

## Effects of Strategy Training on Progressive Matrices Performance

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Two qualitatively different information-processing algorithms for solution of Raven's Progressive Matrices items have been identified. Whereas the *Gestalt algorithm* involves spatial operations upon the test stimuli, the *Analytic algorithm* employs logical operations upon features abstracted from the displays. In this study, training groups were established varying both in the Strength (Weak or Strong) and Type (Gestalt or Analytic) of training at three grade levels. Two sets of post-test measures were given. *Ambiguous* items were constructed such that more than one correct answer was possible, some being the result of the Gestalt algorithm and others of the Analytic algorithm. Subjects' performances on the Ambiguous items indicated that strong Analytic training had been particularly effective and was specific to Analytic answer options. The second post-test measure was Set I of the Advanced Progressive Matrices. Performance on these *Test* items indicated that the effects of strategy training had been maintained, and were due to the facilitation of Analytic item performance by Analytic training. The effects of Strength and Type of training were consistent across Grades. These results support Hunt's analysis of Raven's Progressive Matrices items, and demonstrate that strategy training based upon a precise information processing task analysis can be effective in improving Progressive Matrices performance. The implications of these results for intellectual assessment are discussed.

The concept of strategy is central to an information-processing view of cognitive performance. Within this framework the individual is seen to be capable of developing and using a range of information-processing strategies; much of cognitive psychology is devoted to discovering the nature of these strategies and how they may be trained. Strategy instruction has been done not only to improve specific task performance, but

This research was supported by grants from the Australian Education Research and Development Committee. The authors would like to thank David Porter and Susan Wright for their assistance with data collection. The cooperation of Father F. J. Coolahan and of the staffs and students of the schools involved is gratefully acknowledged. Thanks are also due to John Belmont, Richard Gallagher, Earl Hunt, Robert Sternberg, and an anonymous reviewer for their comments on a previous version of this manuscript. Requests for reprints should be addressed to John R. Kirby, Faculty of Education, University of Newcastle, N.S.W. 2308, Australia.

also to establish the adequacy of theory, as in the case of Piagetian training studies. More recent research has been concerned with examination of the nature of strategies (e.g., Siegler, 1978) and with problems of generalization of strategy use (Brown, 1978). The focus of this study is on the effects of type of training and strength of training on use of strategies in nonverbal analogy problems by children at three different grade levels.

From a developmental point of view, three broad phases of strategy use can be identified. In the first phase, the person does not spontaneously employ the particular strategy, even if instructed to do so; furthermore, if forced to employ the strategy, no performance improvement is observed. In the second phase, the subject does not employ the strategy spontaneously, but can be taught to do so; strategy use also produces improved performance. By the third phase, most subjects are already using the strategy spontaneously, and thus strategy instruction has little effect. This account largely corresponds to that of Flavell (1970), who describes persons in the second phase as experiencing a "production deficiency." By this he means that they possess the requisite subskills and capabilities, but experience difficulty in putting them together in the appropriate task situation.

Past research has tended to emphasize relatively simple tasks and strategies. Thus there is a wealth of information concerning memory and rehearsal strategies in particular (e.g., Butterfield, Wambold, & Belmont, 1973). A consequence of choosing simple tasks and strategies has been the studying of persons at a relatively low level of development, either younger children or the mentally retarded. More recently, attempts have been made to analyze the strategies involved in the solution of more complex tasks, such as verbal analogies (e.g., Sternberg, 1977). In that such tasks are either an important component of school performance or are at least correlated with school performance, they can be described as more ecologically valid (Brown & DeLoache, 1978) from an educational point of view.

Nonverbal analogy tasks, such as those contained in Raven's Progressive Matrices tests (Raven, Court, & Raven, 1977), provide good examples of ones that are adequately complex in nature, involve important cognitive processes, and are related to real-life school performance. Analysis of the strategies and processes involved in solving nonverbal analogies, and the teaching of those strategies or processes, has produced an extensive literature (e.g., Bereiter & Scardamalia, 1979; Corman & Budoff, 1974; Feuerstein, Miller, & Jensen, 1981; Guinagh, 1971; Kirby & Das, 1978; and Ward & Fitzpatrick, 1973).

