differences were also obtained between CF and FF and CD and FD matrices.

TABLE 2

THE DUNCAN MULTIPLE RANGE TEST OF DIFFERENCES BETWEEN TYPES OF MATRICES

CC(2.16)	CF(2.07)	CD(1.99)	FF(1.82)	FD(1.71)	DD(1.54)
———	———	———			
		———	———		
			———	———	
				———	———

C=Concrete; F=Functional; D=Designative. All notations not underscored by the same line are significantly different ($p < .05$).

The grade x type of matrix interaction is illustrated in Figure 4, and Table 3 indicates those differences between grades on each type of matrix which were significant. Quite clearly, there were no reversals of the developmental trend toward improved performance on any of the matrices. Duncan's test revealed significant differences between performance of K and G1, 2, and 3 and between performance of G1 and G2 and 3 ($p < .05$) on four types of matrices (FF, CF,

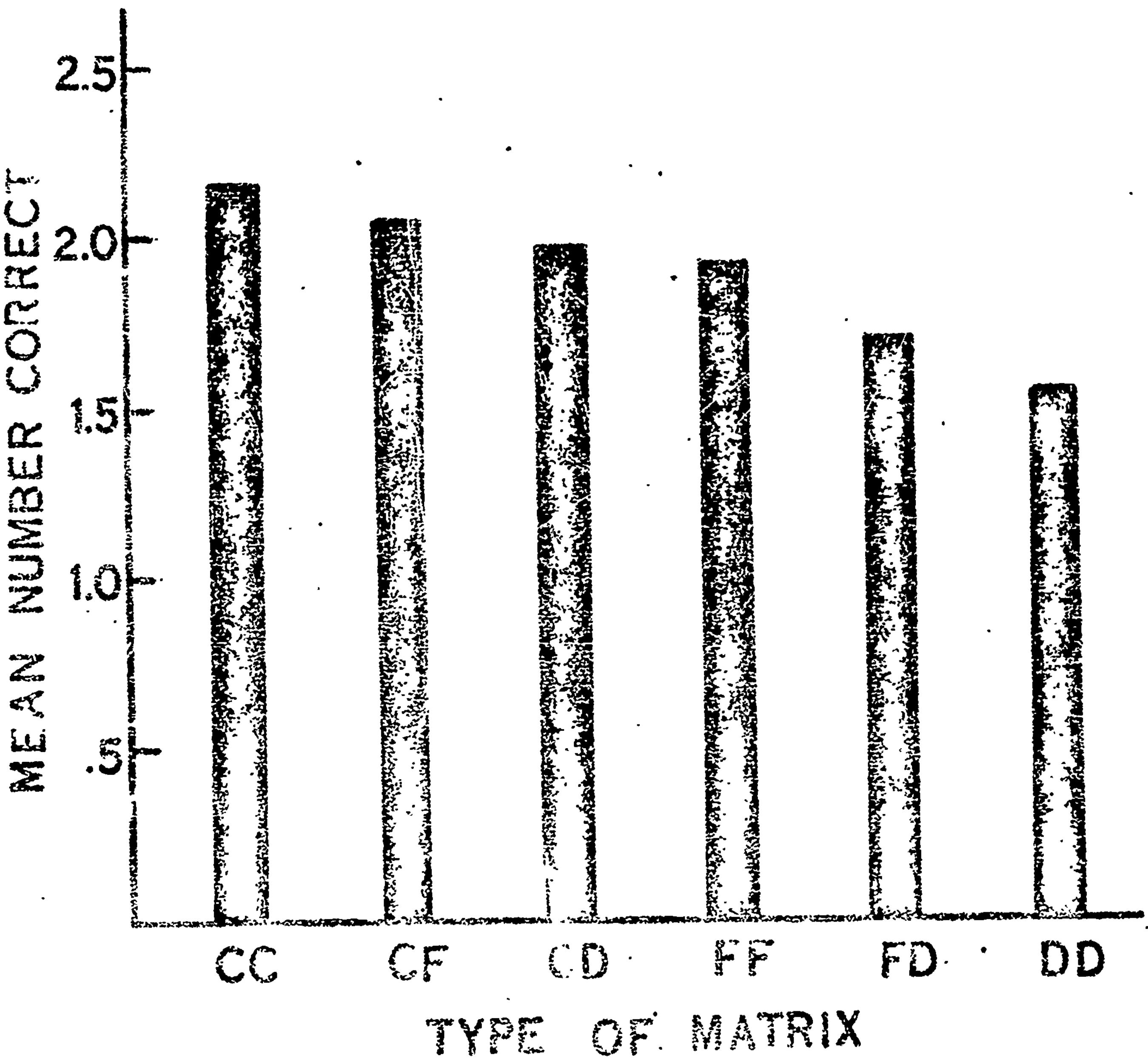

Fig 3. Mean number of correct responses on three exemplars of each type of matrix.

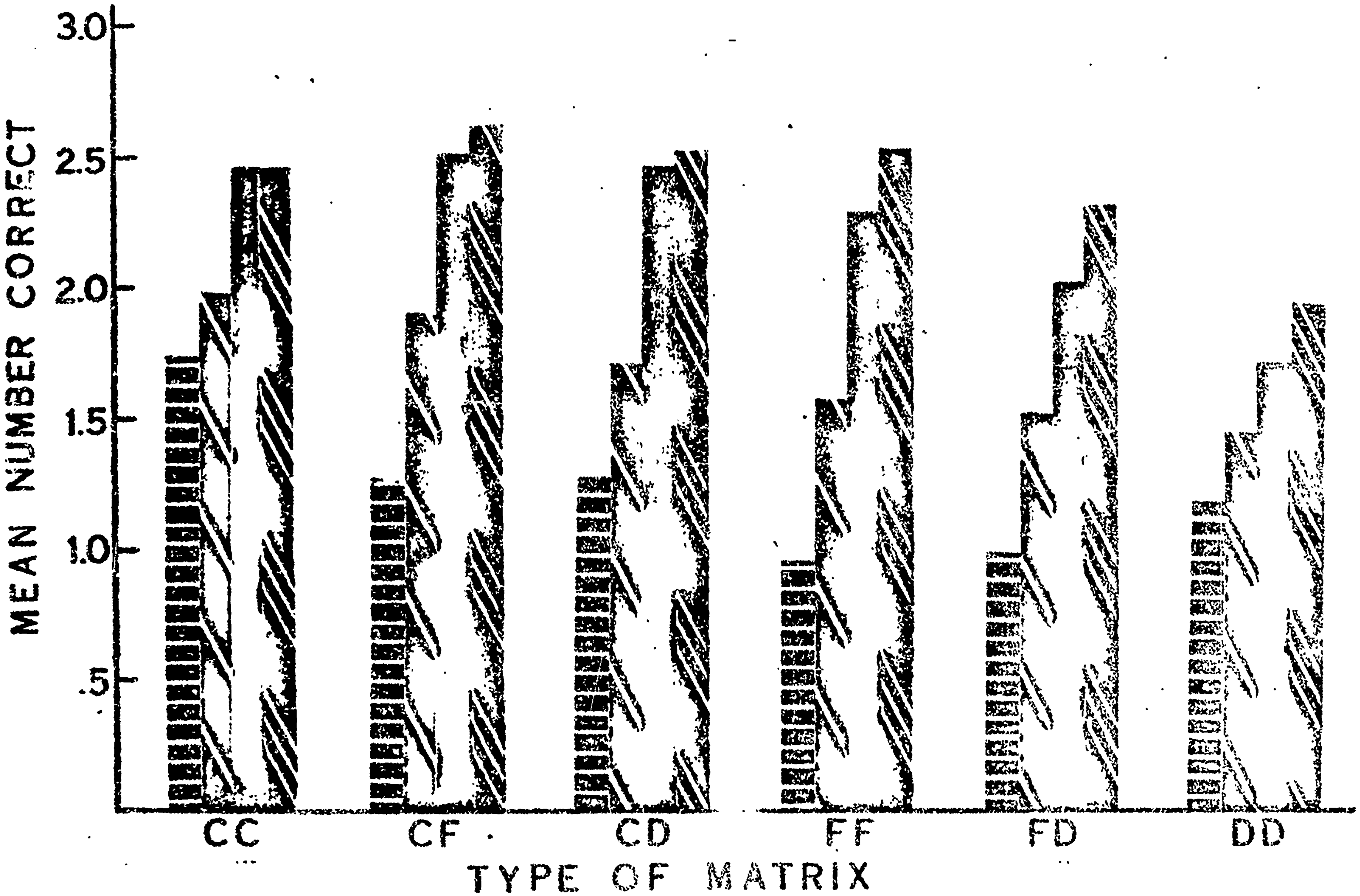

Fig. 4. Mean number of correct responses for each grade on three exemplars of each type of matrix.

