

Spatial and Verbal Abilities in Children's Crossmodal Recognition: A Dual Coding Approach*

Carla J. Johnson, Allan U. Paivio, and James M. Clark
University of Western Ontario

ABSTRACT A dual coding analysis suggests that performance on a tactual-to-visual shape recognition task could be based on either a nonverbal visual imagery strategy or a verbal referential naming strategy and that different ability variables should predict crossmodal recognition under imagery and naming strategies. In two experiments, 184 Kindergarten and Grade 1 children completed individual tests of visuospatial and verbal referential abilities prior to performing a crossmodal shape recognition task under imagery, naming, or control instructions. Multiple regression analyses revealed that, as expected, the major correlate of crossmodal recognition performance was visuospatial ability under imagery instructions and verbal referential skill under naming instructions. Children given no specific strategy instructions apparently implemented a naming strategy. The results are consistent with a dual coding conceptualization of the crossmodal recognition task and suggest that the development of strategy-specific abilities may be a prerequisite for children to employ imagery and naming strategies successfully.

RÉSUMÉ Une analyse de codage double suggère que la performance dans une tâche de reconnaissance de formes du tactile au visuel pourrait être basée soit sur une stratégie d'imagerie visuelle nonverbale soit sur une stratégie d'appellation référentielle verbale et que différentes variables d'habiletés prédiraient une reconnaissance crossmodale basée sur des stratégies d'imagerie et d'appellation. Dans deux expériences, 184 enfants de maternelle et de première année ont été soumis à des tests d'habiletés référentielles visuospatiales et verbales avant de faire une tâche crossmodale de reconnaissance de formes lors d'instruction d'imagerie, d'appellation ou de contrôle. Des analyses de régressions multiples ont révélé que, tel qu'attendu, le corrélat majeur de la performance de reconnaissance crossmodale était l'habileté visuospatiale lors d'instruction d'imagerie et l'habileté référentielle verbale lors d'instruction d'appellation. Les enfants n'ayant reçu aucune instruction quant à une stratégie spécifique exécutaient apparemment une stratégie d'appellation. Les résultats sont consistants avec le concept d'un codage double de la tâche de reconnaissance crossmodale et suggèrent que le développement d'habiletés stratégiques-spécifiques peut être un prérequis pour les enfants en vue d'utiliser avec succès des stratégies d'appellation et d'imagerie.

In tactual-to-visual crossmodal recognition, subjects feel an unseen stimulus shape and subsequently attempt to identify its counterpart in a visual array of shapes. The

*This article is based in part on a master's thesis completed at the University of Western Ontario by the first author under the supervision of the second author. We thank the London Board of Education for providing access to subjects, Sonya Synnons for assisting in data collection for Experiment 1, and three anonymous reviewers for suggesting improvements to an earlier version of this article. Preparation of this manuscript was supported by a postgraduate scholarship to C. Johnson from the Natural Sciences and Engineering Research Council of Canada and by Grant A0087 to A. Paivio from the same agency. A version of this report was presented at the 1988 annual convention of the Canadian Psychological Association. Address reprint requests to C. Johnson, Department of Psychology, University of Western Ontario, London, Ontario, Canada N6A 5C2.

crossmodal task appears amenable to the use of either an imaginal or a verbal representational strategy. For cognitive tasks that permit both types of strategies, relevant individual difference variables, such as spatial and verbal abilities, have proven critical to an adequate explanation of performance (e.g., MacLeod, Hunt, & Mathews, 1978; Sternberg & Weil, 1980).

The current research focusses on children's visuospatial and verbal referential abilities as possible determinants of performance in tactual-to-visual crossmodal recognition. Dual coding theory (Paivio, 1971, 1986) provided the theoretical framework for our experiments, which employed the logic and methodology of aptitude by treatment interaction (ATI) designs (Cronbach & Snow, 1977). Despite their importance to an understanding of individual differences in cognition, ATIs involving specific spatial and verbal abilities have been relatively difficult to identify and replicate (Snow, 1989).