The study reported in this paper is based upon Hunt's (1974) "Quote the Raven? Nevermore!" article, in which he carried out a theoretical analysis of strategies which could be used to solve Raven's Progressive

Matrices (RPM) items. Hunt suggested that for a large number of RPM items, there were two quite different solution algorithms. One was described as the *Gestalt algorithm*, which “deals with a problem by using the operations of visual perception, such as the continuation of lines through blank areas and the superimposition of visual images upon each other” (p. 133). The *Analytic algorithm*, on the other hand, “applied logical operations to features contained within elements of the problem matrix” (p. 133). Whereas the Gestalt algorithm relies upon the mental manipulation of sensory images, the Analytic algorithm deals with abstracted features of the displays, by means of operations such as constancy, supplement/delete, expansion/contraction, addition/subtraction, movement, and composition/decomposition (Hunt, 1974, pp. 146–147). While the Gestalt algorithm is seen as being less developed than the Analytic one, Hunt proposes that use of the Gestalt algorithm alone in Set I of the Advanced Progressive Matrices would result in a score “slightly below average performance in the normal adult population” (p. 141). Similarly, inspection of the Colored Progressive Matrices (suitable for elementary school children) suggests that the Gestalt algorithm could be used to solve almost all of these items. In both tests, the Analytic algorithm is required for solution of the most difficult items.

One difficulty with Hunt’s two algorithms is that any Gestalt operation can be represented as an Analytic operation. For instance, if the task is to select a fourth figure identical to three given figures, which is basically a Gestalt task involving image identity, this could be represented Analytically as (a : a :: a : ?). This is a trivial use of the Analytic algorithm, but no comparable use can be made of the Gestalt algorithm to represent Analytic operations. It is thus possible to infer from error patterns that a person is using the Gestalt algorithm instead of the Analytic (i.e., he makes errors on items solvable only through the Analytic), but not vice versa. This is not due to a fault in Hunt’s analysis, but rather reflects the nature of the world: higher order strategies should be able to solve lower level problems, but lower level strategies should not be able to handle higher level problems. This asymmetry supports Hunt’s suggestion that the Analytic algorithm is developmentally more advanced than the Gestalt.

Lawson and Kirby (1981) tested the adequacy of Hunt’s analysis in a study involving four groups of Grade 6 (12-year-old) boys. Of these four groups, one received Gestalt strategy training, one received Analytic strategy training, one received training in both strategies, and a control group received neutral instructions. Following training, subjects completed a set of ambiguous items and Set I of the Advanced Progressive Matrices (APM). In the latter they were required to justify their responses.

On the basis of the subjects' performance and justifications, we argued that Hunt's two strategies could be identified, that the strategies could be trained, and that the use of the two strategies did affect the level of subjects' performance on post-test matrices items. From an analysis of the response patterns for the APM items it was apparent that particular strategies were superior for different items and that in general the groups given Analytic training were advantaged relative to those given the Gestalt and Control instructions. The superiority of Analytic training was apparent only on the items identified by Hunt (1974) as requiring use of the Analytic algorithm for solution.

The present study extended the Lawson and Kirby (1981) study in two ways, by expanding the age range of subjects and by varying the strength of the training given. Whereas the previous study included only Grade 6 students, the present study involved students from Grades 4, 6, and 8, in order to assess interactions of strength or type of training with grade level. Thus if the developmental pattern of a production deficiency described above is present, training might be maximally effective at a particular grade level.

Lawson and Kirby (1981) provided strong (explicit) training of the Gestalt and Analytic strategies. However, in a pilot study (Lawson & Kirby, Note 1) it had been found that a weaker form of training affected the performance of Grade 8 students on RPM items. This weak training consisted of varying the early items which subjects completed on the test, some items encouraging use of the Analytic algorithm and others the Gestalt algorithm; it was found that encountering Analytic items early in the test advantaged students, relative to those who encountered Gestalt items. In the present study, both weak and strong forms of training were employed.