TABLE 3

THE DUNCAN MULTIPLE RANGE TEST OF DIFFERENCES BETWEEN GRADES ON EACH TYPE OF MATRIX

CC	K(1.72)	G1(2.02)	G2(2.45)	G3(2.45)
CF	K(1.25)	G1(1.90)	G2(2.50)	G3(2.62)
CD	K(1.25)	G1(1.72)	G2(2.45)	G3(2.52)
FF	K(.95)	G1(1.58)	G2(2.28)	G3(2.50)
FD	K(1.25)	G1(1.72)	G2(2.45)	G3(2.52)
DD	K(1.15)	G1(1.42)	G2(1.68)	G3(1.92)

C=Concrete; F=Functional; D=Designative. All notations not underscored by the same line are significantly different ($p < .05$).

CD, and FD). However, on the CC matrices, which may be called easiest by virtue of having elicited the largest number of correct responses, the performance of K and G1 was not significantly different. On the DD matrices, which elicited the smallest number of correct responses and may therefore be termed most difficult, no two successive grade levels were significantly different. Grades separated by one grade did differ significantly ($p < .05$). Table 4 presents these same data in a different way. Here is shown the increasing number of types of matrices on which performance was not significantly different from performance on

TABLE 4

THE DUNCAN MULTIPLE RANGE TEST OF DIFFERENCES BETWEEN MATRICES FOR EACH GRADE

K	CC(1.72)	CF(1.25)	CD(1.25)	FF(.95)	FD(1.25)	DD(1.15)
G1	CC(2.02)	CF(1.90)	CD(1.72)	FF(1.58)	FD(1.72)	DD(1.42)
G2	CC(2.45)	CF(2.50)	CD(2.45)	FF(2.28)	FD(2.45)	DD(1.68)
G3	CC(2.45)	CF(2.62)	CD(2.52)	FF(2.50)	FD(2.52)	DD(1.92)

CC matrices. For K, performance on CC matrices was significantly better than performance on the other five types of matrices. As grade level increases, more types of matrices showed performance similar to that on CC matrices. By G3, children performed equally well on all matrices except DD, on which they exhibited the poorest performance.

Types of errors

Separate analyses were performed on the frequency with which certain kinds of errors occurred for the three types of matrices requiring combination of two types of concepts (CF, CD, and FD). The errors are designated by the types of attributes they have in common with either the row or the column. That is, an error involving choice of a picture having the same function as the row or column is called a functional error, the incorrect picture perceptually similar to the row or column is called a concrete error, and the incorrect picture subsumed under the same class name as a group of three pictures is termed a designative error.

Comparisons between concrete and functional, concrete and designative, and functional and designative errors were made on CF, CD, and FD matrices, respectively. The main effect of grades was significant in all three types of matrices ($p < .01$). However, the grade x type of error interaction was significant only for CF ($p < .05$) and FD matrices ($p < .01$), and the main effect of type of error was significant only for FD matrices ($p < .01$).

The results of an analysis of variance of errors made on CF matrices are summarized in Table 5. The main

TABLE 5

ANALYSIS OF VARIANCE FOR ERRORS MADE ON CONCRETE FUNCTIONAL MATRICES

Source	df	MS	F
Grades (A)	3	7.961	24.271**
Error	76	.328	
Practice (B)	1	.528	2.015
A x B	3	.261	<1.000
Error	76	.262	
Type of error (C)	1	1.653	3.203
A x C	3	1.435	2.782*
Error	76	.516	
B x C	1	.003	<1.000
A x B x C	3	.636	1.330
Error	76	.478	

*Indicates significance at the .05 level.

**Indicates significance at the .01 level.

effect of grades was significant, and the grade x type of error interaction was also significant. Figure 5 compares the mean number of errors made by choosing either the functional or the concrete picture instead of the picture

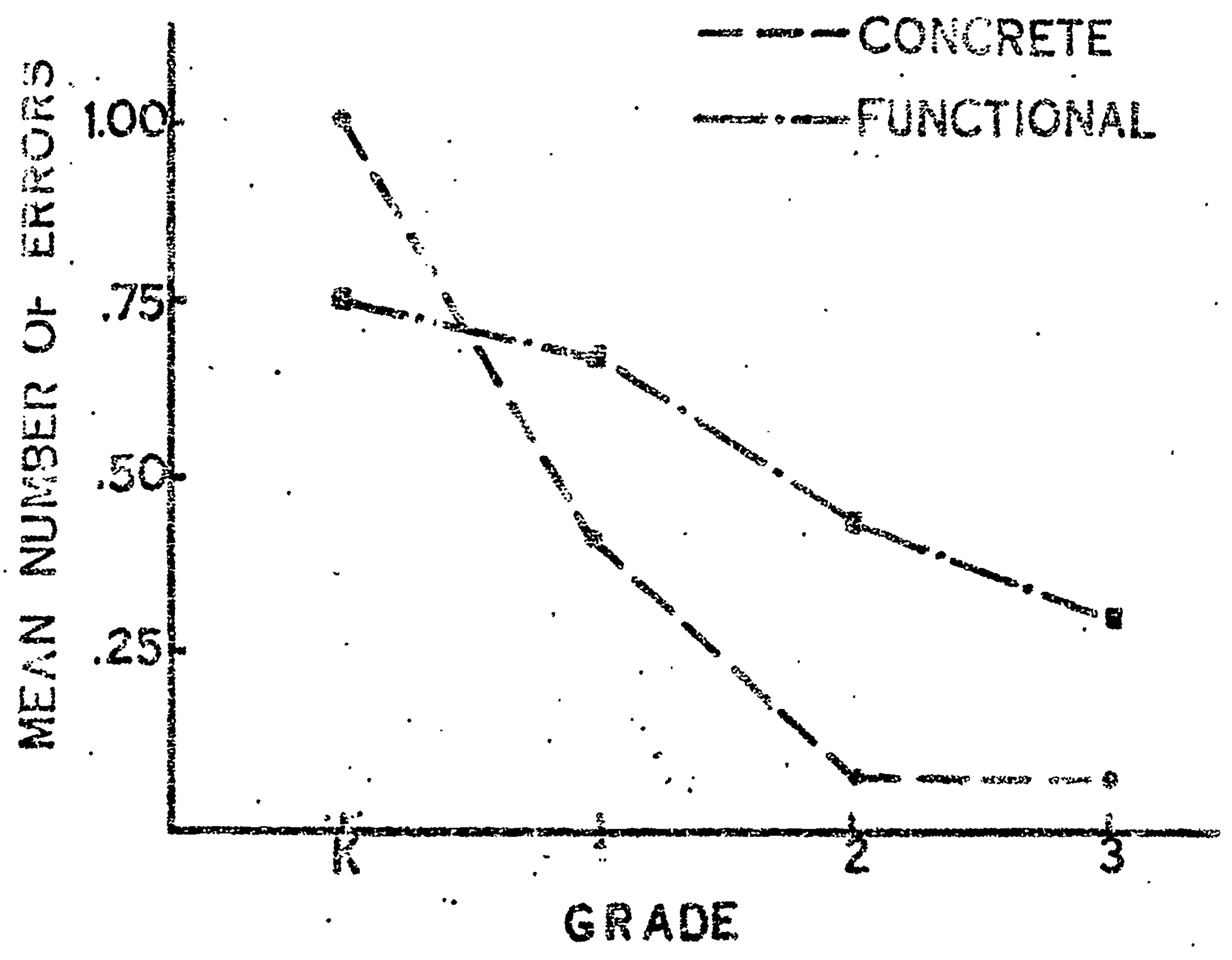

Fig. 5. Mean number of concrete and functional errors made on three exemplars of CF matrices.