Dual coding theory (Paivio, 1971, 1986) maintains that two independent but interconnected representational subsystems are involved in human cognition. The non-verbal subsystem is specialized for processing information about nonverbal objects and events, whereas the verbal system is specialized for processing language. Performance on cognitive tasks involves activation of the representational subsystems, either individually, in parallel, or in an interactive fashion depending on task materials, task requirements, and individual differences in representational skills. Particularly relevant here is the assumption that the two subsystems are interconnected via referential pathways that permit mental translation from the nonverbal to the verbal subsystem (as in naming pictures or shapes) or from the verbal to the nonverbal subsystem (as in imaging to words).

In dual coding terms, subjects who use an imagery strategy in tactual-to-visual recognition rely primarily on the nonverbal symbolic subsystem. Feeling the unseen stimulus activates tactual representations, which in turn arouse a visual image that is later used to identify the target shape in the visual array. Subjects who use a naming strategy activate the nonverbal subsystem in a similar manner, but this activation then spreads to the verbal subsystem via the aforementioned referential connections. In other words, the felt shape first arouses tactual and visual representations, which then jointly and probabilistically activate a mental name for the stimulus. The name is then used, perhaps along with the visual image, to identify the stimulus in the visual array. Following activation of a name, the initial imaginal representation need not necessarily be retained, as it can presumably be regenerated from the name.

Dual coding theory identifies three classes of variables that jointly influence the relative use and efficacy of imaginal and verbal strategies in cognitive tasks: stimulus characteristics, individual preferences or abilities, and task instructions. In the case of crossmodal recognition, for example, stimuli that are amorphous, unfamiliar shapes are more likely to elicit an imagery strategy, whereas familiar shapes will more often elicit a naming strategy. This dual coding emphasis on stimulus characteristics is consistent with evidence that amorphous shapes activate right-hemisphere (nonlinguistic) processing, whereas familiar shapes elicit left-hemisphere (linguistic) activity (Gibson & Bryden, 1983; Witelson, 1974).

Individual differences in representational abilities and preferences are also expected to be important determinants of strategy use. In particular, high visuospatial ability

should foster successful implementation of an imagery strategy, whereas high verbal referential ability should facilitate successful use of a naming strategy. Consistent with this expectation, visuospatial ability, but not verbal ability, has been shown to correlate with children's crossmodal memory for unfamiliar stimuli that favour the use of an imagery strategy (Ford, 1973; Stoltz-Loike & Bornstein, 1987). Verbal referential ability has not been studied in relation to children's crossmodal recognition, although familiar shapes, which should promote the use of a naming strategy, have often been used as stimuli (Kamhi, Catts, Koenig, & Lewis, 1984; Laurendeau & Pinard, 1970; Piaget & Inhelder, 1956).

According to dual coding theory, instructions to use an imagery or a naming strategy should elicit the designated strategy. Instructions apparently have not been manipulated in studies of children's tactual-to-visual crossmodal recognition. With adults, imagery and naming instructions initiated relevant patterns of hemispheric processing (right for imagery, left for naming), but resulted in similar levels of crossmodal accuracy (Lenhart & Schwartz, 1983). Equal effectiveness for imagery and naming instructions has also been demonstrated in recognition memory tasks that are not crossmodal in nature (London & Robinson, 1968; Paivio, 1976; Robinson & London, 1971). One possible reason for these results is that individuals differ in their ability to execute the instructed strategies; that is, that strategy instructions interact with ability (Pressley, Heisel, McCormick, & Nakamura, 1982). High-ability subjects should perform especially well when the instructed strategy takes advantage of their superior ability; low-ability subjects should be particularly disadvantaged when the instructed strategy forces the use of their limited ability. Comparable ability by treatment interactions have been predicted and supported using other cognitive tasks (e.g., MacLeod et al., 1978; Sternberg & Weil, 1980).