The Lawson and Kirby (1981) study had included, in addition to the Gestalt and Analytic training groups, a Control group which received no training and a Dual Training group which received both Gestalt and Analytic training. As had been expected, the Control group performed like the Gestalt group and the Dual Training group performed like the Analytic group. From this we concluded that the Gestalt strategy was normally acquired first, and was in fact the strategy encouraged by the items normally encountered first on RPM tests. For the present study, it can also be concluded that Control and Dual Training groups would serve little purpose. In fact it makes little sense to think of a Control "no strategy" group in a test like the RPM, as some sort of instruction must be given, and these instructions will bias subjects' strategies one way or another. As normally given, RPM tests encourage a Gestalt strategy by means of the early items subject encounter. Thus it is more realistic to think of the Weak Gestalt training given in the present study as the "control" condition. The inclusion of a Weak Analytic group allows the possibility of a

similar encouragement of the Analytic strategy. Put more simply, normal test administration is a very weak form of strategy training; thus we are not interested in whether strategy training itself makes a difference to performance, but rather in the relative contributions of different types and strengths of strategy training.

The purpose of the present study is to investigate the effects of theoretically defined strategy training across a broad age range. The major independent variables are grade of subjects, type of training, and strength of training. The effects of a particular type of training (e.g., Analytic training) is predicted to be specific to particular item types (e.g., those that require the Analytic algorithm for solution).

## METHOD

### *Subjects*

The subjects comprised the entire Grade 4 and 6 population at eight primary schools and the entire Grade 8 population at three secondary schools in Newcastle, Australia. Primary and secondary samples were comparable in that they drew upon the same geographic regions. After elimination of subjects with incomplete data (approximately 5%), the final sample consisted of 150 Grade 4 (75 male, 75 female), 168 Grade 6 (84 male, 84 female), and 252 Grade 8 (123 male, 129 female) students. The mean ages of these groups were, respectively, 117, 142, and 169 months. Within grades, subjects were randomly assigned to four treatment conditions (i.e., conditions were not confounded with either school or classroom).

### *Treatment Conditions*

Treatments varied in Strength (either Weak or Strong) and Type (either Gestalt or Analytic) of training, producing four treatment conditions. Weak training was defined as experience with 10 easy items (selected from Sets A, Ab, and B of the Standard Progressive Matrices; Raven, Court, & Raven, 1977) that encouraged a particular solution strategy, while Strong training consisted of explicit verbal instruction in how to perform 10 other easy items from the same source. The 10 Weak training items in the Gestalt and Analytic conditions were different, while the items used for Strong training were identical to each other though different from those used in the Weak training. Weak training items were selected to encourage a particular solution strategy, while Strong training items were selected to be amenable to either solution strategy (depending upon the nature of the verbal instruction).

In all conditions subjects did training items, followed by Ambiguous items, and then Test items.

*Weak training.* The procedure normally employed for administering Raven's Standard Progressive Matrices was used: test booklets and answer sheets were distributed, the first question was explained (as a "pattern completion" problem), and the students were instructed to proceed at their own pace through the test booklet. For the Weak Gestalt group the training items were A1, A2, B2, A7, A8, A11, Ab4, Ab6, B4, and B5. For the Weak Analytic group the training items were A1, A2, B2, B3, B6, B7, B8, B9, B10, and B11.

*Strong Gestalt training.* The standard procedure was also used, but was augmented by a strong emphasis upon the Gestalt or "pattern" nature of the test. Subjects were instructed:

"We are going to do problems in which you have to work out what is missing from a picture. Each problem is basically a pattern with a piece missing. You have to pick out a piece to put in that space so that the picture or the pattern is finished. Look at each of

the pictures and try to pick out the missing pieces. You have to pick the piece that completes the picture—that makes it look like a good pattern.”

