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The Assessment of Analogical Thinking Modifiability Among Regular, Special Education, Disadvantaged, and Mentally Retarded Children[1]

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The objectives of the current study were (a) to develop a measure of children's analogical thinking modifiability (CATM) based on the Feuerstein, Rand, and Hoffman (1979) theory of dynamic assessment of cognitive modifiability, (b) to compare the performance of groups assumed to be differentially modified by intervention, (c) to compare CATM performance with performance on a conventional test, and (d) to study qualitative changes after a learning process. Subjects were disdvantaged, regular, and special education kindergarten children (N = 140), and mentally retarded children (N = 20). The CATM was administered together with the Ravens Colored Progressive Matrices (RCPM) in a balanced order. Disadvantaged and regular children achieved higher gain scores than other groups in both none-or-all and partial credit methods ($p < .01$*). The MR and the special education groups showed small gains according to the none-or-all credit method; however, according to the partial credit method, the MR group showed high gains and the special education group a performance decrease. Performance scores on the CATM were higher than on the RCPM, especially in comparison to the* B_8-B_{12} *items—differences reach a peak of 61% and 67% for the*

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disadvantaged and regular groups, respectively. Qualitative analysis indicated that form mistakes were most resistant to change, whereas color mistakes were most easy to modify. Results were explained within Feuerstein's theoretical framework of cognitive modifiability. Impaired cognitive functions as well as analytic versus synthetic processes were suggested to explain group differences.

The dynamic assessment of cognitive modifiability (Budoff, 1967; Feuerstein et al., 1979) represents a relatively recent trend in evaluation of learning potential. Instead of measuring existing skills and drawing conclusions about future development, as suggested by conventional methods, the dynamic approach focuses on the individual's ability to change as a result of the learning process. This approach bears special significance for disadvantaged or special-needs children who are jeopardized by conventional psychometric tests.

The development by Feuerstein and his colleagues of the Learning Potential Assessment Device (LPAD) represents a comprehensive, theoretically anchored, and intensive system of measuring cognitive modifiability. The dynamic assessment according to the LPAD model differs from the conventional testing with regard to four main characteristics: (a) the testing situation and testing process, (b) the focus on process rather than on product orientation, (c) test structure, and (d) the interpretation of results (for detailed description, see Feuerstein et al., 1979; Feuerstein, Miller, Rand, & Jensen, 1981).

The LPAD is based on two major theoretical assumptions: (a) Deficient cognitive functions manifested in retarded performance result from lack of Mediated Learning Experience (MLE; Feuerstein & Rand, 1974), and (b) the deficient cognitive functions found in the cognitive processes of input, elaboration, and output can be modified. Furthermore, these cognitive functions can be modified to some extent during an assessment procedure and thus provide indications about an individual's modifiability. A detailed discussion of the nature of the deficient functions is presented by Feuerstein et al. (1979).

The dynamic assessment serves as a sample of an individual's modifiability following a learning experience. The learning experience includes mediation of problem solving, strategy use, efficient learning habits, and learning of abstract principles. The level of modifiability is assessed by the efficiency of learning, application of learned rules and concepts to more complex and/or novel problems, and amount of investment needed in the intervention process.

In the current study our objectives were (a) to develop a measure of children's modifiability in line with the principles of the LPAD, (b) to compare the performance of groups assumed to be differentially modified by similar intervention, (c) to examine this measure's effectiveness as compared to a conventional measure, and (d) to study qualitative changes before and after a learning process.

While the LPAD has been developed mainly for use with adolescents and school-age children, a growing need has emerged for a preschool measure of a similar nature, especially since earlier decisions made about children's learning potential may affect them throughout life. The Children's Analogical Thinking Modifiability (CATM) test is designed for a preschool population and is based on Feuerstein's general theoretical model. Previous attempts at developing dynamic measures for preschool children (Jedrysek, Klapper, Pope, & Wortis, 1972; Lambert, Wilcox, & Gleason, 1974; Stott, 1978) were not based on a systematic integrative approach such as the one suggested by the LPAD model. The CATM includes colored three-dimensional blocks that can be manipulated by the child in solving analogical problems. Despite the gamelike nature of these blocks, the problems constructed for the test are as difficult as and require higher levels of abstract thinking than some of the RCPM analogical problems (items B_8-B_{12}). Our basic assumption was that preschool children can solve analogical problems that require simultaneous consideration of two or three dimensions provided they receive appropriate mediation and an opportunity not only to visualize but also to manipulate the elements making up the problem.