combining both concepts. Although the frequency of both types of errors decreased with increasing grade level, the concrete errors dropped out more rapidly than the functional errors. More concrete than functional pictures were chosen by K, but in G1 the trend had reversed. The functional picture was chosen significantly more often than the concrete picture by G2 ($p < .05$). However, the types of errors made by G3 were not significantly different.

No significant effects other than the main effect of grade were revealed in an analysis of variance of errors made on CD matrices, but Figure 6 does illustrate an interesting finding. The number of designative errors exceeded the number of concrete errors in G1, 2, and 3, although the differences between the two types of errors were not significant. The percentage of designative errors increased from 50% in K to 79% in G3.

The analysis of variance of errors made on FD matrices, summarized in Table 6, yielded significant main effects of grade and type of error and a significant grade x type of error interaction ($p < .01$). When errors were made, functional pictures were chosen an average of .78 times on three exemplars and pictures belonging to the common class were chosen an average of .51 times. The mean number of

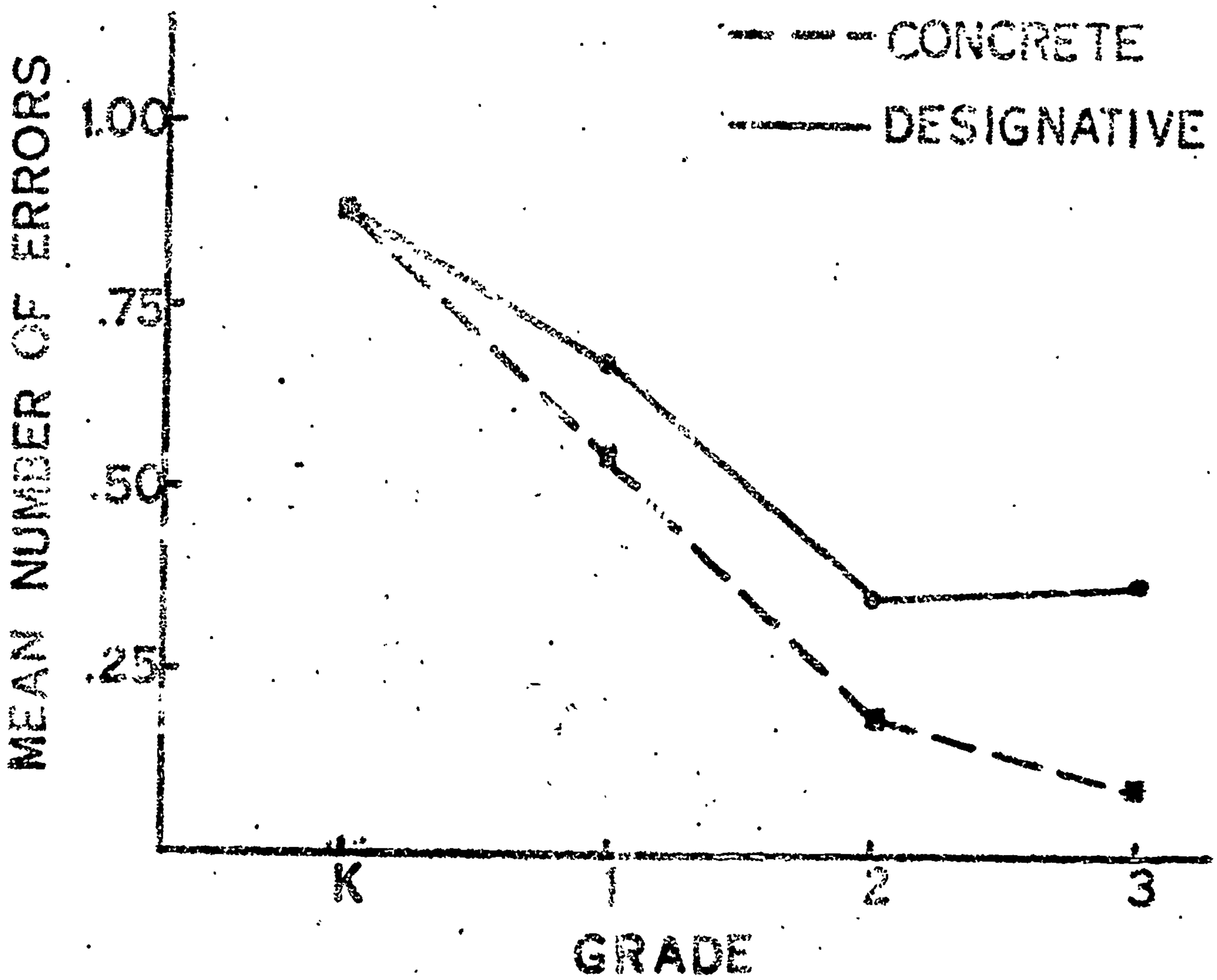

Fig. 6. Mean number of concrete and designative errors made on three exemplars of CD matrices.

functional and designative errors are graphed in Figure 7. The number of functional pictures chosen by K and G2 was significantly larger than the number of designative pictures chosen ($p < .05$).

TABLE 6

ANALYSIS OF VARIANCE FOR ERRORS MADE ON FUNCTIONAL X DESIGNATIVE MATRICES

Source	df	MS	F
Grades (A)	3	6.636	14.649**
Error	76	.453	
Practice (B)	1	.703	2.130
A x B	3	.469	1.421
Error	76	.330	
Type of error (C)	1	5.778	10.524**
A x C	3	2.561	4.664**
Error	76	.549	
B x C	1	.153	1.000
A x B x C	3	.236	1.000
Error	76	.649	

**Indicates significance at the .01 level.

Latencies

Table 7 summarizes the analysis of variance of the latency measures taken for each S on each matrix. The main effect of grade was significant, and the average latency for three matrices is depicted graphically in Figure 8. Multiple comparisons indicated G1 latencies were significantly longer than either K or G3 latencies ($p < .05$).