The experimenter then led the group through items A1, A2, B2, Ab7, Ab9, Ab12, B7, B8, C1, and C4 from the Colored and Standard Progressive Matrices (Raven *et al.*, 1977) as well as one specially constructed ambiguous item (see Fig. 1). The above instructions were repeated for each item, and feedback was given after each item to ensure that a Gestalt strategy was being employed. Training time was approximately 10 min.

*Strong Analytic training.* Standard procedures were again followed, but instruction emphasized the analogical reasoning nature of the task:

“We are going to do problems in which you have to work out what is missing from a picture. For each problem there is a rule which tells you what should be in the empty space. What you have to do is work out the rule and then work out what the missing piece is. First try to work out the rule and it will help you work out what the missing piece is.”

Then the same items were administered as for the Strong Gestalt group. Instructions were repeated after each item and feedback was given to ensure that subjects were using an Analytical strategy. Training time was again 10 min.

### *Post-test Measures*

Two sets of post-test measures were employed, following Lawson and Kirby (1981). The first consisted of nine items, similar to that in Fig. 1, in which either a Gestalt or an Analytic strategy could be used, each producing different answers. In all questions four answer

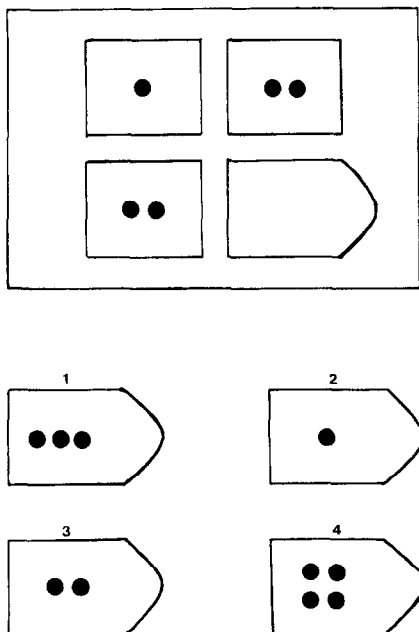


FIG. 1. An example of an Ambiguous item.

options were offered, one or two being derivable by the Gestalt algorithm and one or two others by the Analytic algorithm. (Thus in Fig. 1, Options 1 and 4 are Analytically derived, while 2 is Gestaltically derived). These items are referred to subsequently as the *Ambiguous items*; each subject's Gestalt Ambiguous score is the number of Gestalt options chosen (maximum = 9), while the Analytic Ambiguous score is the number of Analytic options chosen (maximum = 9). While subjects could choose options that were neither Gestalt nor Analytic, in general Gestalt Ambiguous and Analytic Ambiguous scores were strongly negatively correlated ( $r = -.51$  to  $-.94$  for the various groups).

The second set of post-test items are referred to as the *Test items*, and they consisted of the items contained within Set I of the Advanced Progressive Matrices (Raven *et al.*, 1977), which Hunt (1974) had analyzed. Following Hunt's analysis, Items 1-6 were classified as Gestalt items (i.e., those solvable by the Gestalt algorithm), while Items 7-12 were classified as Analytic (solvable only by the Analytic algorithm). The Gestalt Test score was the number correct in Items 1-6, and the Analytic Test score was the number correct in Items 7-12 (maximum for each score is 6).

## RESULTS

Results will be considered separately for the Ambiguous and for the Test items.

### *Ambiguous Items*

In the Ambiguous items, a subject could choose an Analytic or a Gestalt option, but not both; thus a strong negative condition exists between the Gestalt and Analytic ambiguous item scores, making the inclusion of both scores in one analysis of variance inappropriate. For this reason, separate Grade  $\times$  Strength of Training  $\times$  Type of Training analyses of variance were performed for each variable.

The effect of Grade was significant only for the Gestalt answer analysis,  $F(2,558) = 9.73$ ,  $p < .001$ , indicating that older subjects chose more Gestalt options in general. Both Strength and Type of Training effects were highly significant ( $p < .0001$ ) in both analyses; for Gestalt answers, the  $F$ 's for Strength and Type were 76.61 and 88.77, respectively; for Analytic answers, the same  $F$ 's were 87.13 and 105.67 ( $df = 1,558$  in each case). These main effects were clarified by Strength  $\times$  Type of Training interactions in each analysis, for Gestalt options  $F(1,558) = 105.13$ , for Analytic options  $F(1,558) = 102.86$ ,  $p < .0001$  in each case. These interactions are presented graphically in Fig. 2.