To validate the CATM as a measure of cognitive modifiability, four criterion groups assumed to be differentially modified by a similar educational intervention were chosen: *regular, disadvantaged,* and *special education* kindergarten children, and a group of *MR children* with equivalent mental age. The basic assumption was that the regular and disadvantaged children will benefit more than other groups from the given intervention. We also assumed that, in all groups, performance on the CATM pre- and postlearning tests will be better than performance on the RCPM, especially on items B_8-B_{12}, which tap analogical thinking.

METHOD

Subjects

Subjects were 160 children: 140 kindergarten children (70 boys and 70 girls) ranging in age from 4 years to 6 years 6 months, and 20 older mentally retarded (MR) children (11 boys and 9 girls) ranging in age from 10 to 16 years with mental ages of 5 to 6 years. Subjects were randomly selected out of 10 kindergarten classes and four institutions for the mentally retarded. The kindergarten sample included culturally disadvantaged children from low-SES families (N = 51), children of middle-class families (N = 71), and children who were enrolled in special education programs provided as part of an integrative program in a regular kindergarten ($N = 18$). While most of the middle-class parents had 12 years of formal education, all low-SES parents had only 8 years of formal education or less; about a fourth of these families were single-parent families. The special education children came from middle-class families; they were enrolled in special programs due to learning difficulties, social maladjustment, and/or some emotional problem. These preschool children were purposely not given a formal diagnostic label at such a young age.

Measures and Procedure

The Children's Analogical Thinking Modifiability.[3] The CATM consists of 18 colored flat blocks and three sets of analogical thinking problems designed for *preteaching, teaching,* and *postteaching* stages. The problems require the recognition and mental as well as actual manipulation of three dimensions: color (red, blue, yellow), form (circle, square, triangle), and size (big, small). Parallel items with different elements were constructed for the pre- and postteaching phases of the assessment. Each set of problems consists of 13 items ascending in order of difficulty. Four levels of difficulty were constructed. On level I (items 1-2) one dimension changes while the other two are held constant. On level II (items 3-7) two dimensions change and one dimension is held constant. On level III (items 8-10) all three dimensions change. On level IV (items 11-13) two additional elements (blocks) are introduced, in addition to the three dimensions that are changing. Sample items representing each difficulty level of the test are presented in Figure 1. It should be noted that each block contains two different colors, one on each side. The child is taught to use both sides in his search for the right answer. The use of different colors for each side of the block was introduced in order to reduce the total number of blocks needed to 18 (instead of 36).

The first phase of the assessment procedure is aimed at establishing a baseline of familiarity with and mastery of the stimuli dimensions. The child is taught through an inquiry process to construct a matrix using all of the blocks. The classification process is repeated verbally until the child masters the classification operation according to color, form, and size. The tester reinforces successful performance throughout this phase. Some deficient cognitive functions may be identified at this phase—for example, cognitive functions that are related to spontaneous comparative behavior, conservation of constancies (color, form, and size) across variations of other

[3]Detailed instructions for administration of the CATM are available upon request from the first author.

