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Development of Visual Cognition: Transfer Effects of the Agam Program

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The Agam program was designed to foster visual thinking in young children by developing their visual language. This curriculum was implemented in five nursery classes for 2 consecutive school years. Children in these classes were compared with children in classes where the program was not administered. It was hypothesized that the generative nature of the visual language developed in the experimental children would allow the children to extend the language learned to new situations and help them to solve problems in which no prior training was given. Test results confirmed this hypothesis: The effects of training in the Agam program transferred to cognitive domains in which no training was given. Specifically, the findings indicated positive effects on general intelligence and school readiness of children about to enter first grade, with especially pronounced effects in the areas of arithmetic and writing readiness. Other findings revealed an increased visual learning ability in new tasks that developed in the experimental children. Training effects did not transfer to mental rotation and to memory for realistic designs. The program was found to be equally effective for lower-class as for middle-class children. The effect of the program was greater for children who participated in the program for 2 years as compared with those who joined in the second year, indicating a cumulative effect of the program. This latter finding can also be used to refute an alternative explanation of the obtained experimental effects offered by a motivational theory. The findings on cognitive transfer, taken together with previously reported ones on concept learning and visual skills, point to the educational potential of the approach advocated by the Agam program, that is, systematic long-term instruction in the domain of visual cognition in early childhood.

Glaser (1984, 1985) reviewed attempts at teaching thinking skills and maintained that developing these skills is a high priority in education. Several educational programs for training of cognitive skills have been described (Chance, 1986; Costa, 1985; Nickerson, Perkins, & Smith, 1985; Segal, Chipman, & Glaser,

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1985) and are currently being implemented, such as, Instrumental Enrichment (Feuerstein, Jensen, Hoffman, & Rand, 1985), Philosophy for Children (Lipman, 1985), the Problem-Solving and Comprehension Program (Whimbey & Lochhead, 1980), the CoRT Thinking Program (de Bono, 1976), and the Productive Thinking Program (Covington, 1985).

These and other programs cover various important aspects of thinking. However, the emphasis is mostly on verbal, conceptual, and logical thinking. The Instrumental Enrichment program seems to be an exception in that it includes the systematic improvement of visual thinking skills as part of a wider program that also includes logical and verbal skills. The underrepresentation of programs to develop visual thinking skills among thinking-skills training programs is surprising in light of the realization of almost all theoreticians of intelligence that such skills form an important part of intelligence. Guilford (1959), for instance, analyzed human intelligence on the basis of three independent dimensions. The *contents* dimension includes four components, one of which is visual, or *figural* as Guilford called it. Gardner (1983) identified six main kinds of intelligence, *spatial* intelligence being one of them. Likewise, the analysis of the mental processes used by many highly creative persons (Shepard, 1978) is well in line with the assumption that some of our thinking is dependent upon visual processes. Kosslyn (1980) reviewed evidence demonstrating that visual imagery figures significantly in the thinking of young children.

Several reviews, such as Grossman's (1970) and Fowler's (1983), concluded that training of visual, perceptual, and motor skills of normal children was feasible. These programs, however, were conducted mainly within the framework of art education. Another domain where programs to develop visual skills have been attempted is the field of special education. Within this field, programs, such as the Frostig-Horne visual perception program (Weiderholt & Hammill, 1971), have been used extensively. Other special education programs too, such as Kephart's (1971) or Getman, Kane, Halgren, & McKee's (1968), include visual skill development as one component of the program. Common practice, thus, limits visual thinking instruction to special education, or to specialized subjects within general education. Many researchers and educators argue, however, that visual thinking processes are of general significance and should therefore be trained as other basic skills are, for example, verbal skills (Freeman, 1980).

In accordance with these considerations, Agam (1981) designed a general basic program to develop visual thinking skills in young children (for a more detailed analysis of these skills, see Razel & Eylon, 1986). The following features distinguish the Agam program from other curricula for developing visual thinking skills: (a) Whereas the approach of many programs is corrective, attempting to correct deficient cognitive functions of the slow learner, the Agam program is *preventative* in that it tries to prevent a potential modality of human thinking from not developing; (b) Whereas many programs are designed for relatively well-defined groups, such as special education children (e.g., the

Frostig-Horne method), or disadvantaged youth (Instrumental Enrichment), the Agam program is aimed at the normal child; (c) In accordance with the assumption that early teaching may result in greater effects than late teaching (Razel, 1977), the Agam program is designed for very young ages. For example, whereas Instrumental Enrichment is aimed at the adolescent student, the Agam program is designed for the very young and has been implemented successfully with 3-, 4-, 5-, 6-, and 7-year-olds (Eylon et al., 1988; Eylon & Razel, 1986; Razel & Eylon, 1986); (d) The Agam program addresses a much wider range of visual concepts than virtually all other programs.

The Agam program was implemented in five nursery school classes during the school years 1983–1984 and 1984–1985. Evaluation of this implementation indicated strong effects of the program on the visual skills trained in the domains of visual identification, memory, and reproduction skills (Eylon et al., 1988; Eylon & Razel, 1986; Razel & Eylon, 1986). Results of systematic observations and interviews were also reported indicating favorable reception of the program by teachers and children alike. The question hitherto not dealt with was whether there is a transfer of the program's effects to various cognitive domains not immediately trained by the program. The aim of this article is to report data pertinent to the question of transfer of the Agam program's effects to the specific domains of intelligence, school readiness, and some complex visual skills.

Transfer and the Teaching of a Visual Language

For the purposes of this article, however, the most important distinguishing feature of the Agam program is that it attempts to improve visual cognition by developing the individual's visual language. In this, the program accepts the assumption that language affects thinking and widens the application of this assumption to the visual domain. The Agam program's presentation of modular visual concepts that are combined with each other cumulatively according to *grammar*like rules, is assumed to imitate the learning of a language and make the learning process *generative* in the Chomskian sense (Chomsky, 1957). Because of this quality of the program, it is assumed that the child who is trained by it learns to generate creatively his own visual language to suit the problem-solving needs that appear in his life. It is the generative quality of the Agam program's teaching of visual language that forms the basis for the hypothesis that the effects of training in the program will transfer to domains in which no direct training was given. It is expected that the child will be able to solve problems, which are completely new to him, by using the visual language, that is, the basic visual-linguistic concepts and rules taught by the Agam program. This assumption is based on the structure and didactics of the program itself.

The Agam Program

The Agam program includes 36 units which are listed in Table 1. Some of these units train visual skills with regard to one visual concept, such as basic shapes (circle, square, triangle, and other shapes); orientations (horizontal, vertical,

TABLE 1
The Units in the Agam Program

1. Circle	19. Typical Forms
2. Square	20. Proportions
3. Patterns	21. Red
4. Circle & Square	22. Yellow
5. Flash Identification	23. Blue
6. Horizontal	24. Secondary Colors
7. Vertical	25. White, Black & Gray
8. Horizontal & Vertical	26. Trajectory
9. Oblique	27. From Eye to Hand
10. Horizontal, Vertical & Oblique	28. Numerical Intuition
11. Triangle	29. Composition
12. Circle, Square & Triangle	30. First Dimension
13. Variations of Forms	31. Second Dimension
14. Symmetry	32. Third Dimension
15. Curved Line	33. Fourth Dimension
16. Large, Medium & Small	34. Letters
17. Angles	35. Visual Grammar
18. Point	36. Creativity

oblique); colors (red, yellow, blue, white, black); dimensions (length, width, height, time); and other visual elements (point, curved line). For the purpose of discussion, these concepts can be viewed as a "visual alphabet," the letters of which can be combined with each other into higher-order units, or "words" in a visual language, such as a circle intersecting two tangential squares. A unique feature of the Agam program is that a visual element is presented in its isolated conceptual form only when it is first introduced. Subsequently, it is almost always shown in combination with other elements. In teaching of the visual language, the program proceeds from the simple to the complex. First, the relations between instances of the same visual concept are taught, such as two concentric circles, or three parallel vertical lines. Subsequently, the relations between instances of different concepts are taught, for example, concentric circle and square, or a vertical line intersecting a horizontal line. The latter kind of combinations are taught in units such as *Circle & Square*, and *Horizontal & Vertical*.