These results support and extend those of the previous study (Lawson & Kirby, 1981). Selection of Gestalt options appears to be the "natural" response style, and it increases with age or grade level. Only Strong Analytic training altered this pattern, and in the predicted manner. Thus this one form of strategy training was shown to be effective, and specific to a particular answer-option type. Somewhat surprisingly, the effects of training were consistent across grade levels.

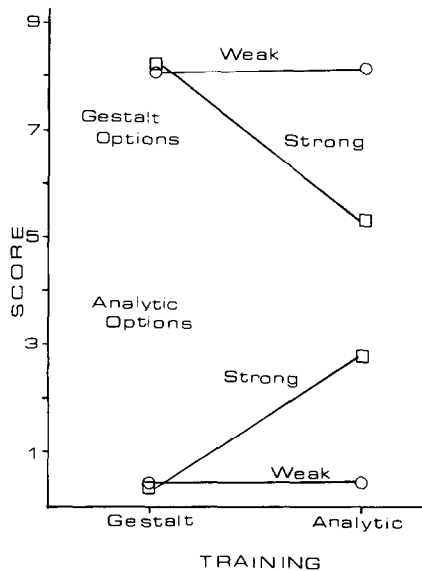


FIG. 2. Mean number of Gestalt and Analytic options chosen in Ambiguous items in four training groups (illustrating the Strength of Training  $\times$  Type of Training effect).

### Test Items

The Test item scores were analyzed by means of a Grade  $\times$  Strength of Training  $\times$  Type of Training  $\times$  Item Type (Gestalt or Analytic) analysis of variance, with repeated measures on the last factor. In this case, Gestalt and Analytic items were independent, making the repeated measures analysis appropriate. The means for Gestalt and Analytic items are graphed, respectively, in Figs. 3a and b. All main effects are significant: performance increases across Grades,  $F(2,558) = 68.87, p < .0001$ ; with Strong training  $F(1,558) = 14.21, p < .0003$ ; and with Analytic training,  $F(1,558) = 6.61, p < .02$ . Gestalt items are more often answered correctly than Analytic items,  $F(1,558) = 1030.28, p < .0001$ .

These main effects are moderated by only one interaction, that between Type of Training and Item Type, illustrated in Fig. 4. This figure indicates that correct answers to Gestalt items are equally likely under Gestalt and Analytic training, while correct Analytic answers are more likely given Analytic training. This effect is not specific to the Strong Analytic group alone, being due to both Weak and Strong Analytic groups.

The absence of interactions between treatment conditions and Grades is remarkable. Echoing the Ambiguous item analyses, there is no evidence that training conditions were more effective at one age than at any other. Inspection of Figs. 3a and b would have suggested that training was most effective for Gestalt answers at Grade 4 (where the four curves are



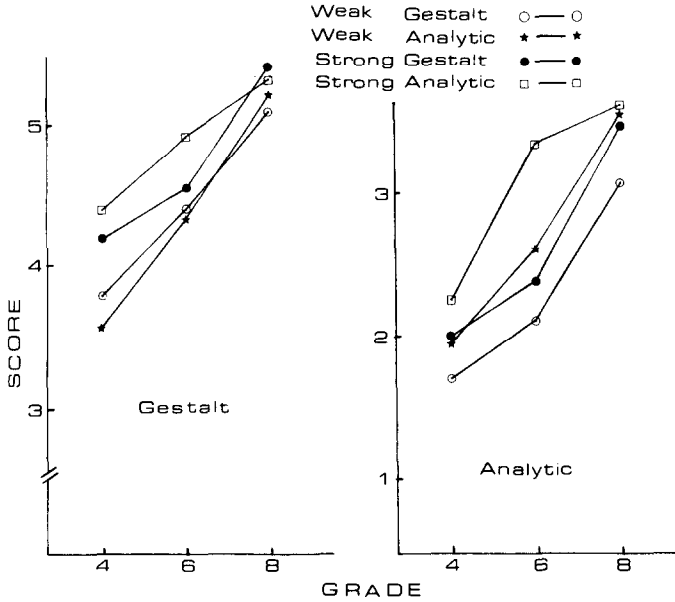


FIG. 3a, 3b. Mean number of Gestalt Test items correct (a) and of Analytic Test items correct (b) in four training groups at three grade levels.