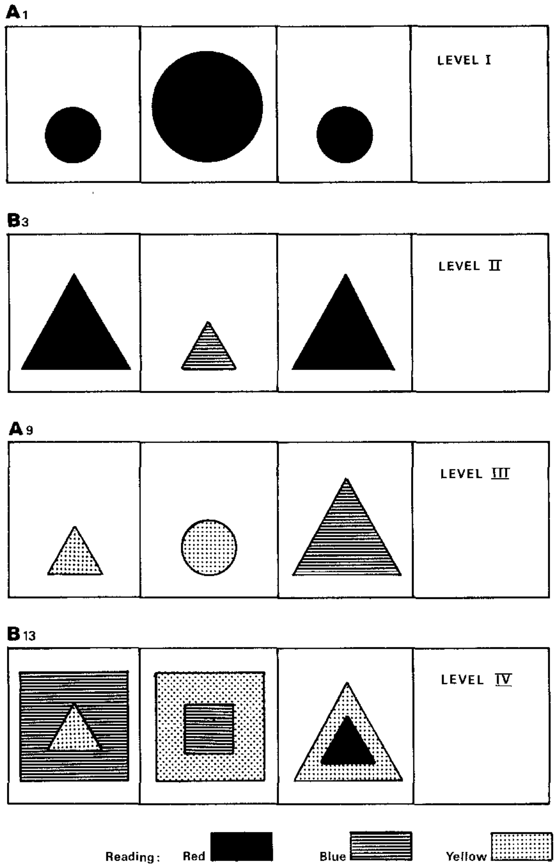

Fig. 1. Examplar items from the CATM.

dimensions, simultaneous consideration of two or three sources of information, and impulsive acting-out behavior.

In the second phase, aimed at assessment of initial analogical thinking, the child is given the preteaching test with no intervention. Each problem contains three parts, and the child is asked to find the fourth element to complete the analogical problem (see Figure 1).

The preteaching test is then followed by an intensive teaching phase. The objective of this phase is to teach the child how to discover relevant dimensions, understand and apply transformations and analogical rules, and perform efficiently. The intervention strategies used in the teaching phase consist of mediated learning experience (MLE; Feuerstein et al., 1981) components such as selection of and focusing on relevant dimensions; labeling, comparing, and contrasting in an analytic way; consideration of two or more sources of information; and summing up. The postteaching test is given after the teaching problems series. All phases of assessment require between 1½ to 2 hours. For most children we found it useful to give short breaks between preteaching, teaching, and postteaching phases.

Item analysis carried out on the CATM revealed corrected item-total correlations of .10 to .64 in the preteaching test and .34 to .73 in the postteaching test. All correlations in the postteaching test were significant ($p <$ .001) as compared to 9 out of 13 in the preteaching test. Cronbach-alpha reliability coefficients for pre- and postteaching tests were .72 and .90, respectively.

The Raven Colored Progressive Matrices. The RCPM was administered as a nonverbal conventional test to be compared with pre- and postteaching scores on the CATM. The order of administration was controlled by giving the RCPM for one-half of the subjects before and for the other half after administrattion of the CATM.

RESULTS

A two-way ANOVA was carried out on the total CATM score with Type of Children as a between factor and the repeated measure of Pre/Post Teaching score as a within factor. An all-or-none scoring method was used according to which only a complete solution with all three dimensions correct was given a score of 1. The latter analysis revealed significant main effects for both variables. The main effect for Type of Children ($F(3, 148) = 44.11, p < .0001$) reveals that, in general, significant gains were achieved from the pre- to the postteaching test. The main effects, however, were modified by the interaction of the two variables (see Figure 2). The amount of gain was significantly different for the different groups ($F(3, 148) = 12.36$, $p < .0001$).

As can be seen in Figure 2, the regular and disadvantaged children achieved highest gains (4.6 and 5.0 points, respectively), whereas the special education and MR groups gained relatively little (.40 and .70 points, respectively).

The Newman-Keuls procedure ($p < .05$) applied separately on the pre- and postteaching tests revealed that in both analyses the regular children scored highest, the MR children scored lowest, and the special education children scored intermediately. The only group that had changed its position relative to other groups from intermediate to higher performance following learning was the disadvantaged group. In order to examine whether the same findings will emerge when partially correct answers are also given some credit,