In a developmental context, the search for such ability by strategy interactions may be particularly fruitful. It is well-known that, as a group, children in the early elementary years do not consistently benefit from memory strategy instructions (Flavell, 1985; Pressley, Borkowski, & Johnson, 1987; Pressley et al., 1982; Waters & Andreassen, 1983). However, it is conceivable that the transition to proficient strategy use begins earlier for children who have developed an important prerequisite ability than for those who have not. Here we studied the relative importance of visuospatial and verbal referential abilities to children's crossmodal performance under imagery, naming, and control instructions.

EXPERIMENT 1

As previously mentioned, the dual coding predictions for a given tactual-to-visual crossmodal recognition task are contingent on the nature of the stimulus items. For our experiments we chose simple shapes (see Fig. 1), the majority of which had been used in previous research with children in our target age range (Kamhi et al., 1984; Laurendeau & Pinard, 1970; Piaget & Inhelder, 1956). We expected that many of the shapes would be familiar to children and, thus, would permit the successful use of either an imagery or a naming strategy. Pilot testing indicated that children were, indeed, readily able to generate names for the tactual stimuli.

Experiment 1 tested the dual coding hypothesis that visuospatial and verbal

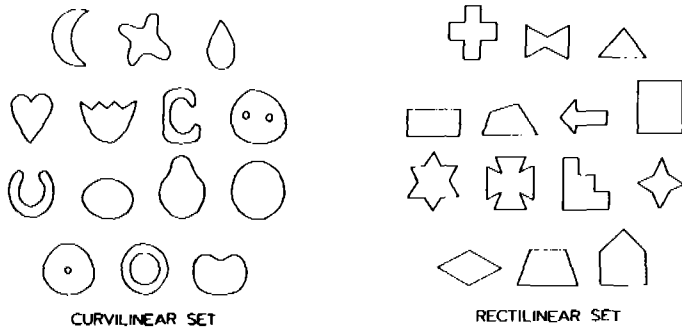


Figure 1. Stimulus shapes and examples from the set of curvilinear and rectilinear response arrays used in Experiments 1 and 2.

referential abilities would differentially predict crossmodal performance under imagery and naming instructions. Children given imagery instructions were expected to rely more on visuospatial ability than on verbal referential ability for crossmodal performance, whereas those who received naming instructions were expected to show greater reliance on verbal referential ability than on visuospatial ability. We also tried to determine the nature of the strategy that young children spontaneously used for the crossmodal task by comparing the ability-performance relations of control subjects with those of instructed subjects.

Method

Subjects: The subjects were 119 English-speaking children (62 boys, 57 girls) from four London, Ontario, public schools. Data from one additional child who refused to complete the study were excluded. The 55 Kindergarten and 64 Grade 1 subjects ranged in age from 5 years, 5 months, to 8 years, 0 months ($M = 6$ years, 5 months).

Individual Difference Testing: In the first session, subjects individually completed four ability tests: (a) the Peabody Picture Vocabulary Test-Revised (PPVT-R), Form L (Dunn & Dunn, 1981); (b) the Expressive One Word Picture Vocabulary Test (EOWPVT) (Gardner, 1979); (c) Items 1 to 15 from the Revised Minnesota Paper Form Board (MPFB), Form AA (Likert & Quasha, 1941); and (d) the Primary Mental Abilities Spatial Relations Test (PMA-SR) K-1 (Thurstone & Thurstone, 1965). Order of test presentation was counterbalanced and randomly assigned to subjects.

We selected our ability tests on the basis of their nominal appropriateness as measures of the relevant dual coding processes (referential and imaginal processing) and their applicability for Kindergarten and Grade 1 subjects. The PPVT-R and EOWPVT operationalized referential processing ability, which is particularly relevant to application of a naming strategy and theoretically involves mental translation between the nonverbal and verbal symbolic subsystems. The PPVT-R requires a child to select, from an array of four, the picture that best illustrates a spoken word. In dual coding terms, performance on the PPVT-R requires bidirectional referential comparison of the target word to the pictured alternatives (Paivio, 1986). We reasoned that crossmodal performance under naming instructions might also require bidirectional referential activity (initial naming of the stimulus and later matching of the name to the appropriate shape in the visual array). The EOWPVT requires a child to name line drawings of familiar objects and measures referential processing in the nonverbal-to-verbal direction (naming of nonverbal stimuli). Both the PPVT-R and the EOWPVT are normed for Kindergarten and Grade 1 children.