most divergent), and for Analytic answers at Grade 6. Had this been the case, the Grade  $\times$  Strength  $\times$  Type  $\times$  Item Type effect would have been significant. In the absence of such an effect, and given the possibility of ceiling effects for at least the Gestalt score, the present results can only be taken as suggestive of these trends, which might become significant with longer and more sensitive tests.

The effects of strategy training upon Test item performance are strong and consistent with predictions. Furthermore the effect of Analytic strategy training was specific to those items which had been defined as Analytic items by task analysis. This again supports the work of Lawson and Kirby (1981), while further indicating that the effectiveness of strategy training is not age-dependent within the Grade 4-8 range.

Taken together, the Ambiguous and Test item results indicate that training was effective in changing and increasing performance, and that effects were specific to predicted item types.

## DISCUSSION

The central hypothesis of this study was that the training we identified as Gestalt would help subjects in the performance of items identified as Gestalt and not those identified as Analytic, while Analytic training would increase Analytic but not Gestalt item performance. It was further ex-

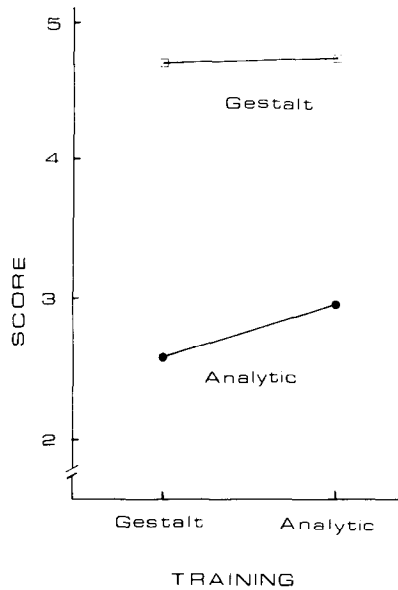


FIG. 4. Mean number of Gestalt and Analytic Test items correct under Gestalt and Analytic training (illustrating Type of Training  $\times$  Item Type effect).

pected that Strong training would be more effective than Weak. While no evidence was found in either the Ambiguous or Test item analyses for an improvement in Gestalt responses due to training, Strong Analytic training was shown to increase selection of Analytic options in the Ambiguous items, and both strengths of Analytic training increased performance on Analytic Test items.

These results support those of Lawson and Kirby (1981) by demonstrating that the effects of training could be identified in Ambiguous item performance and maintained in the performance of Test items. To the extent that Weak Analytic training was effective (cf. the Type of Training  $\times$  Item Type effect illustrated in Fig. 4), the tentative results of our pilot study (Lawson & Kirby, Note 1) are also supported. Taken together, these studies indicate that the Gestalt strategy is normally employed in RPM items, but that relatively brief Analytic training can produce predictable improvements in subjects' performance. Particularly dramatic effects are noted for Strong Analytic training, though even experience with Analytic-type items can positively affect performance.

Contrary to expectations, the effectiveness of strategy training was not age dependent, that is, there was no evidence of a production deficiency pattern. While performance generally increased with Grade (except for the Ambiguous Analytic items), Grade did not interact with either Strength or Type of Training. Though inspection of Fig. 3 might suggest that

strategy training was maximally effective for Gestalt items at Grade 4, and for Analytic items at Grade 6, the absence of a significant Grade  $\times$  Strength  $\times$  Type  $\times$  Item Type effect does not support this interpretation. It is possible that this interaction would have been significant if younger and older subjects had been sampled; while this remains a question for future research, the educational or psychological significance of training much younger subjects is doubtful.