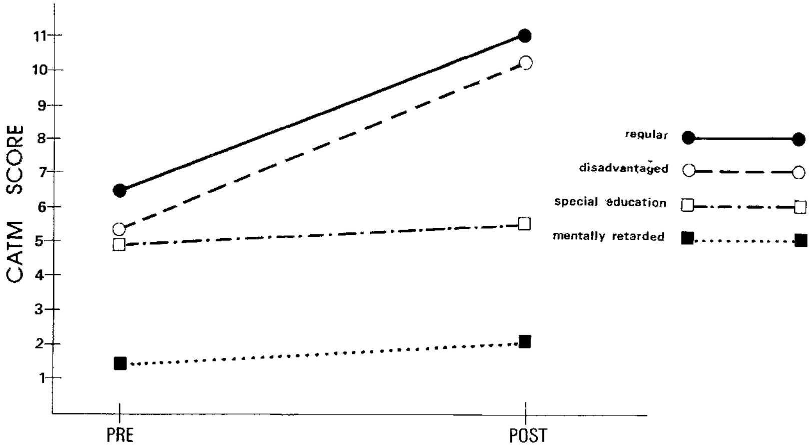

Fig. 2. CATM pre- and postteaching scores according to the all-or-none credit scoring method.

a partial credit scoring method was used. Each correct dimension was given a score of 1. Thus, a score of 0 was given only when all dimensions were incorrect. A similar two-way ANOVA carried out on these data revealed significant main effects for Type of Children ($F(3, 145) = 4.61, p < .01$) and Pre/Post Teaching ($F(1, 145) = 27.00, p < .0001$), and a significant interaction of both factors ($F(3, 145) = 3.01, p < .05$). The results are presented in Figure 3.

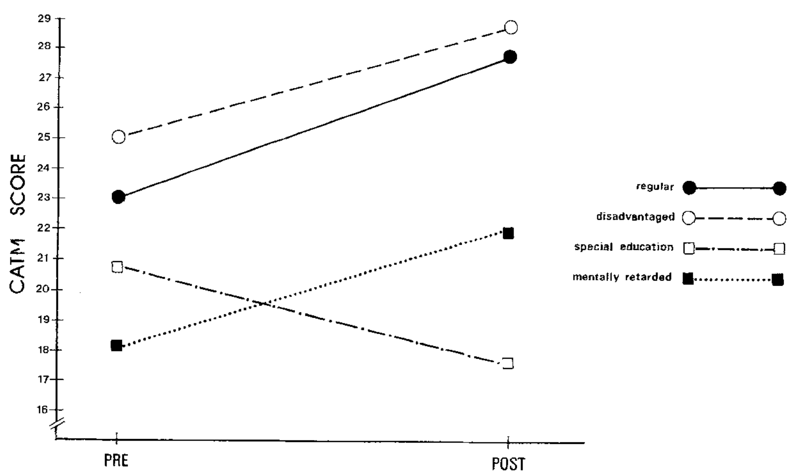

Fig. 3. CATM pre- and postteaching scores according to the partial credit scoring method.

As can be seen in Figure 3, the MR group showed the same gains as the disadvantaged and regular groups, though the overall performance was lower. Another interesting finding is related to the overall higher performance of the disadvantaged group over any other group. It is also interesting to note that the special education group showed a decrease from pre- to postteaching tests. A detailed analysis revealed that, while for all the other groups the increase was simialr across levels of item difficulty (levels I-IV; see Figure 1), for the special education group there was a decrease that was contributed mainly by levels III and IV of item difficulty.

Comparison of CATM and RCPM Scores

The CATM was compared both with the total score on RCPM and with a score composed of items B_8-B_{12} from the RCPM. The B_8-B_{12} items that tap analogical thinking are considered by Raven (1965) and Jensen (1969) to represent a conceptual ability and reflect self-initiated elaboration and transformation of registered information. Jensen (1969), in his distinction between level I and level II of thinking, argued that the ability to function on an associative level (level I) or on a conceptual level (level II) is determined ultimately by hereditary factors and that this type of thinking is untrainable (see Feuerstein et al., 1979, for counterarguments). The RCPM scores were compared with both preteaching and postteaching performance on the CATM test. In addition, three separate scores of the CATM were analyzed: a score for items 1-10, a score for items 11-13, and a total CATM score. (The none-or-all scoring method was used in these comparisons.) It should be mentioned that items 11-13 represent a much higher level of complexity (three stimuli dimensions in each of the two required elements) than the B_8-B_{12} items. For comparison convenience all scores were converted into percentages. Table I presents the RCPM and the CATM scores.