The similarity between visual language as taught in the Agam program and verbal language is revealed in additional points. For example, the visual combinations, or words in the visual language, are formed using combination rules taught in additional units of the Agam program, such as, *Large, Medium & Small* (that focuses on the size relationship in combinations, such as a big and small triangle), *Angles and Proportions*. Furthermore, rules that can be viewed as grammatical, that provide for the combination of combinations of visual elements (words) into combinations of a higher order (*sentences* in the visual language), are taught in separate units, such as *Patterns*, and *Symmetry*. The unit, *Patterns*, teachers cyclic series and that a series, say of alternating circles and squares, is a correct pattern, and that if the square will suddenly appear twice consecutively, then this pattern is incorrect grammatically. The unit *Symmetry*, teaches, for example, that the butterfly's wings are connected symmetrically to its body, and that if two equal right-angle triangles are combined so that an isosceles triangle is obtained, then the combination is symmetrical and correct according to this grammatical rule. Finally, the visual sentences turn into *stories*, that is, combinations of a still higher order, in such units as *Flash Identification*, which trains the child with stylized pictures.

In the Agam program, two concentric circles and two intersecting circles are two different visual words with two different visual appearances, each of which deserves to be learned. Of course, it is impossible to teach all possible words, or visual combinations, of the elements taught. But each unit works on a sample of such combinations, with 30 combinations provided in each unit on flash cards. In comparison, most educational programs relate to visual concepts in isolation. For example, if they teach the concept, circle, they teach it as a geometric concept and do not teach its different appearances when combined with other circles or other shapes. This is analogous to a parent who teaches an infant the alphabet, or more precisely, a set of phonemes, without showing how these letters or phonemes can be combined into meaningful words and sentences.

Didactic Approach

Figure 1 shows one sample activity in the Agam program as it appears in one of the 36 teacher manuals. In the manual, a simple verbal description of the activity is printed underneath each set of four pictures, as depicted in Figure 1. The instructions for this activity are: "The teacher quickly presents the children with flash cards containing oblique lines (Figure 1a). The children, equipped with a similar set of cards, must point to the cards that are identical with those shown by the teacher (Figure 1b). The teacher gradually increases the number of cards that have to be memorized by the child before he is allowed to point at them (Figures 1c and 1d)."

In achieving its goal of teaching a visual language, the Agam program uses several didactic means. First, a structured approach is used for teaching each new concept. Instruction starts with passive identification of the concept, which is presented by the teacher, and continues with its active discovery, first in its simple form (e.g., looking for plastic circles hidden by the teacher in the classroom), and then, in tasks that require visual analysis, in concrete objects (e.g., finding squares in picture books). Only after the concept is well identified, does the teacher present tasks demanding recognition from memory of combinations based on the concept. The task shown in Figure 1 belongs to this group of activities intended to improve processes of storage and retrieval from visual memory. The last activities are the most complex activities of reproduction and reproduction from memory. This sequence of activities focusing on identifica-

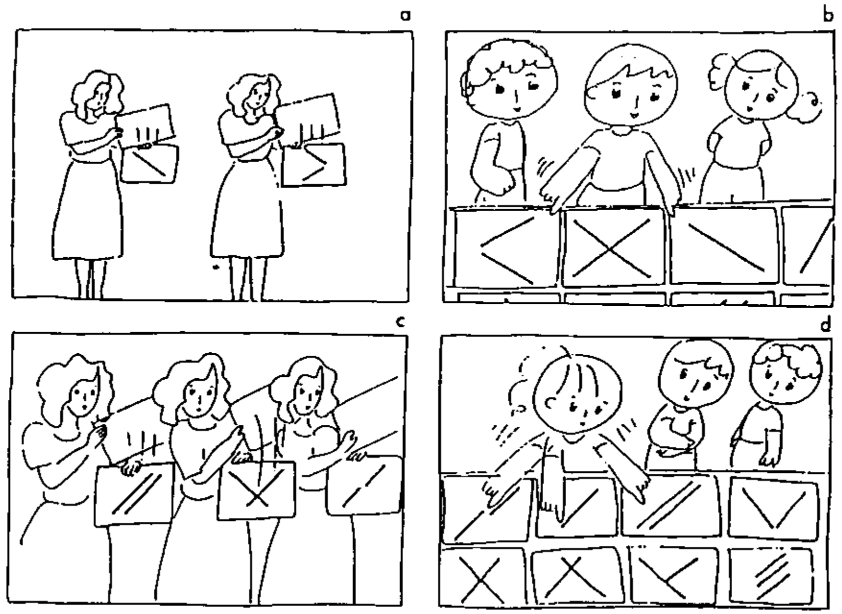

FIG. 1. A series of pictures depicting one activity in Unit 9 of the Agam program: recall of memory cards containing combinations of obliques.

tion, memory, reproduction, and reproduction from memory, repeats itself in each unit.

A second feature of the program is the repeated presentation of the same concept in a large number of activities. Within each unit, a particular concept is taught in some 30 different activities. Multiple modes of representation, such as those involving bodily activity, group activity, or auditory perception, are employed to enhance the mastery of the concepts. For example, children are given auditory codes for circle and square and are asked to create a visual pattern by following an auditory dictation of these codes.

A third didactic characteristic employed is the use of a strict cumulative presentation strategy: Combinations of concepts are taught only after the individual concepts have been mastered. For example, the combination of horizontal and vertical is taught in Unit 8 after both horizontal and vertical are taught separately in Units 6 and 7; the combination of horizontal, vertical, and oblique is contained in Unit 10 following the teaching of the concept oblique in Unit 9.

Another didactic means employed in the Agam program is the *intuitive* presentation of visual concepts. For example, the square is not introduced as "a rectangle with all sides equal." Rather than supplying verbal definitions, the children are allowed to experience the learned concepts in a direct visual manner. Throughout the program, minimal use is made of verbal instruction. It is assumed that when a visual stimulus is accompanied by a torrent of words, the visual experience may not be well attended to by the child. Generally, verbal labels are supplied only after the concepts have been introduced visually. Practising what it preaches, the teacher manuals of the Agam program are written in a pictorial language as demonstrated in Figure 1, in addition to the customary verbal text describing each activity, its objectives, and the materials required. These pictures raise the teacher's sensitivity to the visual language, and demonstrate concretely that it is this language that the program is intended to strengthen. Note the resemblance between this feature of the Agam program and the common method of teaching a second language using the second language rather than the child's mother tongue.