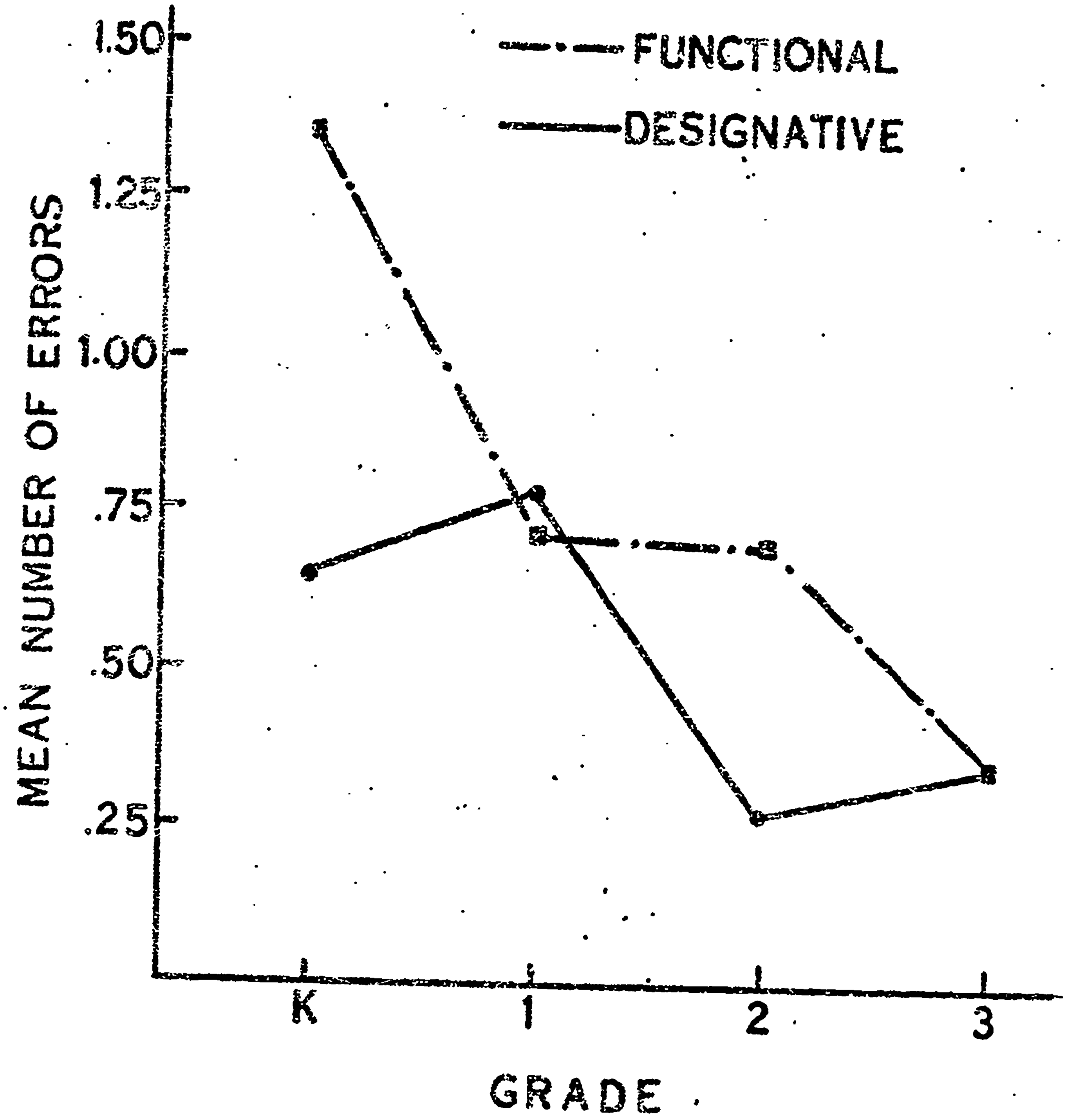

Fig. 7. Mean number of functional and designative errors made on three exemplars of FD matrices.

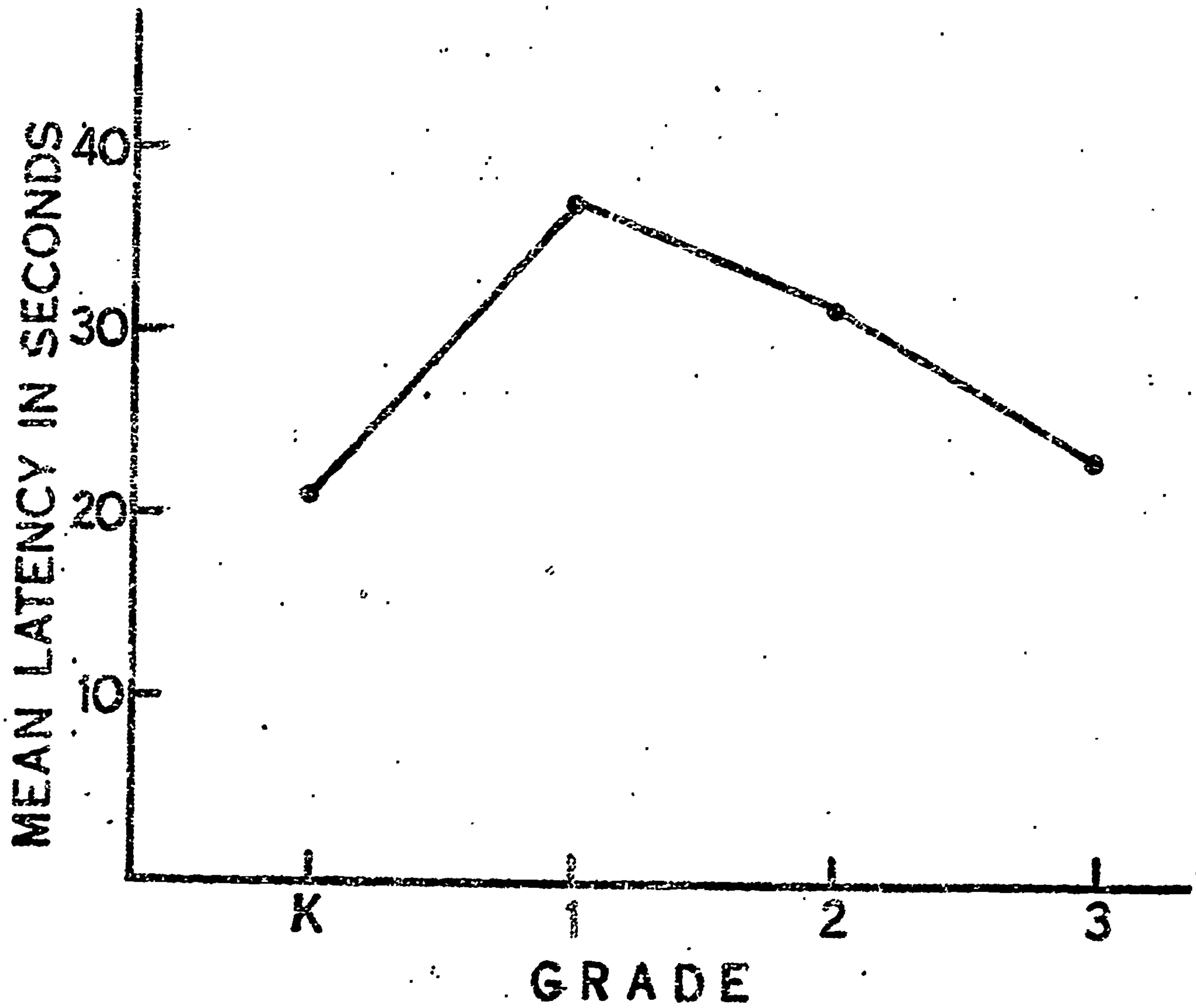

Fig. 8. Mean latency of response to three matrices at four grade levels.

TABLE 7

ANALYSIS OF VARIANCE FOR LATENCIES

Source	df	MS	F
Grades (A)	3	13331.476	3.982*
Error	76	3347.853	
Practice (B)	1	4864.501	7.843**
A x B	3	509.737	1.000
Error	76	620.178	
Matrices (C)	5	1399.683	7.625**
A x C	15	277.038	1.509
Error	380	183.543	
B x C	5	405.258	2.303*
A x B x C	15	291.671	1.657
Error	380	175.931	

*Indicates significance at the .05 level.