As can be seen in Table I, the total scores on the RCPM were lower than the CATM postteaching scores for all groups except the MR group. The comparison of B_8-B_{12} scores with the CATM scores of each group revealed significant differences between these two scores in all groups, including the MR group. The scores on the CATM were higher on both the pre- and postteaching tests than on the B_8-B_{12} items; the largest difference between B_8-B_{12} score and CATM score was found for disadvantaged (67%) and regular (61%) groups in the postteaching test. Gain scores for regular and disadvantaged groups were higher than the gain scores of the special education and MR groups. A comparison of the regular and disadvantaged groups revealed almost equal gains on items 1-10 (30.14 and 31.18, respectively). On items 11-13, however, the disadvantaged group had higher gain scores than the regular group: 31.7% versus 25.82%, respectively.

Table I. Percentage of Correct Responses on the RCPM and CATM in Regular, Disadvantaged, Special Education, and Mentally Retarded Children

			CATM								
	RCPM		Items 1-10 (levels I-III)			Items 11-13 (level IV)[a]			Total score		
Group	Total	B_8-B_{12}	Pre	Post	Gain	Pre	Post	Gain	Pre	Post	Gain
Regular	39.00	10.70	47.18	77.32	30.14	28.64	54.46	25.82	40.23	68.75	28.52
Disadvantaged	43.60	8.63	39.21	70.39	31.18	21.24	52.94	31.70	32.52	63.77	31.25
Special education	34.86	8.88	42.78	42.78	.00	13.89	20.37	6.48	31.94	34.37	2.43
Mentally retarded	16.41	2.00	12.50	16.50	4.00	3.33	8.33	5.00	9.06	13.44	4.37

[a]The range score for items 11-13 was 0-2; each of the two elements was given a credit of 1.

To examine gain scores as a function of preliminary performance level on the CATM, a two-way ANOVA was carried out with Type of Children and Performance Level as independent variables and gain scores as dependent variable. The sample was divided into three performance levels (low, medium, high) according to their score on the preteaching test. The MR group was excluded from this analysis since there were not enough MR children in the medium and high performance cells. Significant main effects were found for Performance Level ($F(2, 131) = p < .001$) and Type of Children ($F(2, 131) = 4.99, p < .01$). In general, low performers achieved the highest gain scores (41.16%), followed by medium (20.24%) and high performance (19.62%). No significant interaction was found between the independent variables. The main effects of Type of Children repeats the former results indicating higher gains for regular and disadvantaged children than for special education children.

Correlation Analysis

A correlation coefficient was calculated for the pre- and postteaching performance on each item. The objective of this analysis was to examine, on item level, whether gains were differential for children with low or high preteaching scores. In other words, our aim was to explore whether children benefited equally from teaching in each of the criterion groups. Logically, we expected that low insignificant correlations or significant negative correlation would indicate a differential gain, whereas significant positive correlation would indicate about equal gains. The results revealed that for the regular group, 9 out of 13 correlations were insignificant ($p < .05$ or less), ranging between .19 to .40. For each of the other three groups, only one significant correlation was found.

Another set of correlations was carried out between level of item difficulty and the corresponding gain on the same item. Our basic assumption was that the more difficult the item, the higher the benefit from the intervention. Operationally we expected the item's difficulty level to significantly correlate with the item's gain. The question was whether this correlation would be differential in each of the criterion groups.

Significant correlations were found between item difficulty and gain score only for the regular children ($r = -.84$, $p < .001$) and special education children ($r = -.70$, $p < .01$). Pearson correlations of the disadvantaged ($r = -.40$) and MR ($r = -.30$) groups were not significant, although in the same direction.