Method

Sample. An experimental versus comparison group design was used to measure the effect of the Agam program on intelligence, school readiness, and visual thinking skills. Ten nursery classes were chosen to participate in the experiment. Five of these were assigned randomly to the experimental group that received instruction in the Agam program. The other 5 were used as comparison classes. The children studied were all the 4-year-olds in the classes chosen, that is, those who were 4 years old by December of the school year. These children were tested and followed up over the 2-year implementation period. In the first year there were 5 experimental and 5 comparison classes totalling 70 and 49 children, respectively. In the second year, due to reasons unrelated to the experiment, there were only 4 experimental and 4 comparison classes. New children were accepted in these classes in the second year. Of these, the ones who were in the same age group as the experimental and comparison children, that is, who were 5 years old by December of the school year, joined the experiment for the study's second year, bringing the number of children in the experimental and comparison classes to 90 and 97, respectively. The breakdown of the number of children in each participating preschool class by age, gender, number of years in the experiment, public school division and town of preschool is given in Table 2. About half of the experimental classes were located in a primarily middle-class town. The other half were located in a primarily lower-class town. The comparison classes were matched pairwise with the experimental preschools and chosen so that they were serving the same neighborhoods in the same towns. This means that they were matched on social class, as this variable was operationalized in this study, that is, living in a primarily middle-class or a primarily lower-class town. The experimental and comparison classes were also matched on religious orientation, that is, on whether the preschool belonged to the religious or general public school system, the two major divisions of the Israeli public school system. This last variable was controlled for more for political reasons than for theoretical reasons, in order to avoid possible complaints of exclusion of one public school division.

TABLE 2
Number of Children per Preschool Class by Age, Gender, Number of Years in Experiment, Public School Division, and Town of Preschool

Preschool	Town	Public School Division	1983–1984 4-yr-olds	1983–1984 5-yr.-olds	1984–1985 4-yr.-olds	1984–1985 5-yr.-olds 2nd yr.	1984–1985 5-yr.-olds 1st yr.
Experimental schools							
1	A[a]	Religious	12(8)[b]	20(9)	12(8)	9(6)	5(5)
2[c]	A	State	21(13)	—	7(1)	21(12)	—
3	B	Religious	19(9)	14(7)	—	17(8)	19(5)
4	B	State	10(6)	22(13)	10(5)	7(4)	12(5)
5[c]	A	State	8(5)	16(9)	—	—	—
Total			70(41)	72(38)	29(14)	54(30)	36(15)
Comparison schools							
6	A	Religious	15(10)	17(9)	12(4)	15(10)	2(1)
7[d]	A	State	9(6)	18(12)	12(8)	18(10)	3(2)
8	B	Religious	5(2)	30(14)	12(6)	4(1)	20(10)
9	B	State	10(6)	—	—	4(2)	31(16)
10[d]	A	State	10(4)	14(9)	—	—	—
Total			49(28)	79(44)	36(18)	41(23)	56(29)

[a] A and B denote the primarily middle-class and lower-class towns, respectively. [b] Numbers in parentheses indicate number of boys in group. [c] Three 4-year-olds from Preschool 5 were transferred in 1984–1985 to Preschool 2. [d] Nine 4-year-olds from Preschool 10 were transferred in 1984–1985 to Preschool 7.

The children in the experimental preschools studied and did group work in the Agam program about three times a week, 20–30 minutes each time. These small-group activities took place while the other children in the class played outdoors. Other activities took place during the arts and crafts hour and still others were included in circle time. During the experiment's 2 years, the average experimental class worked on less than one-third of the Agam program (Units 1 through 10 as listed in Table 1; two classes also managed to work on Unit 11). Children in the comparison preschools received no training in the Agam program. This experimental design was intended to help answer the question of whether introducing the Agam program into the preschool would constitute a beneficial addition to its normal curriculum. This design had the disadvantage that the experimental children alone, and not the comparison children, would be conscious of their being a part of an experiment. This difference in condition could create a difference in general motivation between the two groups. Thus, differences in test performance, if obtained, could be explained by this motivational difference. In the Discussion section, it will be shown that this motivational theory cannot account for major parts of the data and must therefore be rejected.

Tests. Three tests were administered to measure the effect of the Agam program on intelligence. The testing was carried out in two periods: the pretest during November–December 1983 and the posttest during May–June 1985. The Coloured Progressive Matrices (CPM; Raven, Court, & Raven, 1977) and the Goodenough-Harris Draw-a-Man Test (Harris, 1963) were administered as a pre- and posttest to all children. The Draw-a-Woman test was given to all children only as a pretest. The Wechsler Preschool and Primary Scale of Intelligence (WPPSI; Lieblich, 1979) was administered as a pretest to the majority of the experimental group ($n = 67$) and to a random subsample of the comparison group ($n = 22$). During the posttest, the WPPSI was given to 49 and 28 of the experimental and comparison children, respectively. The inequality of the numbers of experimental and comparison children who were given the WPPSI was caused by technical and financial difficulties. Children who joined the experiment in the second year were given the CPM as a pretest at the beginning of the school year. The scoring of the CPM was based on empirical multiple weighting, which was shown to be superior to standard scoring in terms of both validity and reliability (Razel & Eylon, 1987, 1988, 1989). According to this method, each of the six answers of each CPM item received a weight that was the average standard CPM score of all children from a standardization group who chose that answer. The standardization group used were the 857 children who participated in the second 2-year implementation cycle of the Agam program during the years 1985–1987.

A test referred to as the Summary test was given at the end of the 2-year implementation period. In contradistinction to the unit-specific tests administered over the 2 years immediately after learning each unit (the results of which were reported elsewhere, Eylon et al., 1988; Eylon & Razel, 1986; Razel & Eylon, 1986), the Summary test was intended to measure the cognitive transfer of the Agam program's effect to domains not taught directly, such as school readiness, ability to learn in new visual contexts, and two relatively complex visual thinking skills. The test's items are described in greater detail in the Results section. It may be noted that the intelligence tests used in this study could also be considered as indices of cognitive transfer. The intelligence tests measure transfer to domains that are more general and further removed from the content areas of the Agam program than the domains covered by the Summary test. The Summary test was administered by two testers at a time to small groups of 4–5 children in two separate daily sessions, an arrangement that turn out, in pilot testing, to be feasible and to allow satisfactory concentration of the children on the tasks. The Cronbach reliability coefficient ($\alpha = .70$) supported our impression that the testing conditions were conducive to reliable testing. Most testers and scorers of the tests were hired especially for the testing and scoring, and were not part of the regular Agam project's staff. They received detailed instructions and intensive training. The possibility of tester and/or scorer bias influencing the results seems, therefore, unlikely. Furthermore, several of the results reported depend upon difference scores (i.e., between pre- and posttests, or between items) and on interactions between variables that would not be affected by any systematic bias favoring either the experimental or the comparison group.

Results

Intelligence. The scores of the three different intelligence tests, WPPSI, CPM, and Draw-a-Man/Woman, were converted into standard deviation, or z scores to make them comparable in terms of means and standard deviations, and were then averaged to yield an estimate of intelligence as reliable as possible. In doing this, we followed the well-accepted ideas of integrating findings by meta-analysis proposed by Glass, McGaw, and Smith (1981), and applied them to the particular case of integrating several findings within a single study. In order to obtain the most reliable measure of intelligence for each child, the average score was based on all the intelligence tests (i.e., 1, 2, or 3 tests given to the child). For each subject the difference between this average score in the pretest and the posttest testing periods was calculated. The average difference score (i.e., posttest minus pretest) in the experimental and comparison groups was 0.03 and −0.40, respectively. As shown in Table 3, this results was statistically significant; effect size equalled 0.52. Effect size was defined by Glass (1978) as the difference between the means of the experimental and comparison groups divided by the comparison group standard deviation. To make this measure of effect size more meaningful, one may compare the value obtained here to the effect size value of about 1 found in the Coleman (1966) study that compared American whites and blacks on scholastic achievement and in the parallel study of Minkowich, Davis, and Bashi (1982) comparing Israeli advantaged and disadvantaged children. Thus, the data seem to indicate that the experimental children improved in their performance on intelligence tests more than the comparison children and that this advantage was about half as large (in terms of standard deviations) as the difference between advantaged and disadvantaged children in school achievement.