**Indicates significance at the .01 level.

Latencies of G2 were significantly greater than those of K ($p < .05$), although G2 and G3 latencies were not significantly different. Type of matrix also significantly affected the latency measures. Differences in latency of response to each type of matrix are shown in Figure 9. Comparisons between means indicated latencies to FD and DD matrices did not significantly differ, but both types of matrices required significantly longer response times than the remaining four types of matrices ($p < .05$). The difference between latency of response on the first and second stages of practice was significant beyond the .01 level.

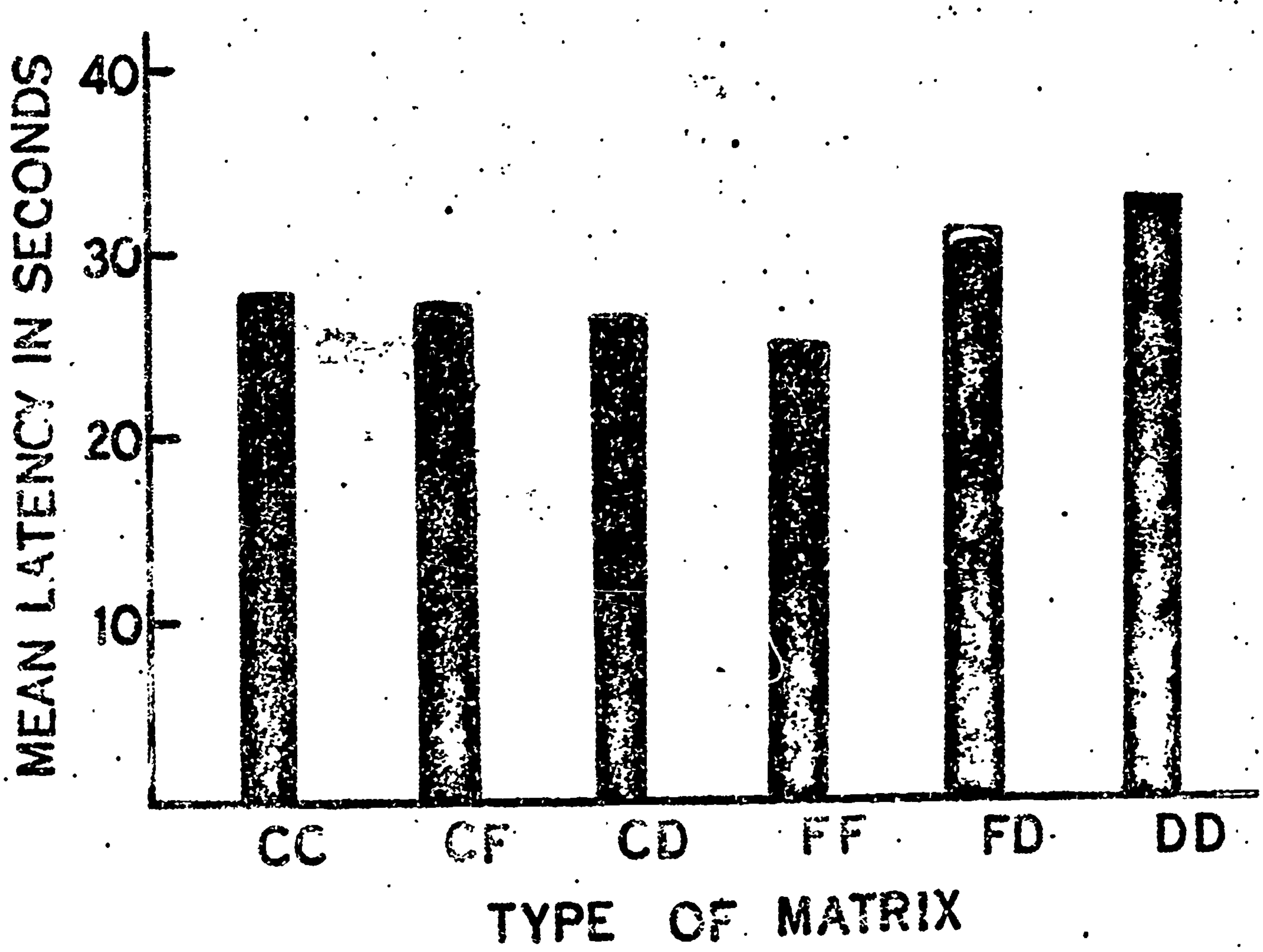

Fig. 9. Mean latency of response to three exemplars of each type of matrix.

The average number of seconds required for response to three matrices decreased from a mean of 30.5 seconds on the first half of the matrices to a mean of 26.0 seconds on the second half.

The significant practice x type of matrix interaction is illustrated graphically in Figure 10. The latency decreases for CC, CD, and DD matrices were significant ($p < .05$), but the decreases in latency for the other three types of matrices were not significant.

Correlations between measures

The Pearson product-moment correlation coefficient computed between CA and number of correct responses summed over type of matrix and stage of practice was significant beyond the .001 level. This correlation of .794 indicated that as CA increased, total number of correct responses increased. Mental ages were available only for the third graders. A correlation between MA and number of correct responses proved to be significant beyond the .05 level ($r = .391$), although the correlation between CA and number of correct responses was not significant ($r = .05$) when only third-grade scores were employed.

The Pearson product-moment correlation coefficient was also computed between CA and latency. When K was