These results concerning interactions with Grade cannot be taken as conclusive, however, as ceiling effects may have existed for the Test items. As will be argued below, these results indicate not that analytic thinking is equally uncommon across the Grade 4–8 range, but rather that the RPM items bias subjects equally across the range toward Gestaltic thinking.

### *Size of Effects*

An important question in any training study concerns the magnitude of the effects found. In the Ambiguous items, Strong Analytic training increased Analytic option selection by roughly 2.5 items out of 9. This is a considerable effect, raising essentially zero-level performance to a level where approximately one out of three responses in Analytic. This effect was obtained after only a short period of training.

The effect of training upon the Test items was less dramatic. In Fig. 3b, for instance, the greatest effect of Strong Analytic training (at the Grade 6 level, compared to Weak Gestalt) is 1.25 items on a 6-item test. In Fig. 4, the average effect of Strong and Weak Analytic training on Analytic item performance is about .5 of an item, again on a 6-item test. The magnitude of this effect is best compared to the increase in Analytic item performance across grades shown by subjects receiving essentially standard test instructions, the Weak Gestalt group (cf. Fig. 3b). This group improves its performance .4 of an item between Grades 4 and 6, or 1.3 of an item between Grades 4 and 8. On this scale, and particularly given the brevity of training, an increase of .5 of an item is a worthwhile effect.

### *Implications for Intellectual Assessment and Education*

It could be suggested that the results of the study simply reflect item difficulty effects, that the strategy training amounted to nothing more than instruction in how to solve the more difficult problems. This argument fails in two ways. First, the pattern of responses on the Ambiguous items clearly shows that two *different* strategies were being used by subjects in this study, and performance therefore reflects the differential effectiveness of these two strategies. Second, the interpretation of item difficulty implicit in the above view is simplistic. The advantage accruing to those given Analytic training reflects the operation of a specific strategy which

facilitated more successful processing of task information than did the other, Gestalt strategy. Item difficulty is clearly related to the availability of specific strategies.

On the other hand, it would be equally incorrect to conclude that these results demonstrate that students in Grades 4–8 do not normally think analytically. These students are known to perform quite adequately on various reasoning or analogy measures, such as those which play a part in standard intelligence tests. Instead we would conclude that the Raven tests bias subjects toward Gestalt thinking, by the sequence of early items that are normally given. In fact, the cumulative effect of items upon strategy development was a deliberate feature in the design of the RPM tests, accounting for the inclusion of the term “Progressive” (Court, Note 2). It is unlikely, however, that the RPM tests were designed to encourage subjects to develop an inadequate strategy.

Under normal test administration conditions, a subject obtains a high score on RPM tests by overcoming the test bias toward the Gestalt strategy, that is, by monitoring his success with the first strategy used, and then inventing or applying the Analytic strategy when the first strategy is seen to fail. Thus it could be argued that a *strategy-ambiguous* test like the RPM assesses these strategic or metacognitive factors more so than it measures any single capacity to reason or to think analytically. If this were true, it is possible that the strategy training included in the present study worked, not because it taught a strategy, but because it informed subjects which strategy (already existing) to employ. The dividing line between strategy instructions and test directions thus becomes exceedingly fine. This is an important point, because it is not clear that the subject who scores highest under ambiguous directions will also score highest when the appropriate strategy is indicated. Similarly it is not obvious which of these scores we should be measuring, nor do we know which would be more predictive of academic achievement.

Hunt (1974) questioned the value of the RPM as a measure of intelligence, because a variety of solution strategies was available to subjects and because the tester could not be certain which was being used. This does not alter the fact that RPM scores do correlate well with other measures of intelligence. It should also be noted that other standard measures of intelligence (e.g., the various WISC subtests) are equally open to a variety of solution strategies.