A breakdown of this result for the different intelligence tests indicates a statistically significant advantage of the experimental over the comparison group in increased performance from pretest to posttest as measured by the CPM, $t(167) = 1.88$, $p < .03$, and statistically nonsignificant differences in favor of the experimental group on the Draw-a-Man/Woman test, $t(86) = 1.45$, and the WPPSI, $t(68) = 0.82$. A further breakdown of the latter result for the two subparts of the WPPSI indicates a nonsignificant difference in favor of the experimental group in both the verbal, $t(68) = 0.42$, and the nonverbal subtest, $t(68) = 1.11$. The fact that the significance levels of the individual intelligence tests are lower than that of their combined average should not be surprising. Glass (1978) pointed out that it is the essence of research integration that many

TABLE 3
Statistical Analyses of Differences Between Experimental and Comparison Classes on Main Dependent Variables

Variable	Experimental			Comparison[a]		Effect		
	M^b	n	SD	M	n	size	t	p
Intelligence	0.03	81	0.77	−0.40	87	.52	3.48	.0007
Overall transfer	2.57	78	7.60	−2.20	84	.63	3.97	.0001
School Readiness	1.57	78	3.81	−1.37	84	.77	4.87	.0001
Reading	0.16	78	1.52	−0.15	84	—	1.27	n.s.
Writing	0.64	78	1.75	−0.54	82	.68	4.24	.0001
Geometry	0.78	78	2.41	−0.69	84	.61	3.86	.0002
Visual Learning Ability	0.45	78	2.09	−0.49	84	.45	2.82	.004
Mental Rotation	0.11	78	1.70	−0.04	84	—	0.57	n.s.
Complex Memory	0.15	78	1.86	−0.14	84	—	0.99	n.s.
Realistic Designs	−0.06	78	1.02	0.06	84	—	−0.72	n.s.
Geometric Designs	0.24	76	0.99	−0.23	82	.48	2.98	.002

[a]The comparison group's standard deviation is not given because it can be calculated by dividing the group mean difference by effect size. [b]Corrected by ANCOVA.

weak findings "can add up to a strong conclusion" (p. 356). In our case, the consistency in which the results of all the intelligence tests point in the same direction allows us to make a strong conclusion.

Overall Transfer. Before reporting the rest of the findings, one aspect of the data analysis, the covariate, must be described. Except for the aforementioned results on intelligence which were based upon a score of difference between two tests, the findings reported here were based on a single testing, and required an assumption of initial equality of the experimental and comparison groups. The groups were, however, not equal at the beginning of the study. The experimental children were younger, and scored lower on the intelligence tests at the beginning of the study. This may have been caused by random sampling errors and/or by the fact that the assignment of classes to the experimental or comparison conditions was, after all, not completely random. It is possible that requirements for random choice were sometimes overruled by a tendency of the educational establishment to choose the weaker classes as recipients of the educational treatment. Mental age, a measure of intelligence that is not corrected for age, was thus chosen as a covariate. To obtain the most reliable measure of initial mental age, the scores on the three different tests, WPPSI, CPM, and Draw-a-Man/Woman, multiplied by the child's age, were transformed into standard, or z scores, and then averaged in the same way as previously described for the intelligence data. The means of standardized mental age scores in the experimental and comparison groups were −0.31 and 0.32, respectively, $t(168) = -2.30$, $p < .03$ (by a two-tailed test because of the lack of a one-sided hypothesis), indicating a significant difference in favor of the comparison group in initial intellectual maturity, which would bias the results against finding an experimental effect. To overcome this bias, all the data reported in this study were based upon the adjusted means computed in an analysis of covariance (ANCOVA). It should be noted, however, that although the differences between the experimental and comparison groups were less significant with the regular analysis that with the ANCOVA, in all tests listed in Table 3, there were no cases in which a test that came out significant in the ANCOVA was not significant when analyzed without the covariate.

In order to evaluate overall transfer as measured by the Summary test, the data from all items of this test were transformed to standard scores and combined into a single measure. As shown in Table 3, the superiority of the experimental group over the comparison group in this overall measure was statistically significant with a substantial effect size. Since the experimental hypotheses—that the experimental group would exceed the comparison—were one-directional hypotheses, the nondirectional F test provided by the ANCOVA was replaced by a one-sided t test using the formula $t = \sqrt{F}$ (e.g., Hays, 1963). The superiority of the Agam-trained children in the overall measure of transfer suggests that the effects of the program do transfer to various cognitive domains and do not remain restricted to items directly taught by the program. This overall result is based upon the combination of results concerning several variables of transfer. The separate findings for each variable are reported in the following.

School Readiness. One of the main objectives of the Summary test was to measure skills associated with school readiness for the three Rs (reading, writing and arithmetic), where arithmetic included geometry readiness and some aspects of logical reasoning. Looking at overall school readiness as measured by the three domains combined, we obtained a significant difference between the experimental and comparison groups favoring the Agam-trained children as shown in Table 3. This finding seems to indicate that participation in the Agam program could increase a child's readiness for school and, hence, improve the chance of scholastic success. Next, we may try to see how much each of the three Rs contributed to the overall increased school readiness of the experimental children.

Reading readiness was measured by two items. One, containing four tasks adapted from Anderhalter's (1975) School Readiness test, tested the ability to match a picture to a sentence read to the child. The second item, containing eight problems modelled after Anderhalter (1975), examined the ability to find a matching Hebrew word, or a matching multiple-digit number, or a matching shape among various scrambled and reversed distractors. As indicated in Table 3, the difference between the experimental and comparison groups did not reach statistical significance.

Writing readiness was measured by three items: two items requiring the child to draw a line between two circular or jagged lines that tested fine motor control, and one item containing two tasks modelled after Anderhalter (1975) that measured the ability to copy letters and numbers. The average z scores of these items in the experimental and comparison groups were 0.64 and -0.54, respectively. In Table 3 it is shown that this result was highly significant with a large effect size. This finding seems to point to the conclusion that training by the Agam program could facilitate the child's process of learning to write.

Arithmetic readiness was measured by five items, three of which dealt with geometry. The first tested the child's ability to find as many as possible of the 18 different triangles embedded in a Jewish star with a vertical line drawn through the center. The second and third items measured the child's identification of the right-angle and isosceles triangles among 9 different triangles (an item adapted from Hershkowitz, 1987). The fourth and the fifth items also measured a logical ability. The fourth item tested the ability to solve the problem of completing a cyclic pattern of geometrical shapes. The fifth item examined the ability of finding an area common to several geometrical shapes. As shown in Table 3, the average z scores of these items in the experimental group was higher than in the comparison group. This finding suggests that administering the Agam program could favorably affect the later arithmetic studies of the child.