Visuospatial tests require the mental organization and/or transformation of nonlinguistic stimuli and presumably assess imaginal processing within the nonverbal symbolic subsystem

(Paivio, 1971, 1986). Unfortunately, few visuospatial tests have been developed or standardized for use with young children (Johnson & Meade, 1987). Therefore, for one of our measures, we chose the first 15 items of an adult test, the MPFB. These items loaded on a spatial factor in previous studies of the abilities of primary school children (Forisha, 1975; Paivio & Cohen, 1979). For each MPFB item, the child inspects separated pieces of a figure and selects, from a choice of five, the picture that shows the pieces joined into a complete figure. The majority of items (14/15) appear to require mental transformation of the integrated figure or its parts in order to evaluate the alternatives. Our second visuospatial measure, the PMA-SR (K-1), is one of the few visuospatial ability tests specifically designed for use with Kindergarten and Grade 1 children. It should be noted, however, that the K-1 version of the PMA-SR differs from versions for older children and adults in both task requirements and stimuli. The PMA-SR tests, therefore, may not assess the same cognitive operations at all age levels (Johnson & Meade, 1987). In particular, the K-1 version of the PMA-SR does not appear to require mental transformation in order to complete the two types of items it contains. For the first type, the child sees part of a square and selects, from four alternatives, the picture that shows the rest of the square. In the remaining items, the child completes a line drawing to match a sample figure.

Crossmodal Recognition Task: Following Session 1, subjects were randomly assigned to imagery, naming, or control conditions within blocks of three subjects ranked on age and matched on gender. Age and ability scores were examined to insure that the distributions of these variables were similar across the three conditions and approximated those from the full sample (see *Results*). In Session 2, which occurred 2-4 weeks after Session 1, the subjects performed a tactual-to-visual crossmodal recognition task under imagery, naming, or control instructions, as described below.

Stimuli, Response Arrays, and Apparatus. The tactual stimuli were 14 curvilinear and 14 rectilinear two-dimensional hardboard shapes (see Fig. 1), each approximately 8-10 cm in diameter. The response arrays for each subset of shapes (curvilinear and rectilinear) consisted of 14 random arrangements of line drawings illustrating the figures from the corresponding subset (see Fig. 1). The stimuli were grouped into subsets to insure that: (a) recognition distractors would be somewhat similar to the target shapes; (b) chance performance would be relatively low (1/14); and (c) response alternatives would not be too numerous.

A box with its open side toward the experimenter was placed between the subject and experimenter. The child inserted his or her hands into two small openings to receive each stimulus. A curtain inside the box prevented subjects from seeing the stimuli.

Pre-Task Orienting Activities. Each experimental group completed a pre-task orienting activity involving stimulus shapes that were not used in the later crossmodal task. To maximize use of the intended strategies in the subsequent crossmodal task, imagery subjects completed four trials in which they felt an unseen, hard-to-name stimulus and then drew it, whereas naming subjects named each of four nameable tactual stimuli. Control subjects manually explored two hard-to-name and two easy-to-name stimuli to equate their experience with tactual shapes with that of the naming and imagery subjects.

Strategy Instructions. The imagery instructions for the crossmodal task were:

Now I will give you shapes to feel, one at a time. Try to make a picture of the shape in your mind. Think about how the shape looks so you will be able to find it in a picture of many different shapes. Let's try one now. Remember, try to think about how the shape looks.

The naming instructions used parallel wording, but references to picturing the shape were replaced by "give the shape a name." Control subjects were instructed to "remember the shape."