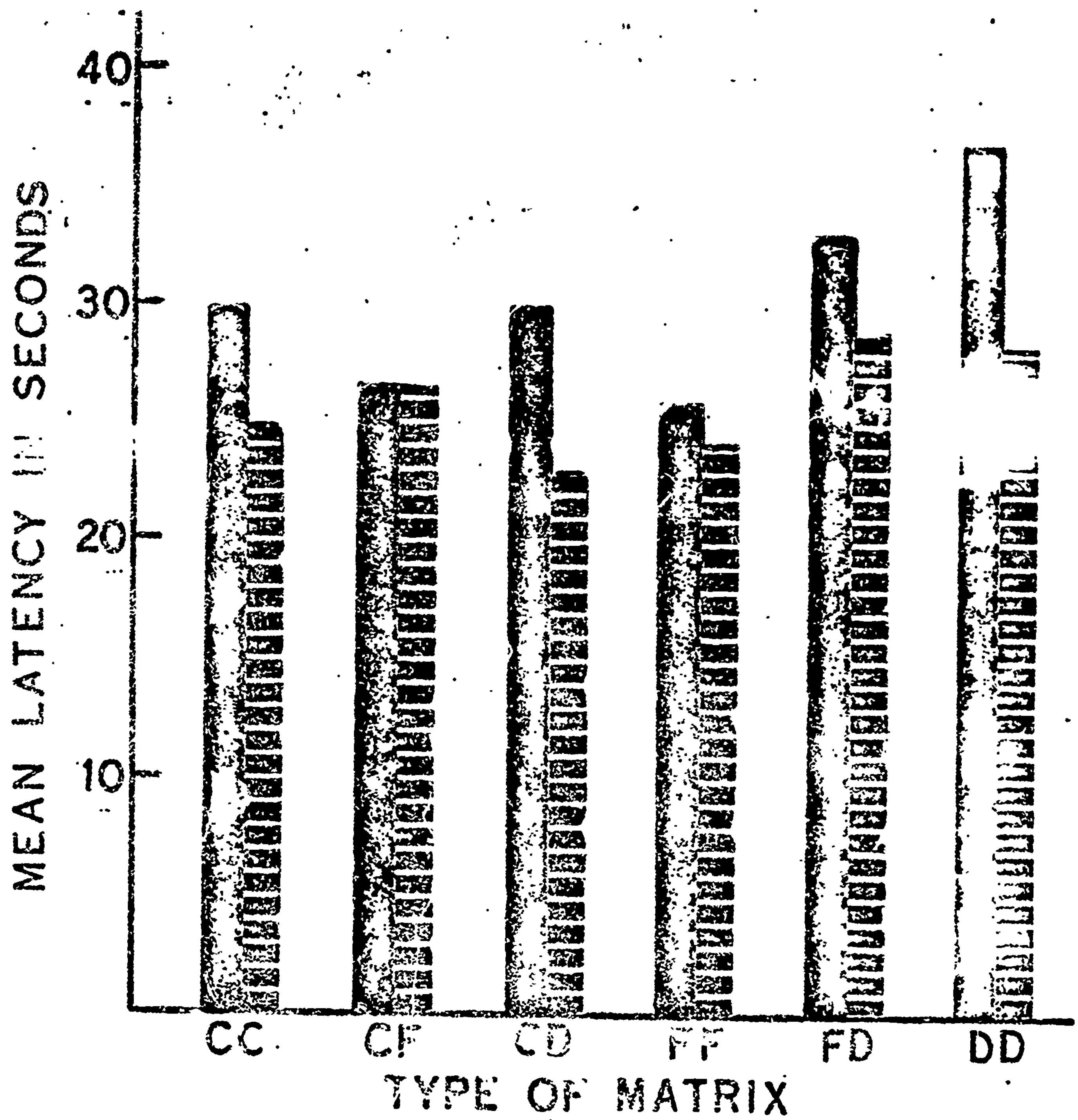

Fig. 10. Mean latency of response to three exemplars of each type of matrix during the first and second stages of practice.

included, the correlation was not significant (r = .01), but the negative correlation between CA and latency, excluding K, was significant beyond the .005 level (r = -.34). The negative correlation between number of correct responses and latency, excluding K, was also significant beyond the .005 level (r = -.80), although the correlation was not significant when K was included (r = .01).

DISCUSSION

The striking developmental changes in performance, indicated by both the differences between grades and the significant correlation between CA and performance, replicate the results of other studies of multiple classification (Kofsky, 1966; Lovell, Mitchell, & Everett, 1962; Reichard, Schneider, & Rapaport, 1944). Kindergarten children, first, second, and third graders performed correctly on 41%, 57%, 74%, and 79% of the matrices, respectively. This increase between six and nine years of age in ability to combine the relevant attributes of two classes lends support to Piaget's placement of the acquisition of "bi-univocal multiplication of classes" at the level of concrete operations, years seven to eleven (Flavell, 1963).

The influence of type of matrix on performance both indirectly supports and extends studies of object-sorting behavior and provides evidence for the theoretical positions concerned with changing bases of classification. Object-sorting tasks have consistently shown groupings based on perceptual or concrete attributes of objects to be most common at six years of age. From age six there is a steady increase in the number of groups based on common function, with peak use of functional concepts occurring around eight or nine years of age. Use of more abstract concepts increases steadily with age and years of education. Because children at age six use perceptual attributes for determining equivalence, all children included in the sample would supposedly be familiar with this type of equivalence. Functional attributes would most likely be used in classification by the older half of the sample. Although designative concepts are being used more often by older children, their use of this type of concept has probably not yet reached asymptote. Thus it would be expected that most children would be able to identify a common perceptual attribute of several objects, fewer would be likely to identify correctly a common function, and even fewer children would be likely to note a generic class name which provides equivalence. In accordance with this expectation, performance was significantly better on CC matrices than on FF or DD matrices, and performance on FF matrices was significantly better than that on DD matrices.

The differences in performance on the different types of matrices within grades support this interpretation of the effect of type of matrix. The performance of K was better on CC matrices than on all other types of matrices. The performance of G1 on CF and CD matrices was not significantly different from their performance on CC matrices, although they did handle CC matrices significantly better than FF, FD, and DD matrices. Only FD and DD matrices elicited more errors than CC matrices in G2, and G3 performed equally well on all but the DD matrices.

Two notable points may be drawn from the grade type of matrix interaction. First, the performance in this structured matrix task paralleled performance found in object-sorting studies and reflected the classification schemes which are typically found at different ages. Kindergarten children performed better on CC matrices than any others, G2 combined functional attributes as readily as concrete attributes, and G3 performed equally well on all matrices except DD. Thus the ability to combine concrete concepts appeared first and was followed by the ability to combine functional concepts, with the ability to combine designative attributes appearing last.

Second, the finding that children can combine certain concepts and not others at particular ages supports, in general, Piaget's conception of the phenomenon of "horizontal decalage." Horizontal decalage refers to the ability of children to perform certain operations on some materials before they can on others. For example, the conservation of quantity studies, showing conservation of matter appearing first, then conservation of weight, and, last, conservation of volume, illustrate this developmental trend (Flavell, 1963). In this multiple classification task, children as young as six years of age (K) were able to combine concrete concepts, but only at eight years of age (G2) were functional attributes combined as accurately. Although nine-year-olds (G3) were able to combine functional and designative concepts, they were not yet capable of combining two designative concepts as accurately as two functional or two concrete concepts. However, this explanation is confounded by the first point considered--that of different schemes of classification and different ability to identify common attributes at various ages. Unless children recognize a common attribute, they are certainly not going to be able to combine it with another common attribute. The finding that in the G2 and G3, DD matrices elicited more errors than CD and FD matrices, which also require identification of designative concepts, seems to indicate that the combination and not the identification may be the determining factor here. A criticism of this argument is apparent, however, for the concepts to be identified may be more difficult in the DD matrices than in the CD or FD matrices.

The analysis of the performance of each grade on each type of matrix showed that K and G1 chose significantly fewer correct responses than G2 and G3 on all matrices except DD, on which G1 and G2 did not differ. These differences may stem from the inability of K and G1 to categorize objects on two dimensions as readily as older children. According to Piaget, seven-year-olds are at the lower end of the age range of children who are capable of multiplication of classes, and six-year-olds have not yet entered the period of concrete operations (Flavell, 1963). An interpretation of the low percentage of correct responses, the short latency of response, and the spontaneous verbalizations of kindergarten children may aid in understanding their performance. Their responses seemed to be determined by rather idiosyncratic tendencies whenever relevant attributes could not readily be identified and combined. Typical comments were "I just want it to be a dog" and "Jeff and Dan like Snoopy." Thematic connections between two and among all pictures were common: "The dog is chasing the kitten" and

"They're all going uptown." Overgeneralized categories were also verbalized, such as "You can measure all of them" and "They're all animals." This inability of six-year-olds to consider correctly two class attributes simultaneously replicates the findings of other investigators (Lovell, Mitchell, & Everett, 1962; Reichard, Schneider, & Rapaport, 1944). The difficulty of young children in simply identifying a common attribute of a group of objects has also been noted. Charlesworth (1968) asked kindergarten children to select an object to go with two other objects which were alike in some way. Only a small percentage of the children were able to choose the correct object. However, Goldman and Levine (1963) found common attributes were identified by kindergarten children. These attributes were mainly concrete or situational, though, and 60% of the children could not change their view of the common attribute when the group of stimuli was altered.

The significant grade x type of error interaction obtained in the analysis of errors made on concrete x functional matrices provided some confirmation of the expectation that certain "dominant" cues would be chosen more frequently than other cues. The term "dominant" cue refers to that attribute of a row of column in the matrix which is most representative of the child's preferred mode of categorization. Kindergarten children, who are closely tied to the surface attributes of objects, chose pictures equivalent to the relevant concrete concept more often than those equivalent to the common functional concept, but the difference was not significant. Slightly more functional than concrete pictures were chosen in G1, and in G2 significantly more functional than concrete pictures were chosen when errors were made. In object-sorting tasks, eight-year-olds show asymptotic preference for functional concepts, and thus it appears that the preferred attribute is chosen more often when errors are made. In G3 the difference between types of errors is no longer significant.