Visual Learning Ability. The ability to learn new visual tasks, or the ability of *learning to learn*, was tested by three tasks. In the first one, the child was asked four times to draw the horizontal water level within a given picture of a bottle slanted 45°. In the first and last drawing no particular assistance was provided to the child. These two tasks were separated by four training tasks. The first and second of these were drawing the water levels in pictures of a vertical and a slanted bottle, respectively, while an actual bottle containing coloured water was being presented to the child in the vertical and then slanted positions. The third and fourth tasks were simple copying from juxtaposed examples picturing the water levels in a vertical and a slanted bottle, respectively. The average deviations in degrees of the water levels drawn by the children from the correct horizontal water level in the first and last drawing tasks and in the two training tasks in which the bottle was slanted are given in Figure 2. The figure shows the reversal of an initial advantage of the comparison group to a consistent advantage of the Agam-trained children. Whereas the superiority of the comparison children in the first trial was not statistically significant, $t\,(164) = 1.36$, the advan-

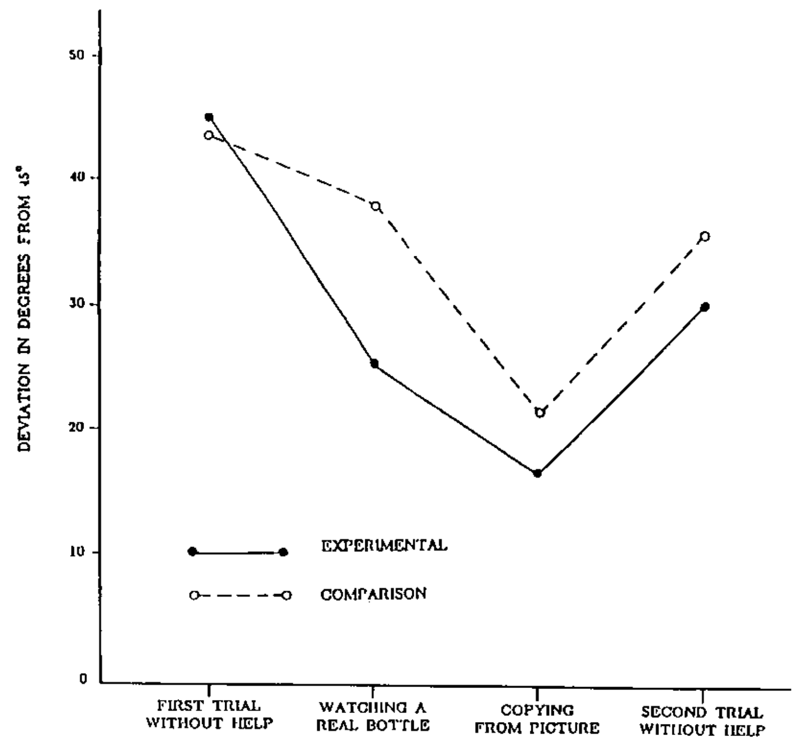

FIG. 2. Mean deviation from the horizontal of the drawn water level in pictures of slanted bottles.

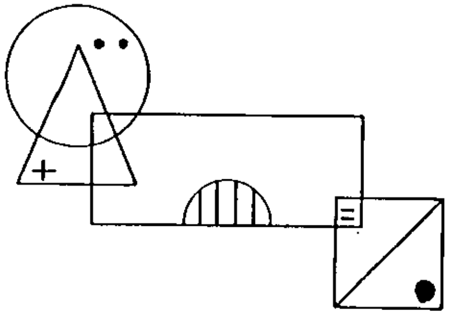

FIG. 3. Rey's composition used in a series of two tasks to measure visual learning ability.

tage of the Agam-trained children on the following three trials of water level drawing in pictures of slanted bottles was statistically significant, $F(3, 154) = 4.35$, $p = .006$, using a MANCOVA test. The fact that the experimental children were not better than the comparisons when the task was first presented to them seems to indicate that the experimental children did not have a prior familiarity with the task, either through direct training or through transfer from other tasks. The experimental children were, however, better prepared to learn and absorb new knowledge from the training sessions leading to superiority in the later trials.

In the second task the child was asked twice to draw Rey's complex composition: the first time while Rey's composition was held in front of the children, and the second time from memory. Rey's composition is given in Figure 3. The performance of the children was rated on a great number of variables belonging to seven categories, for each of which a mean percent correct was computed. Figure 4 shows the advantage of the experimental over the comparison group in mean percent correct. The figure reveals a systematic advantage of the Agam-trained children over the nontrained ones on the first trial, which seems to indicate that the experimental children were able to apply knowledge gained from training in the Agam program to this task. The figure also shows a systematic increase in this advantage going from the first to the second trial for all rating categories. The data seem to indicate that the Agam-trained children gained and retained more from the first opportunity to study and reproduce Rey's composition than did the nontrained children. Statistically this difference was significant, $t(171) = 1.76$, $p < .04$.

In the third task, the tester pointed quickly to three squares in a 3×3 matrix. The child was to remember what he saw and mark these three squares on a matrix in the test booklet. An identical demonstration by the tester of the same three squares and the child's recording of his perception on a new matrix in the booklet was repeated 10 times. Figure 5 plots the learning curves that resulted from this task. The curves show that Agam-trained children were superior to the com-

parison children in both the learning rate as indicated by the slope, and the final level of performance as indicated by the asymptote. What is particularly interesting about these curves is that the task seems to have been just as new and unfamiliar for the experimental as for the comparison group. This can be learned from the equality of performance on the first trial where the corrected relative frequencies for the experimental and comparison groups were .110 and .106, respectively, $t(171) = 0.0$. In spite of this initial equality, a gap slowly developed between the two groups indicating a learning to learn effect in the experimental group. A MANCOVA test of the difference between the experimental and comparison groups on relative frequencies correct on Trials 2 to 10 indicated a statistical superiority of the Agam-trained children $F(9, 147) = 2.25$, $p < .03$.

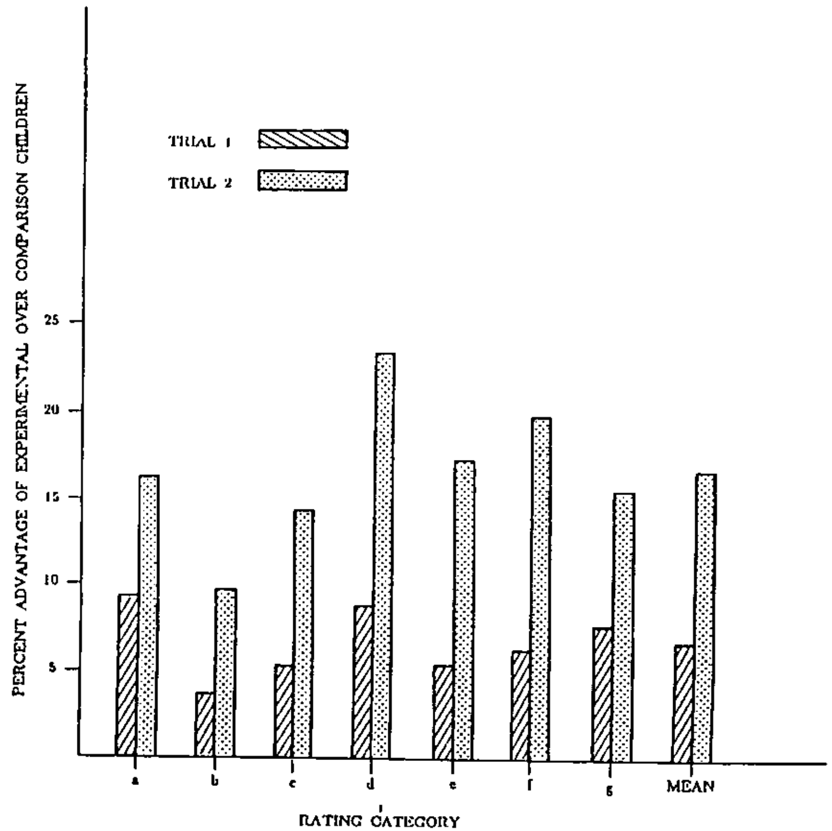

FIG. 4. Advantage in mean percent correct of the experimental over the comparison group on two trials of reproduction of Rey's composition for seven rating categories: (a) number of reproduced elements, (b) absolute size, (c) relative size, (d) geometric correctness, (e) correctness of intersections, (f) relative positioning, (g) correctness of details.