Procedure. In the crossmodal task, a shape was placed in the subject's hands for a 10-s exploration period.¹ The stimulus was then withdrawn and an appropriate (curvilinear or rectilinear) response array was presented. The child pointed to the line drawing that matched

TABLE 1

Descriptive Statistics and Correlations for Dependent Measures and Individual Difference Variables in Experiments 1 and 2

Variable ^a	Crossmodal	Names	PPVT-R	MPFB	EOWPVT	PMA-SR	<i>M</i>	<i>SD</i>
Experiment 1 (<i>N</i> = 119)								
Age (months)	.26*	-.11	.34*	.18*	.39*	.43*	77.30	7.30
Crossmodal (26)	—	.09	.43*	.41*	.37*	.45*	17.82	3.68
Names (26)	(.13) ^b	—	.07	.12	.05	.11	7.97	9.32
PPVT-R (175)	(.38)*	(.12)	—	.35*	.73*	.54*	77.85	16.85
MPFB (15)	(.38)*	(.15)	(.31)*	—	.38*	.42*	7.06	2.60
EOWPVT (110)	(.30)*	(.10)	(.69)*	(.34)*	—	.48*	69.50	12.06
PMA SR (24)	(.38)*	(.17)*	(.46)*	(.39)*	(.38)*	—	15.29	4.46
Experiment 2 (<i>N</i> = 65)								
Age (months)	.59*	-.11	.65*	.31*	—	—	70.25	6.89
Crossmodal (26)	—	.17	.61*	.38*	—	—	15.43	4.79
Names (26)	(.30)*	—	.03	.09	—	—	11.98	10.00
PPVT-R (175)	(.37)*	(.14)	—	.37*	—	—	76.37	15.30
MPFB (15)	(.26)*	(-.06)	(.23)*	—	—	—	6.95	2.15

^aMaximum possible raw scores appear in parentheses.^bFirst-order partial correlations (age removed) are shown in parentheses below the diagonal.**p* < .05.

the stimulus. Two practice items (square and circle) preceded 26 test items. Half of the subjects in each group felt the curvilinear subset before the rectilinear one; the others did the reverse. Eight random presentation orders of each subset were used. After the first subset, the child was reminded to "think about how the shape looks" (imagery), "give the shape a name" (naming), or "remember the shape" (control).

Accuracy in identifying the 26 test shapes and the number of overt names given by each subject were recorded. The latter measure was intended to confirm that subjects followed the strategy instructions.

Results and Discussion

Following descriptive statistics for the predictor variables and dependent measures, we report multiple regression analyses that evaluate our main hypotheses concerning the interactive effects of strategy instructions and abilities on crossmodal recognition accuracy in the three experimental conditions.

Descriptive Statistics: Kuder-Richardson reliability estimates were .97, .94, .57,² .81, and .65 for the PPVT-R, EOWPVT, MPFB, PMA-SR, and crossmodal recognition, respectively. Table 1 shows the means and standard deviations for the individual difference variables (age, two verbal referential tests, and two visuospatial tests) and dependent measures (crossmodal accuracy and number of items named) for the full sample. Separate analyses of variance (ns) confirmed that children in the three conditions were similar in age and abilities.

¹Two-handed exploration is known to increase the salience of shape as a property of tactual stimuli (Klatzky, Lederman, & Reed, 1987).

²The modest reliability of the MPFB is at least partially attributable to the small number of items (15). Nonetheless, it exceeds the .50 level recommended as a minimum standard for research (Smith & Glass, 1987, p. 106).

We expected the two visuospatial tests to measure abilities that were relatively distinct from those measured by the two verbal referential tests. Such a pattern of relations would permit aggregation of each set of tests into a single, more reliable measure of the corresponding ability construct (Rushton, Brainerd, & Pressley, 1983). Table 1 shows the intercorrelations among the ability tests. The high correlation between the two verbal referential tests corresponded to the expected pattern. In addition, one visuospatial measure, the MPFB, showed the predicted distinction from the verbal tests, but the other, the PMA-SR, did not. In fact, the PMA-SR showed higher correlations with the verbal referential tests than it did with the MPFB. This pattern suggested that aggregating the PMA-SR and MPFB into a single visuospatial ability measure would have been unjustified. Therefore, we used an aggregate measure only for verbal referential ability and used the MPFB alone as our measure of visuospatial ability.³