Although there were no significant main effects or interactions in the analysis of errors made on concrete x designative matrices, there was a slight increase with age in percentage of designative errors. Kindergarten children made 50% designative errors, first graders 57%, second graders 64%, and third graders 79%. The steady increase in percentage of designative errors seems to parallel the increased use of designative concepts with age found in object-sorting studies. Thus, as designative concepts became "preferred," the percentage of designative pictures chosen when errors were made increased.

The analysis of errors made on functional x designative matrices showed that K and G2 chose functional pictures significantly more often than designative pictures. The greater use of functional than designative attributes by K is not explainable by reference to existing empirical findings or to the previous interpretation of the performance of K. Requiring the child to explain his responses would aid in determining why this effect occurred. The significantly greater use of functional than designative concepts in G2 may be explained by the eight-year-olds' preferred functional mode of imposing equivalence. By the time children have reached G3, designative concepts are being used more frequently, as suggested by the performance on the CD matrices and as found in object-sorting tasks, fewer errors were made on FD matrices, and there was no difference in the types of errors made.

The significantly shorter response times on the second half of the matrices, with no significant change in performance, seem to indicate that with practice, children acquired more efficient problem-solving techniques. Several children made comments after having correctly solved quite a few matrices, [illegible] "Oh, I see now," which support this interpretation. However, the existing literature offers no suggestions concerning the reason this decrease in latency was significant only for CC, CD, and DD matrices. The relatively short response times of the kindergarten children and yet their near-chance level of performance on all types of matrices except CC seem to support the interpretation of their approach given previously. From G1 to G3, mean latency decreased while mean number of correct responses increased. Although there was much variability in latency within each grade, it appears that, overall, as children develop the ability to solve the matrices correctly, the time required for response decreases. Indeed, when kindergarten was not considered, the negative correlation between chronological age and latency was significant. The significant negative correlation between number of correct responses and latency for Grades 1, 2, and 3, as well as the relatively long latencies for DF and DD matrices, support the suggestion that the more difficult the matrices, the longer the latency of response.

The significant correlation between MA and performance in G3 supports the findings of other investigators who have shown a relationship between classification skills and scores of verbal ability. Silverstein and Mohan (1965), using factor-analytic techniques, found "passive" object-sorting, the identification of the common attribute of a group of objects, and IQ scores to be related. Both Charlesworth (1968) and Lee (1965) found significant correlations between measures of verbal ability and performance on classification tasks. Charlesworth (1968) found a correlation of .41 ($p < .001$) between Peabody Picture Vocabulary Test scores and "mature" sorting principles, and Lee (1965) found the correlation between Binet vocabulary scores and total number of errors on his classification task to be -.38 ($p < .05$).

This investigation suggests certain important methodological improvements and also illuminates several theoretical issues which are amenable to further experimental study in the area of multiple classification. Methodological improvements include: (1) developing matrix concepts (concrete, functional, and designative) that vary in level of conceptual difficulty from very easy to very complex, (2) developing matrix items that vary in stimulus properties from the symbolic, representative materials (e.g., line drawings) to the concrete (e.g., real, three-dimensional objects), and (3) varying amount and kind of instruction (demonstration) given to S prior to the task. Theoretical and empirical issues may be clarified by (1) isolating the prerequisite skills necessary to solve the matrices, (2) developing a training program to teach these skills through proper sequencing of materials and instructions, (3) determining the relationship between the ability to identify and the ability to combine attributes of groups of objects, and (4) assessing the performance differences of various populations and the interactions of types of matrix, instructions or training programs, and population of Ss.

It seems obvious that both the instructions and the materials employed affect performance on the task. Although after the brief training procedure, the children seemed to understand the task, different initial training procedures might have produced different results. The stimulus properties of the matrices also determine performance to a great extent. Birch and Bortner (1966) have pointed out the influence of competing stimuli on identification of common attributes, and competing stimuli were definitely present in this task. The fact that pictures, representative materials, were used might also have had an effect. Sigel and Olmsted (1968) have shown that the use of pictures rather than actual objects significantly lowers the performance of lower class children on classification tasks, and Olver and

Hornsby (1966) have noted the differences in equivalence formations when pictures and verbal materials are used, underscoring again the importance of determining the effects of different training procedures and different stimuli.

Resnick (1968) has emphasized the need to analyze in more detail the behaviors involved in solution of matrix problems. In development of an early learning curriculum, she has used the technique of component analysis to generate a hierarchy of prerequisite skills necessary for matrix solution. For example, before the common attributes of a row or a column can be stated, a child must have mastered the following prerequisite skills, which are listed in order of increasing difficulty: (1) match objects in an array, (2) identify a named object, (3) name objects in an array, (4) scan a group without irrelevant attributes and state the commonality, (5) scan a group with irrelevant attributes and state the commonality, (6) state that the identity cell defines the row or column, and (7) state the defining attributes for the row or column. The sequencing of these skills, based on the logical technique of component analysis, needs to be empirically validated. The implications of this step-by-step approach for education are extremely important. Resnick has pointed to the variety of information which may be efficiently organized in a matrix fashion, and a knowledge of the skills required for matrix organization according to two or more dimensions would be an extremely valuable tool. Thus empirical evidence concerning the hierarchy and relationships of prerequisite skills would contribute not only to clarifying theoretical positions but also to developing teaching methods and curricula for organization skills.

Also important for both theory and an extension of empirical data are further investigations of the relationship between the ability to correctly identify the common attributes of groupings and the ability to combine these attributes. Although many studies (Goldman & Levine, 1963, Olver & Hornsby, 1966) have shown organizational changes paralleling changes in the types of attributes used for grouping, this relationship specifically has not been investigated, nor have the interactions between the various types of representation.

In summary, the matrix format provides a profitable technique for further research on multiple classification and modes of representation. Given certain methodological improvements, the next phase of this research program should isolate the prerequisite skills, determine the relationship between the ability to identify and the ability to combine common attributes of groups, and develop a training program in multiple classification following the principles of programmed instruction. This systematic approach will contribute to the existing body of empirical data, aid in theory building, and, more importantly, ultimately contribute significantly to education.

APPENDIX

MATRICES AND CHOICES

Attribute	Attribute	Choices
	Practice Matrices	
Striped	Decorate at Christmas	
Barber's pole	Tree	Candy cane
Flag	Ornament	Striped bedspread
Shirt	Christmas tree lights	Wreath
Striped	Candy	
Barber's pole	Sucker	Candy cane
Flag	Candy bar	Striped bedspread
Shirt	Lifesavers	Box of chocolates
Candy	Decorate at Christmas	
Sucker	Tree	Candy cane
Candy bay	Ornament	Box of chocolates
Lifesavers	Christmas tree lights	Wreath
	Concrete x Concrete	
Polka dot	Dress	
Polka dot cat	Striped dress	Polka dot dress
Polka dot skirt	Print dress	Polka dot gloves
Polka dot sofa	Solid color dress	Dress with lace
Leaf	Green	
Blue leaf	Green ball	Green leaf
Red leaf	Green cap	Yellow leaf
Brown leaf	Green car	Green house

Attribute	Attribute	Choices
Brush	Long and Narrow	
Hair brush	Pencil	Artist's paint brush
Shoe brush	Walking cane	Clothes brush
Tooth brush	Arrow	Yardstick
Round	Wavy lines	
Globe	Dress	Lined beachball
Orange	Zebra	Record
Record	Package	Shirt
Brick	Rectangular	
Brock chimney	Shoe box	Part of brick wall
Brick house	Buffet	Pile of bricks
Brick barbecue	Trunk	Suitcase
Red	Triangular	
Red book	Teepee	Red party hat
Red chair	Christmas tree	Red dress
Red toy car	Volcano	Sailboat