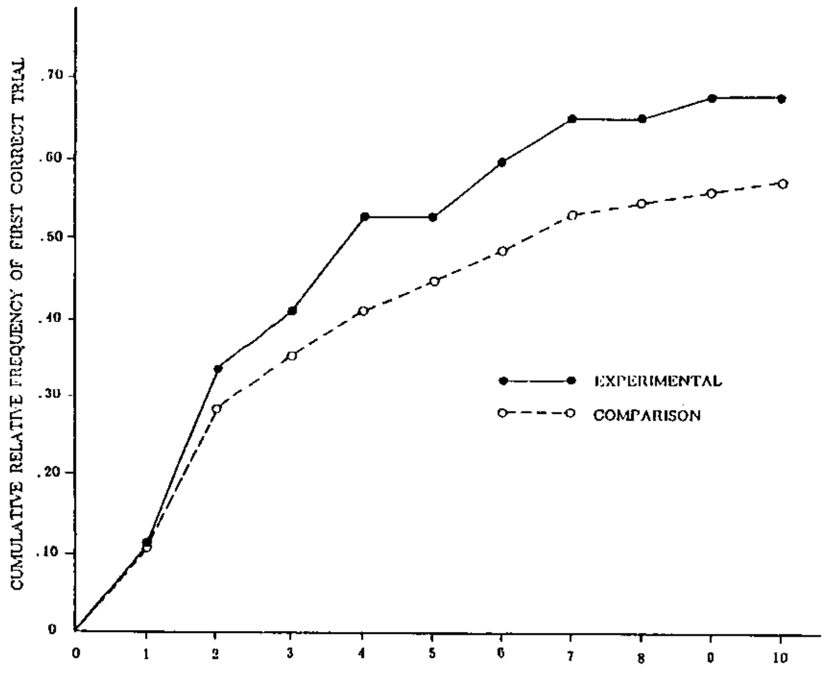

FIG. 5. Learning curves of the experimental and comparison groups in a task requiring identification of three squares in a 3 × 3 matrix.

The average z score of these three items, the water level task, Rey's composition task, and the 3 × 3 matrix task, was significantly higher in the experimental than in the comparison group, as shown in Table 3. This result seems to indicate that the children in the Agam program improved their ability to learn in new visual contexts.

Complex Visual Skills. The Summary test studied two skills that were not directly trained by the program. The ability of the children to perform mental rotation or to maintain constancy in a rotated visual environment was tested by three items. In one item, the child was asked to draw a vertical line (a tree) on a slanted base (a mountain side), that is, to keep the tree vertical in face of the rotation of the ground. The child was then asked to draw lines that were perpendicular to variously rotated bases and to draw a given triangle after mentally rotating it. As shown in Table 3, the average z scores for these tasks did not differ significantly in the experimental and comparison groups, failing to reveal any transfer of the effects of learning in the Agam program to this skill.

The visual memory studied in the Summary test was for stimuli that were of a

greater complexity than those directly trained in the Agam program. The overall effect of the program on complex visual memory did not reach statistical significance, as shown in Table 3. This overall result was based on two types of tasks. The first type consisted of two items that tested memory for *realistic* designs: being able to remember the path travelled by a dog going to his master as depicted on a map showing streets, trees, buildings, traffic lights, and so on, and remembering which items had previously appeared, and which not, in a picture of children playing at the seashore. The average z scores for these items were not significantly different in the experimental and comparison groups, as indicated in Table 3. The task of the second type tested memory for complex geometrical designs and required reproduction from memory of Rey's design shown in Figure 3. The Agam-trained children were better at this task than the comparison children, their average z scores being 0.24 and −0.23, respectively, a statistically significant result as shown in Table 3. Conflicting results were thus obtained for the two types of complex memory: memory for realistic and for complex geometrical designs. These findings must be understood in light of the consistent and large advantage of Agam-trained children over the comparison children in simpler memory tasks (Eylon et al., 1988; Eylon & Razel, 1986; Razel & Eylon, 1986). It seems that the improvement in visual memory for simple geometric shapes of the experimental children trained on these simple shapes transferred to memory for complex geometrical designs but not to memory for complex realistic drawings.

Student Characteristics. Additional analyses aimed at the question of differential effects of the program on different children. The analyses were based upon the overall transfer variable computed by combining the data from all items of the Summary test as reported above. The results of these analyses are summarized in Table 4 and indicate that there was no difference in overall transfer between boys and girls, and between those who were higher in verbal than nonverbal intelligence, and those for whom the reverse relationship held. The advantage of the children from the predominantly middle-class town over those from the predominantly working-class town, even after the effect of intelligence was eliminated, probably indicates that the learning advantage of middle-class children goes beyond what is represented by the intelligence score. The superiority of the children with higher intelligence, whether general, verbal, or nonverbal, over children with lower intelligence was not unexpected and replicated previous findings (Covington, 1985). The most interesting finding is that children who were in the program for 2 years did better than those who joined the program only during the second year. This finding provides support for a hypothesis of cumulative effectiveness of the Agam program.

A review of the data in Table 4 pertaining to the interaction between subgroups and experimental classification reveals that no interaction was even close to statistical significance. We may thus conclude that low-intelligence experi-

TABLE 4
Overall Transfer in Different Subgroups

Subgroups A/B	Subgroup A *M*	Subgroup A *n*	Subgroup A *SD*	Subgroup B *M*	Subgroup B *n*	Subgroup B *SD*	Subgroup Difference *t* Values	Experimental-Comparison × Subgroup *F* Values
Boys/Girls	−0.18	77	8.22	0.82	78	8.21	−0.66	1.19
Two/One Year	1.85	93	8.31	−2.11	76	8.26	2.33**	0.03
Middle-/Lower-Class Town	2.47	72	8.21	−1.72	97	8.11	1.97*	0.00
High/Low Intelligence[a]	3.96	67	7.99	−2.41	95	7.81	4.65**	0.68
High/Low Nonverbal Int.[a,b]	3.65	69	7.98	−2.37	93	7.85	4.57**	0.62
High/Low Verbal Int.[a,c]	5.76	40	7.27	−1.78	31	12.04	3.94**	0.00
Higher/Lower Nonverbal than Verbal Int.	2.85	49	9.92	3.32	22	8.13	0.10	0.11

[a]These analyses were performed without the covariate. [b]Based on the average score of the nonverbal subtest of the WPPSI, CPM, and Draw-a-Man tests. [c]Based on the verbal subtest of the WPPSI.
*$p < .05$. **$p < .01$.

mental children progressed relative to the low-intelligence comparison children just as much as high-intelligence children did relative to the high-intelligence comparison children. In addition, the program did not seem to affect differentially children whose intelligence was more nonverbal than those who were more verbal. Similarly, the experimental lower-class-town children benefitted from the Agam program relative to the lower-class comparison children just as much as the middle-class-town experimental children derived from it relative to the middle-class comparison children. Figure 6 demonstrates this conclusion very clearly with its parallel lines showing equal progress of experimental relative to comparison children in the lower-class and middle-class groups. (Note that the lines in Figure 6, as well as in Figure 7, connect different groups, and their purpose is to facilitate visual comparison of the relevant conditions.)