Our results suggest further that the actual construct validity of the PMA-SR (K-1) may be different than its putative construct validity as a visuospatial ability measure. It is not uncommon to find modest correlations among different paper-and-pencil tests assumed to measure visuospatial ability (Ernest, 1977; Katz, 1983; Paivio, 1971, 1986), but visuospatial abilities generally are found to be distinct from verbal abilities for both children and adults (Forisha, 1975; Guilford, 1967; Paivio, 1986, Chp. 6). Given the limited study of visuospatial tests with subjects as young as ours (Johnson & Meade, 1987), it is unclear why the PMA-SR (K-1) correlated more highly with the verbal referential measures than with the MPFB.

Effects of Strategy Instructions and Ability Variables: Analysis of variance revealed that strategy instructions influenced overt naming behaviour, $F(2, 116) = 22.10, p < .001$. Post hoc pairwise comparisons (Tukey's HSD, $p < .05$) demonstrated that, as expected, naming condition subjects named significantly more items ($M = 14.95$) than either imagery ($M = 4.15$) or control subjects ($M = 5.00$). Imagery and control subjects did not differ significantly.

Strategy instructions had little overall effect on crossmodal accuracy, when analyzed without taking account of the ability variables. The means for accuracy in the crossmodal tactual-to-visual recognition task were: imagery, 18.25; naming, 17.97; and control, 17.25. Analysis of variance revealed no significant differences among the means for the groups, but subsequent analyses demonstrated that the success of strategy instructions depended on different abilities in a pattern consistent with the dual coding task analysis.

Within-Condition Regression Analyses: Our primary hypothesis concerned which (if either) of the two abilities (visuospatial and verbal referential) predicted crossmodal accuracy within each strategy condition, independent of the effects of age. Accordingly, for each strategy group, crossmodal accuracy was regressed on three predictors: age, visuospatial ability (MPFB scores), and verbal referential ability (an aggregate

³When the PMA-SR (K-1) was retained as a separate predictor in the subsequent regression analyses, its effects on crossmodal recognition were redundant with those of the verbal aggregate and distinct from those of the MPFB. These results provided further verification that the PMA-SR (K-1) tapped an ability similar to that required by the verbal referential measures but different from that required by the MPFB.

of EOWPVT and PPVT-R raw scores).⁴ For each regression, age was statistically controlled by forcing its entry at the first step. Analyses in which age was not statistically controlled revealed results similar to those reported below. Following age, the ability variables were entered in both possible orders, MPFB first followed by the verbal aggregate and vice versa. Reversing the order of entry allowed us to determine whether either ability variable predicted unique variance in crossmodal performance within each condition.

The original task analysis suggested that crossmodal accuracy for the imagery condition should be predicted best by visuospatial ability. In line with this expectation, the MPFB uniquely predicted crossmodal accuracy in the imagery condition (see Table 2). Age failed to contribute significantly to the regression equation at the first step of the analysis. When entered at the second step, the MPFB significantly predicted crossmodal scores, accounting for an increment of 28% in the explained variance, $F(1, 37) = 14.88, p < .001$. The verbal aggregate measure did not add significantly to the variance beyond that accounted for by the MPFB. With order of entry reversed, the MPFB added a unique increment (19%) to prediction of crossmodal accuracy, $F(1, 36) = 9.78, p < .01$, over and above the effects of age and the verbal aggregate.

Verbal referential ability was expected to be the best ability predictor of crossmodal performance for naming subjects. Consistent with this prediction, the verbal aggregate measure accounted for a significant 12% increment in the explained variance, $F(1, 36) = 6.59, p < .05$, above the 20% initially attributed to age, $F(1, 37) = 9.54, p < .01$. The MPFB did not contribute to prediction once age and the verbal aggregate had entered the equation. The verbal aggregate also accounted for a unique increment to the explained variance (8%) even after age and MPFB were forced into the equation, $F(1, 35) = 4.33, p < .05$.