Qualitative Changes

Qualitative changes between pre- and postteaching tests were examined by analyzing the type of mistakes (color, form, and size) in the four criterion groups. A 4 × 2 × 3 ANOVA of Type of Children as a between variable and Pre/Post Teaching test and Type of Mistake as within variables was carried out; the last variable was nested within the second one. Significant differences for Pre/Post Teaching ($F(1, 148) = 11.43$, $p < .001$) and Type of

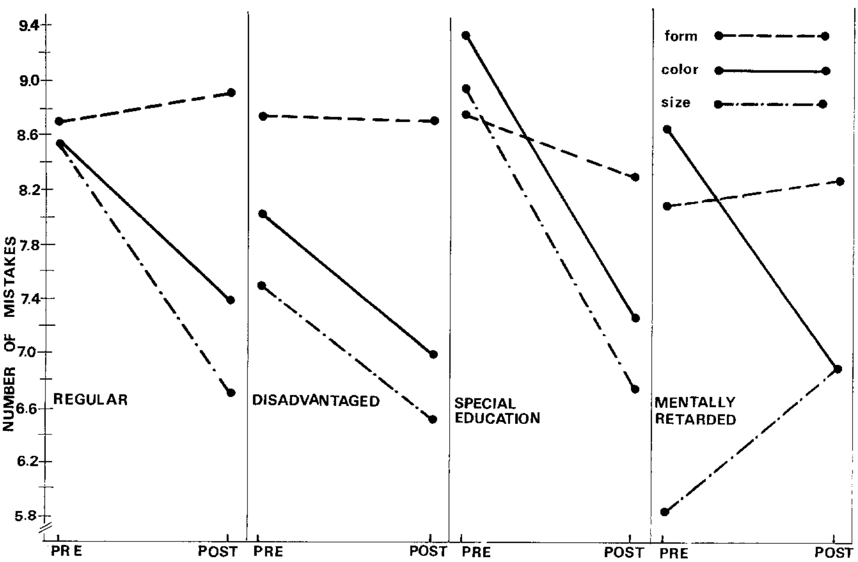

Fig. 4. Number of color, form, and size mistakes in pre- and postteaching tests.

Mistake ($F(2, 148) = 55.28$, $p < .0001$) indicate more mistakes in the preteaching than in the postteaching test and more mistakes of form than mistakes of size. Significant interaction of Pre/Post Teaching test and Type of Mistake ($F(2, 148) = 16.08$, $p < .0001$) indicates that while mistakes of color and size decreased, mistakes of form slightly increased from pre- to postteaching test. A triadic significant interaction (see Figure 4) of all factors ($F(6, 148) = 3.36$, $p < .005$) indicates that while color mistakes decreased in all groups from pre- to postteaching tests, mistakes of size increased in the MR group and decreased in the other three groups; mistakes of form were at about the same level in all groups.

DISCUSSION

The findings indicate clearly that the disadvantaged and the regular children were similarly modified by the intervention procedure, both groups showing higher modifiability than the MR and special education groups (see Figure 2). The lack of improvement found for the MR and special education groups should not be interpreted as indicating lack of cognitive modifiability but rather lack of appropriate intervention strategies compatible with the unique needs and learning modes of these groups. It should be emphasized that while the intervention procedures were standardized for all children, they were primarily aimed at modifying cognitive impairments characterizing disadvantaged or regular kindergarten children. The cognitive impairments of these children, in the input, elaboration, and output level, were described in detail by Feuerstein et al. (1979). The main difficulties characterizing the other two groups as reported by the trained testers (i.e., short attention span, distractibility, difficulties in simultaneous consideration of two or more sources of information, and summing-up behavior) were such that they may call for another intervention approach. The latter two difficulties were reported to be most common in all groups of children tested. We assume that higher gains would have been achieved by the MR and the special education groups if we had used a teaching approach more in line with their needs, i.e., a more graduated teaching strategy, repetition of analogical principles, elaboration of the transformation principles, and improving efficiency of simultaneous consideration of several sources of information.

The fact that the results showed no significant gains for the MR group should not be misunderstood to mean that no modifiability had taken place. The analysis of data by the partial scoring method revealed that the MR children showed improvement similar to that of the disadvantaged and regular children. The different findings that evolve out of the two ways of analysis have a diagnostic value especially in understanding the functional difficulties underlying analogical thinking. Analogical problems require inductive reasoning composed of two complementary phases: analytic processing of the given information (i.e., dimensions, relation between elements) and synthesis of the analyzed information. The MR group showed high modifiability (see Figure 3) when partial solutions were given credit but failed when the full solution, in which all dimensions had to be integrated, was required. It appears that the main difficulty of the MR children lies in the integrative-synthetic phase of the inductive process rather than in the analytic process.