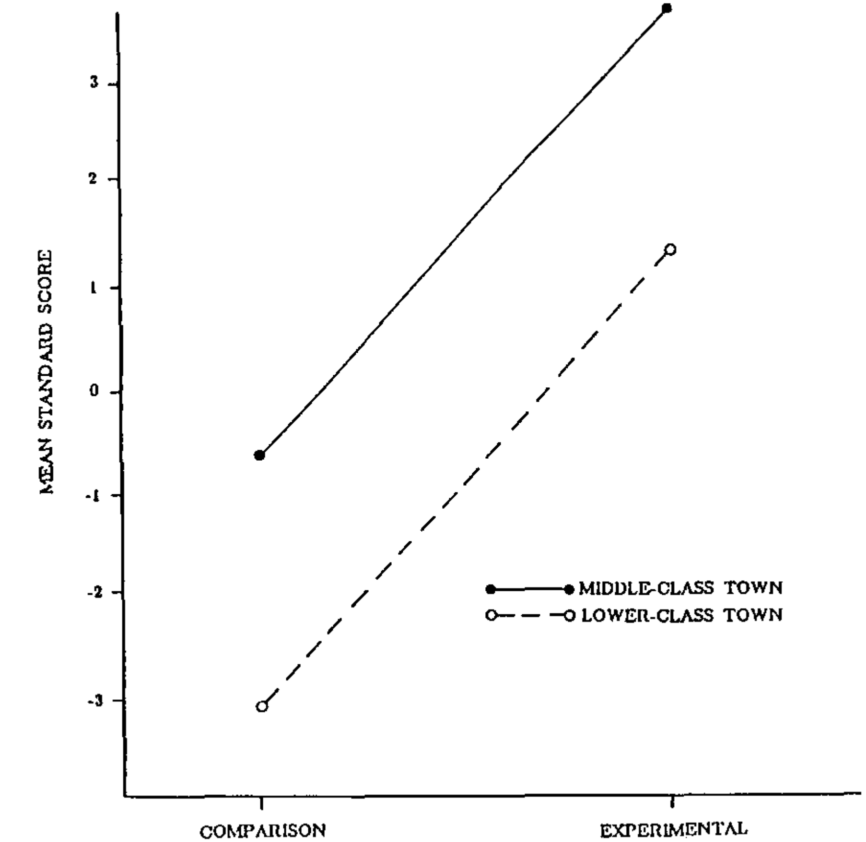

FIG. 6. Overall transfer effects of the Agam program for experimental and comparison children from primarily middle-class and primarily lower-class towns.

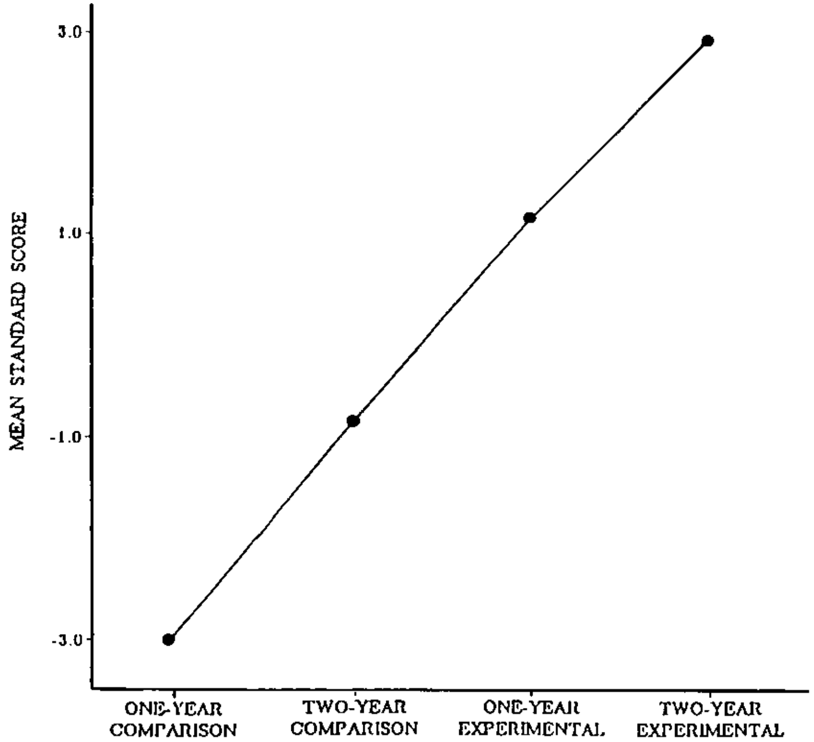

FIG. 7. Overall transfer effects of the Agam program as a function of years in the program and experimental classification.

The findings in Table 4 also indicate no interaction between number of years in the program and classification as experimental or comparison. The four means upon which this finding is based are plotted in Figure 7. The figure shows that the lack of interaction indicates a cumulative effect of receiving instruction in the Agam program. This is explained as follows. During the first year of implementation, the 2-year comparison group received a Summary test administered at the end of the first year plus six to eight visual tests not given to the 1-year comparison group, which joined the study only during the second year, the exact number of tests depending upon the progress in the program of the matched experimental class. These tests included one pretest before and one posttest after the experimental children learned each of the first four units: *Circle, Square, Patterns,* and *Circle and Square*. According to the proposed explanation, taking these visual tests created the advantage of two standard scores of the 2-year comparison group over the 1-year comparison group (−3.00 vs. −0.86). One year of exposure to the program elevated the performance of the 1-year experimental group by two additional standard scores, to 1.16. One more year of exposure to the program improved the performance of the 2-year experimental group by another two standard scores, to 2.90. In support of this explanation, it should be noted that increasing amounts of experimental effects on several control groups receiving an increasing number of tests have also been observed in other studies (Zelazo, Zelazo, & Kolb, 1972).

DISCUSSION

The results reported here portray a promising picture of the educational potential of the Agam program. The two findings concerning the program's positive effect on intelligence test and on Summary test performance lend consistent support to the conclusion that there is cognitive transfer from learning in the Agam program. In this respect, the intelligence tests can be viewed as consisting of a collection of cognitive tasks that are general, and not necessarily close in nature to those upon which the children were trained as part of the Agam program. In comparison with these tasks, the tasks included in the Summary test were close to the ones used in the Agam program because most of them were chosen based upon their salient visual character. The finding of a greater effect size, 0.63, for performance on the Summary test than for performance on intelligence tests, 0.52, is compatible with our conclusion of different distances of transfer being measured by these two kinds of tests, given the assumption that the closer the transfer, the larger the effect.

Considering intelligence tests as a measure of cognitive transfer is based upon a very general level of reference to these tests. On a more specific level we may relate to the particular nature of the tasks included in these tests, that is, their nature of measuring general intelligence. The data concerning the effect of the program on measured intelligence indicate that training in the Agam program increased the measured intelligence of the trained children in comparison with nontrained ones. This finding is congruent with findings of other studies concerning effects on general intelligence of thinking-skills training programs (Feuerstein, et al., 1985; Lipman, 1985). It is legitimate to ask whether the obtained effects on intelligence scores represent a superficial change in performance with no related changes in the underlying abilities, or whether the change in performance also indicates a change in the underlying ability. We tend to prefer the latter alternative based upon the following considerations. First, the program represents a relatively long, 2-year, intervention program, a period for which a change of underlying ability should not be ruled out. Second, the program was not designed to prepare the children for the intelligence tests used in this study, nor for any other existing test. For example, nowhere in the program were the children trained on tasks such as those in the Raven et al.'s (1977) CPM. The children were never asked to find a missing part of a matrix; they were not trained in visual or verbal analogies, and so on. The Agam program is not a preparatory course for psychometric tests, and if it affects performance on intelligence tests, this may represent more than a superficial change. On the other hand, the assumption that training in the Agam program generalized to a change in intelligence depends upon the view according to which intelligence is also affected by environmental factors and upon the assumption that the intelligence score also reflects learning experiences of the individual (Cleary, Humphreys, Kendrick, & Wesman, 1975; Razel, 1989).