In the control condition, as in the naming condition, the verbal aggregate was the best ability predictor of crossmodal performance. Verbal referential ability accounted for a 14% increment in the explained variance at the second step, $F(1, 37) = 6.64, p < .05$, following a nonsignificant contribution of age. The MPFB made no significant contribution to the equation. When the verbal measure was entered last, it uniquely accounted for a 9% increment in the explained variance, $F(1, 36) = 4.20, p < .05$.

As shown in Table 2, the pattern of standardized regression coefficients (beta weights) across the three conditions indicated that visuospatial ability, as measured by the MPFB, contributed more to the crossmodal performance of imagery subjects ($\beta = .483$) than to that of naming ($\beta = .218$) or control subjects ($\beta = .183$). Verbal referential ability showed the opposite pattern of weightings, contributing more to performance in the naming ($\beta = .315$) and control groups ($\beta = .356$) than in the imagery group ($\beta = .149$).

Tests of Ability-Strategy Interactions. As indicated earlier, specific strategy instructions did not improve mean crossmodal performance relative to control instructions. A possible explanation for this result is that strategy instructions interacted with ability; that is, instructions to use a particular strategy benefitted high ability

⁴An aggregate based on standard scores for each variable yielded virtually identical results in all analyses.

TABLE 2

Within-Condition Multiple Regression Analyses Predicting Crossmodal Recognition Accuracy in Experiments 1 and 2

Condition	Step	Variable	Simple <i>r</i>	Mult. <i>R</i> .	<i>R</i> ² Chng.	<i>F</i>	β^a
Experiment 1							
Imagery (<i>n</i> = 40)	1	Age	.10	.10	.01	0.42	-.033
	2	MPFB	.54	.54	.28	14.88***	.483
	3	Verbal ^b	.35	.56	.02	0.86	.149
Naming (<i>n</i> = 39)	1	Age	.45	.45	.20	9.54**	.313
	2	Verbal	.50	.57	.12	6.59*	.315
	3	MPFB	.34	.61	.04	2.44	.218
Control (<i>n</i> = 40)	1	Age	.26	.26	.06	2.65	.048
	2	Verbal	.45	.46	.14	6.64*	.356
	3	MPFB	.34	.48	.03	1.30	.183
Experiment 2							
Imagery (<i>n</i> = 22)	1	Age	.72	.72	.52	21.68***	.464
	2	MPFB	.60	.81	.14	7.51*	.333
	3	PPVT-R	.67	.83	.03	1.58	.225
Naming (<i>n</i> = 22)	1	Age	.47	.47	.22	5.59*	.059
	2	PPVT-R	.67	.67	.23	8.15*	.620
	3	MPFB	.24	.67	.00	0.06	.045
Control (<i>n</i> = 21)	1	Age	.63	.63	.40	12.80**	.450
	2	PPVT-R	.57	.66	.04	1.20	.260
	3	MPFB	.30	.66	.00	0.00	.018

^aStandardized regression coefficient (beta weight) in three variable equation.^bAggregate of EOWPVT and PPVT-R scores.**p* < .05, ***p* < .01, ****p* < .001.

subjects but hampered low ability subjects. In this regard, dual coding theory suggests that the effectiveness of imagery instructions might depend on visuospatial ability, whereas the effectiveness of naming instructions might depend on verbal referential ability. Such interactions would be revealed by differences across conditions in the slopes of the regression equations predicting crossmodal performance from ability (MPFB or verbal aggregate). Because earlier results suggested that control children also implemented a naming strategy, two orthogonally coded interaction contrasts (Cohen & Cohen, 1983, p. 325) were of particular interest. The first contrast compared the regression slopes for the naming and control conditions. Separate analyses for the MPFB and the verbal aggregate revealed no significant differences between the naming and control condition slopes for either ability measure. The second contrast compared the imagery slope to the common naming/control slope for each ability. The slope of the equation predicting crossmodal performance from MPFB was significantly steeper for the imagery condition [$\hat{y} = 11.97 + .90(\text{MPFB})$]