Comparison of the disadvantaged and the regular children according to both scoring methods revealed interesting differences (compare Figures 2 and 3). Following the analytic-synthetic phases explanation of the cognitive process suggested above, it is plausible to assume that while the disadvantaged children are tuned toward detailed analytic processing of information, they are not proficient, relatively, in integrating the information that is a necessary operation in the analogical reasoning process. The regular children, on the other hand, who are more proficient than the disadvantaged children in integrating several sources of information showed higher performance when the all-or-none scoring method was applied.

In contrast to the small improvement found for the special education children according to the all-or-none method (Figure 2), a peculiar decrease from pre- to postteaching test was found according to the partial credit method (Figure 3). The differential pattern of performance found in both scoring methods indicates that in the postteaching test there were slightly more correct solutions than in the preteaching test; however, when a wrong solution was given in the postteaching test, it was a "full-blown" mistake with more incorrect dimensions. Most mistakes of this type were given on the more difficult levels (items 8-13; levels III, IV). In the preteaching test, on the other hand, there were more wrong solutions; however, the mistakes were not gross (e.g., they were not wrong on many dimensions). This performance pattern might be attributed to factors such as task satiation, novelty of situation, ability to invest mental efforts on task, and resistance to mediation, which affect the special education group more than other groups, especially on difficult items. Since this group was heterogeneous, further research is suggested in which specific classification of individual difficulties will be compared to specific modifiability pattern. Also, detailed behavioral observations during testing might be greatly informative when compared to actual cognitive performance.

The performance scores on the CATM were, as expected, higher than scores on the RCPM, especially when B_8-B_{12} score was compared with CATM postteaching score (see Table I). These results strengthen our position that young children as well as older MR children can reach a higher level of thinking provided they are given direct mediation of the basic principles of analogy, strategies of problem solving, and alleviation of cognitive deficiencies that interfere with actualization of their learning potential. Differences in the subjects' performances on the CATM as compared with the RCPM could be attributed at least partially to the special features of the CATM assessment materials. Whereas the RCPM is two-dimensional, the CATM includes three-dimensional blocks, giving the child an opportunity not only to visualize the problems but also to manipulate the elements making up the solution. The information needed for solving the analogical problems on the CATM is more articulated and demands the child's attention more than the information given in a two-dimensional page. The level of abstraction as reflected in the CATM problems is not reduced by the manipulative mode of presentation. The colorful tangible elements are functional for young children as a means of bridging between their concrete approach and the abstract thinking required for solution.

The high gains of the low-performance children (41.16%) as compared to the medium (20.24%) or high (19.62%)-performance children seem to be more affected by the intervention procedure than by a floor effect. It seems that this group benefited more from the mediated learning than the other groups since there was still much room for improvement for the medium- and high-performance children.

A finer understanding of the differential gains achieved by each criterion group can be inferred from the correlational analysis. In the regular group, 9 out of 13 preteaching test items were significantly correlated with their parallel postteaching test items as compared to only one significant correlation in the disadvantaged group. Since the two groups showed similar gains, it might be concluded that the gains in the regular group were more or less equal for all children, whereas gains in the disadvantaged group were differential for low and high performers. In the special education and MR groups the single significant pre/post correlation that was found was related to the lack of improvement rather than to the differential gains characterizing the disadvantaged group.

The results of the qualitative analysis (see Figure 4) clearly indicate that mistakes of form are most resistant to change in all groups, whereas mistakes of color are most easy to modify. The MR group demonstrated a peculiar pattern of changes. While form mistakes stayed at about the same level as in other groups, color mistakes decreased drastically and size mistakes increased. Except for the MR group, the results coincide with theories indicating color as the most perceptually primitive element, followed by size and form, the last one being more differentiated and therefore more difficult to modify. The instructional implications that may derive from the qualitative results point toward more emphasis on form in the analogical thinking process since it is most resistant to change. Further research with exceptional groups to investigate the process of cognitive modifiability, the effects of different teaching strategies, and the influence of different stimuli dimensions on cognitive performance seems warranted.

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