The findings concerning school readiness indicate a strong positive effect on general school readiness. The effect was particularly pronounced for writing readiness, and was highly significant as well for arithmetic readiness as measured in the domain of geometry and logical thinking. The effects for reading readiness did not reach statistical significance. We may thus conclude that exposure to the Agam program during the preschool years will result in the child being better prepared for school. Assuming that better school readiness is related to higher school achievement, these results are compatible with findings of other studies that reported positive effects of thinking-skill programs on school achievement (Lipman, 1985). One may note that the two sets of data, the program's effect on intelligence and its effect on school readiness provide additional support for each other because the intelligence test is the best predictor of school performance, whereas school performance is the most important criterion for the intelligence test's validity. The finding of positive cognitive effects of the Agam program is compatible with Shepard's (1978) hypothesis that early childhood stimulation of visual thinking is a factor that contributes later to a highly developed visual thinking ability responsible for many significant contributions in almost all fields of human endeavor.

The main explanation we offer for the transfer of the Agam program's effect to intelligence and school readiness is based upon our conception of the Agam program as a program that develops the child's visual language. It is assumed that the program teaches the child a set of rules, techniques, and abilities that are generative in the Chomskian sense of the word, that is, permit the independent production of visual language by the child. Specifically, the program teaches the child to combine single visual elements or letters into higher-order combinations, or words and then to combine several of these into even higher-order units. The program develops the skills of identifying these combinations in the child's environment and in the visual imagery, store and retrieve them from memory, and produce them either manually or mentally. These skills and the attitude that goes with them are assumed to help the child generate new visual sentences to solve problems presented in intelligence tests and in tests of school readiness. The assumption that a more developed visual language can produce better visual thinking is itself supported by many experimental findings that show this relationship to exist in the verbal domain (Gagne & Smith, 1964).

Although we tend to explain the transfer effect in visual-linguistic terms, other explanations can be given that are couched in different terminology. These explanations need not necessarily rule out the visual-linguistic explanation. Feuerstein et al. (1985) explained the long-range effects of Instrumental Enrichment by assuming that the program furnishes the individual with "cognitive tools" that increase the capacity to learn from life experience. Another possibility is to view the theoretical construct of "representational competence" proposed by Copple, Sigel, and Saunders (1984) as the cognitive tool mediating the transfer effect of the Agam program. This construct is defined as one's ability to construct and utilize different representations of the same concept. According to Copple et al., human beings function intelligently and adaptively in the world by processing their representations of it. They assume that the rate of development of representational competence depends upon environmental and educational factors. It is possible that the Agam program encouraged the development of representational competence by offering the child a repetitious and systematically graded series of exercises of representation. For example, in the memory activities, the child must memorize representations of shape combinations and match them against a given array of shape combinations. In the reproduction activities, the child represents the same concept with the body, in physical activities with a group of other children, with transparencies, with plastic forms, graphically, and so on. It is possible that the improved representational competence of children trained in the Agam program is the mediating variable responsible for the transfer of the program's effect to the domains of intelligence and school readiness.

Whatever the particular nature of the cognitive tool that mediates the transfer effect, the cognitive tool hypothesis is strongly supported by the substantial effect of training in the Agam program on visual learning ability in new tasks. This finding indicates that the child acquired a new tool in the form of skills for approaching new problems and mastering new learning tasks.

We have thus far used a cognitive learning theory to explain the findings of this study, that is, a superiority of the experimental group was explained by the cognitive impact of the Agam program on this group. An alternative explanation for the findings of this study must, however, be considered. The children in the experimental group were the focus of an educational effort whereas the comparison children were not. This could have created a higher level of motivation in the experimental children than in the comparison children. A higher motivation could have caused the experimental children to try harder on all the tests and could have been the reason for the overall superiority of the experimental group. Although this motivational theory is attractive in its simplicity, it fails to explain several aspects of the data. The theory would have difficulties in explaining the learning-to-learn effects obtained in several tasks (see Figures 2–5). If motivation affected performance, why was there no effect on the first trial? On the other hand, we have seen that the cognitive learning theory was capable of explaining the learning-to-learn effect. The lack of superiority of the experimental group on the first trial was explained by the fact that this task was as new to this group as it was to the comparison group. The increasing performance gap between groups, which appeared following the first trial, was explained by the greater ability to learn new visual tasks that the Agam program fostered in the experimental group.

It would be even more difficult for the motivational theory to explain the cumulative effect of the Agam program. The children's motivational level, which was affected by the excitement aroused by the introduction of a novel educational program, would be expected to habituate with time as the novelty wore off. This motivational level would, therefore, be lower in children who finished their second year in the program than in children who finished their first. If test performance were determined by motivational level, we would expect test performance to be higher for children who studied only 1 year than for those who studied 2. But the reverse finding was obtained, thus refuting the motivational theory. Again, this finding was easily explained by the cognitive learning theory: The more the children learned, the higher their achievement. We conclude that the motivational theory cannot explain major parts of the findings and must be rejected.

An investigation of the effects of the program upon different groups of children indicated that the program was equally beneficial for middle-class as for lower-class children. Figure 6, which presents this finding graphically, also shows that the program's effect was about twice as large as the effect of social class after the effect of intelligence was removed. In other words, after 2 years in the Agam program, the visual skills of the lower-class children far exceeded those of the untrained middle-class children. The data in the figure indicate, that by providing 2 years of training in the Agam program only to the lower-class children, the initial gap in visual skills associated with social class could be reversed.

It was found that the program was equally effective for more nonverbal as for more verbal children. This result does not fit well with the finding of naturalistic observations made by teachers and research workers (Eylon et al., 1988; Eylon & Razel, 1986; Razel & Eylon, 1986). These observations highlighted the fact that some verbally inhibited children in the experimental classes were affected most favorably by the heavily nonverbal Agam program. It was observed that these children opened up as a result of the program, and gained self-confidence that gradually transferred to other domains of activity in the nursery school. It was the interpretation of the observers that these children had a low verbal ability, combined with a relatively high visual ability that could not be fully appreciated and put to use in the existing verbally oriented preschool. The Agam program enabled these children to utilize their visual ability in various cognitive tasks and to succeed in these tasks. The difference between the test findings and the natural observations lead us to one of the following conclusions: Either our measures of what constitute more verbal and more nonverbal children are not sensitive enough, or the phenomenon of special children, who are particularly well affected by the program, is too limited to show up in an analysis of the whole sample. Further research is needed to clarify this issue.

The analysis also provided strong support for the notion of the cumulative effect of the program, that is, greater exposure to the program leads to greater

experimental effects. In more specific terms, the longer the children participate in the Agam program, the greater the cognitive transfer, the better the children's school readiness, and the more developed is their ability to learn new visual tasks. One must keep in mind that the positive effects of the Agam program reported here resulted from exposure of children only to the first one-third of the curricular material constituting the Agam program. An exposure to the full program, which will probably require starting the program earlier (e.g., at age 3) and/or continuing to work on the program when the children move into grade school, may result in even larger effects.

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