<u>**Functional x Functional**</u>

Make music	Hit	
Bugle	Hammer and nails	Drum
Record player	Tennis racket and ball	Fiddle
Piano	Toy hammer set	Baseball and bat
Cut	Take care of yard	
Butcher knife	Hoe	Lawn mower
Machete	Rake	Table knife
Scissors	Sprinkling can	Water hose
Heat	Light	
Radiator	Lightbulb	Campfire
Pot bellied stove	Flashlight	Iron
Oven	Streetlight	Fluorescent light
Hold garbage	Carry things	
Wastebasket	Bicycle with basket	Garbage truck
Kitchen trash can	Small truck	Outdoor garbage can
Garbage can	Camel with chair	Pony and cart

Attribute	Attribute	Choices
Look through	Wear	
Binoculars	Dress	Eyeglasses
Window	Hat	Magnifying glass
Microscope	Gloves	Shirt
Listen to	Watch (look at)	
Man with megaphone	Painting	Television
Radio	Snapshot album	Transistor radio
Stereo	Picture book	Newspaper

Designative x Designative

Toy	Animal	
Jump rope	Pig	Rocking horse
Ball and jacks	Cow	Ball and bat
Toy train	Dog	Cat
Elements of nature	Water	
Sun	Sprinkler	Rain
Snow	Pond	Lightning
Wind	Bathtub with water	Faucet with water
Desserts	Fruits	
Slice of cake	Pear	Slice of apple pie
Dish of ice cream	Banana	Cookies
Pudding	Half grapefruit	Pineapple
Cartoon characters	Water animals	
Yogi bear	Fish	Donald Duck
Cartoon bird	Seal	Snoopy
Mickey Mouse	Frog on lily pad	Alligator
Cats	Pets	
Leopard	Rabbit	Domestic cat
Panther	Parakeet	Tiger
Lion	Goldfish	Puppy
Old	Buildings	
Old man with cane	School	Old house
Tattered dress	Capital	Old beaten-up car
Old worn sofa	Church	New home

Attribute	Attribute	Choices
	Concrete x Functional	
Round	Eat	
Beachball	Hot dog	Apple
Globe	Cake	Beachball
Clock	Ice cream	Sandwich
Long and narrow	Cleaning	
Rifle	Dust pan	Broom
Ruler	Mop	Bat
Walking cane	Washing machine	Sudsy water
Hats	Keep warm	
Beret	Gloves	Cap and ear muffs
Straw hat	Heavy coat	Flowered hat
Top hat	Fireplace	Fur-lined boots
Brush	Paint	
Artist's brush	Step ladder	Paint brush
Toothbrush	Bucket of paint	Hair brush
Bottle brush	Roller brush and pan	Man in coveralls
Yellow	Ride	
Banana	Horse	School bus
Daffodil	Car	Dandelion
Baby chick	Bicycle	Train
Red	Stop	
Red car	Stop sign	Red light
Red book	Policeman	Red flower
Red dress	Barricade	Dead end
	Concrete x Designative	
Sitting	Furniture	
Child on swing	Table	Man on sofa
Boy on grass	Bed	Child on bike
Boy in boat	Dresser	Chair
Round	Fruit	
Beachball	Pineapple	Orange
Baseball	Banana	Bowling ball
Globe	Pear	Watermelon

Attribute	Attribute	Choices
Shell	Animal	
3 Kinds	Snake	Turtle
of	Squirrel	Mouse
shells	Bird	Another shell
Yellow	Young	
Chair	Puppy	Chick
Car	Foal	Pocketbook
Jack-in-the-box	Chick	Kitten
Green	Vegetables	
Grass	Tomatoes	Lettuce
Branch	Corn	Green car
Emerald ring	Carrots	Radishes
♀ Shaped	Musical instruments	
Lollipop	Trumpet	Banjo
Tennis racket	Guitar	Hand mirror
Lamp	Harp	Drum

Functional x Designative

Electric appliances	Fix hair	
Electric mixer	Brush	Hair dryer
Record player	Comb	Iron
Toaster	Curlers	Wig
Tools	Cut	
Pliers	Scissors	Saw
Hammer	Lawn mower	Screwdriver
Brace and bit	Axe	Dinner knife
Toys	Fly	
Top	Airplane	Kite
Model train	Helicopter	Doll
Blocks	Flying bird	Jet
Weapons	For eating	
Bow and arrow	Fork	Knife
Rifle	Plate	Spear
Sword	Glass	Cup and saucer

Attribute	Attribute	Choices
Furniture	Store things	
Chair	Box	Chest of drawers
Table	Trunk	Sofa
Bookshelves	Closet	Jewelry box
Jewelry	Wear around neck	
Ring	Bow tie	Necklace
Ear rings	Tied neck scarf	Jeweled pin
Charm bracelet	Collar	Man's tie

REFERENCES

Birch, H. G., & Bortner, M. Stimulus competition and category usage in normal children. Journal of Genetic Psychology, 1966, 109, 195-204.

Bruner, J. S., Olver, Rose R., & Greenfield, Patricia M., et al. Studies in cognitive growth. New York: Wiley, 1966.

Charlesworth, Rosalind. Cognitive growth in preschool children: Classification skills. Research Memorandum 68-13. Princeton, N. J.: Educational Testing Service, 1968.

Elkind, D. Conceptual orientation shifts in children and adolescents. Child Development, 1966, 37, 493-498.

Flavell, J. The developmental psychology of Jean Piaget. Princeton: Van Nostrand Co., 1963.

Goldman, A. E., & Levine, M. A developmental study of object sorting. Child Development, 1963, 34, 649-666.

Guilford, J. P. The nature of human intelligence. New York: McGraw-Hill, 1967.

Heald, J. E., & Marzolf, S. S. Abstract behavior in elementary school children as measured by the Goldstein Scheerer Stick Test and the Weigl-Goldstein-Scheerer Color Form Sorting Test. Journal of Clinical Psychology, 1953, 10, 59-62.

Kofsky, E. A scalogram study of classificatory development. Child Development, 1966, 37, 192-204.

Lee, L. C. Concept utilization in preschool children. Child Development, 1965, 36, 221-227.

Lovell, K., Mitchell, B., & Everett, I. R. An experimental study of the growth of some logical structures. British Journal of Psychology, 1962, 53, 175-188.

Olver, Rose R., & Hornsby, Joan R. On equivalence. In J. S. Bruner, R. R. Olver, P. M. Greenfield, et al., Studies in cognitive growth. New York: Wiley, 1966. Pp. 68-85.

Piaget, J., & Inhelder, Barbel. La genese des structures logiques elementaires: classifications et seriations. Neuchatel: Delachaux et Niestle, 1959 Cited by J. Flavell, The developmental psychology of Jean Piaget. Princeton: Van Nostrand Co., 1963. Pp. 192-193.

Reichard, S., Schneider, M., & Rapaport, D. The development of concept formation in children. American Journal of Orthopsychiatry, 1944, 14, 156-161.

Resnick, Lauren B. Design of an early learning curriculum. Working paper 16, December, 1967, Learning Research and Development Center, University of Pittsburg, Pittsburg, Pennsylvania.

Sigel, I. E. Developmental trends in the abstraction ability of children. Child Development, 1953, 24, 131-144.

Sigel, I. E. Dominance of meaning. Journal of Genetic Psychology, 1954, 85, 201-207.

Sigel, I. E., & Olmsted, Patricia. The development of classification and representational competence. Paper read at the Preschool Conference, Ontario Studies in Education, Toronto, Ontario, Canada, March, 1968.

Silverstein, A. B., & Mohan, P. J. A factor-analytic approach to object-sorting behavior. Journal of Consulting Psychology, 1965, 29, 89.

Thompson, Jane. Ability of children of different grade levels to generalize on sorting tests. Journal of Psychology, 1941, 11, 119-126.