Two directions would seem to be indicated for future research. One line of research should be devoted to determining why complex strategy-ambiguous tests such as the RPM are good indicators of intelligence. It may be because they do measure analytical thinking, or it may be because they assess the metacognitive skills of performance monitoring, strategy

switching, and strategy invention. If the latter is true, then tests like the RPM measure intelligence *because* they are strategy-ambiguous.

A second direction for future research would be to devise a test battery in which, for instance, analytical thinking was assessed under strategy-ambiguous and strategy-nonambiguous conditions. A comparison of these scores would provide separate indices of analytical thinking per se, and of the metacognitive skill of deciding when analytical thinking was appropriate.

The results of such research will have clear implications for educational goals. To the degree that metacognitive skills are good predictors, increased attention to problem solving and flexible adaptation to tasks would seem indicated. However, if it is the actual abilities such as analytical reasoning that are the better predictors, we are faced with the task of trying to increase ability levels, which has not proved easy in the past. The third alternative, teaching subjects to use other abilities to attain the same goals, may not be feasible in many situations.

## REFERENCES

- BEREITER, C., & SCARDAMALIA, M. Pascual-Leone's M-construct as a link between cognitive-developmental and psychometric concepts of intelligence. *Intelligence*, 1979, 3, 41-64.
- BROWN, A. L. Knowing, when, where, and how to remember. In R. Glaser (Ed.), *Advances in instructional psychology*. Hillsdale, N.J.: Erlbaum, 1978. Vol. 1.
- BROWN, A. L., & DELOACHE, J. Skills, plans and self-regulation. In R. Siegler (Ed.), *Children's thinking: What develops*. Hillsdale, N.J.: Erlbaum, 1978.
- BUTTERFIELD, E. C., WAMBOLD, C., & BELMONT, J. M. On the theory and practice of improving short-term memory. *American Journal of Mental Deficiency*, 1973, 77, 654-669.
- CORMAN, L. & BUDOFF, M. Factor structures of retarded and nonretarded children on Raven's Progressive Matrices. *Educational and Psychological Measurement*, 1974, 34, 407-412.
- FEUERSTEIN, R., MILLER, R., & JENSEN, M. R. Can evolving techniques better measure cognitive change? *Journal of Special Education*, 1981, 15, 201-219.
- FLAVELL, J. Developmental studies of mediated memory. In H. W. Reese & L. P. Lipsitt (Eds.), *Advances in child development and behaviour*. New York: Academic Press, 1970, Vol. 5.
- GUINAGH, B. J. An experimental study of basic learning ability and intelligence in low-socioeconomic-status children. *Child Development*, 1971, 42, 27-36.
- HUNT, E. Quote the Raven? Nevermore! In L. Gregg (Ed.), *Knowledge and cognition*. Potomac, Md: Erlbaum, 1974.
- KIRBY, J. R., & DAS, J. P. Skills underlying Colored Progressive Matrices. *Alberta Journal of Educational Research*, 1978, 24, 94-99.
- LAWSON, M. J., & KIRBY, J. R. Training in information processing algorithms. *British Journal of Educational Psychology*, 1981, 51, 321-335.
- RAVEN, J. C., COURT, J. H., & RAVEN, J. *Manual for Raven's Progressive Matrices and Vocabulary scales*. London: Lewis, 1977.

- SIEGLER, R. S. The origins of scientific reasoning. In R. S. Siegler (Ed.), *Children's thinking: What develops?* Hillsdale, N.J.: Erlbaum, 1978.
- STERNBERG, R. J. *Intelligence, information processing and analogical reasoning: The componential analysis of human abilities.* Hillsdale, N.J.: Erlbaum, 1977.
- WARD, J. & FITZPATRICK, T. F. Characteristics of matrices items. *Perceptual and Motor Skills*, 1973, 36, 987-993.

#### REFERENCE NOTES

1. LAWSON, M., & KIRBY, J. R. *An initial investigation of the development of solution strategies for Raven's Progressive Matrices items.* Unpublished manuscript, Flinders University, Australia, 1978.
2. COURT, J. *Raven's Progressive Matrices.* Paper presented at the Annual Meeting of the Australian Psychological Society, Adelaide, August 1977.