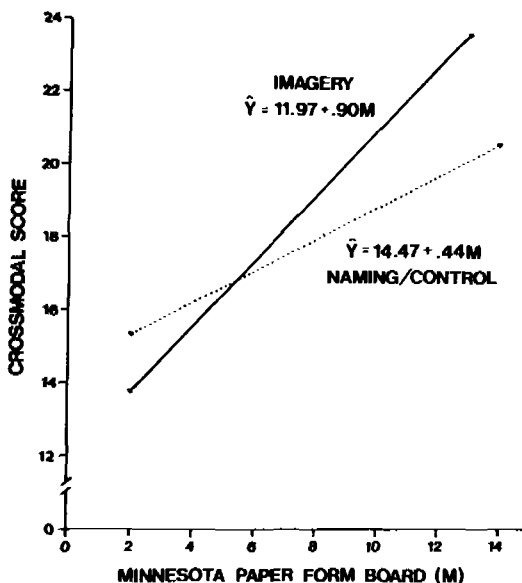


Figure 2. Experiment 1 imagery and combined naming/control condition regression equations showing the interaction of strategy instructions with visuospatial ability, as measured by the MPFB. The interaction is graphed only in the range of actual MPFB scores.

than for the combined naming/control conditions [$\hat{y} = 14.47 + .44(\text{MPFB})$], $t(113) = 1.72$, $p < .05$. Figure 2 shows the ability by strategy interaction, graphed in the region of actual MPFB scores. The crossover pattern illustrates that high visuospatial ability (MPFB) subjects benefitted from imagery instructions relative to naming/control instructions, but low visuospatial ability subjects actually performed worse under imagery instructions than they did under other instructions. An analogous test showed that verbal referential ability did not interact with instructions; that is, the slope for the combined naming/control equation [$\hat{y} = 8.64 + .06(\text{Verbal})$] was not significantly steeper than that for the imagery condition [$\hat{y} = 10.13 + .05(\text{Verbal})$].

To summarize Experiment 1, strategy instructions elicited the two distinct cognitive strategies suggested by the original dual coding analysis of the tactual-to-visual crossmodal recognition task. Children in the imagery condition apparently used a visual imagery strategy that drew on visuospatial ability. Children in the naming condition used a naming strategy that relied on verbal referential skill. Children in the control condition appear to have implemented a covert naming strategy that relied on the same ability used by naming subjects. Overall, imagery instructions did not improve crossmodal accuracy relative to naming/control instructions because visuospatial ability interacted with strategy instructions. Naming instructions did not enhance crossmodal accuracy relative to control instructions because control children spontaneously used a similar naming strategy.

EXPERIMENT 2

Our main objective in Experiment 2 was to replicate the results of Experiment 1 with the principal difference that we included only one measure for each ability

construct (MPFB for visuospatial ability and PPVT-R for verbal referential). Our choice of the PPVT-R was based on a supplementary analysis of Experiment 1 in which the PPVT-R demonstrated essentially equivalent results to those for the verbal aggregate measure. We reasoned that if the ability-strategy relations identified in Experiment 1 were robust, they should be revealed by the MPFB and PPVT-R in Experiment 2. A secondary objective of Experiment 2 was to determine whether recognition performance was dependent on the quality of overt names used by the children.

Method

Subjects: The subjects were 65 English-speaking children (38 girls, 27 boys) from two London, Ontario, public schools that were not included in Experiment 1. The 32 Kindergarten and 33 Grade 1 subjects ranged in age from 4 years, 11 months, to 6 years, 9 months ($M = 5$ years, 10 months).

Procedure: Experiment 2 exactly replicated Experiment 1 in all but two aspects: (a) Subjects completed only the MPFB and the PPVT-R ability tests; and (b) subjects' overt naming responses were recorded verbatim during the crossmodal task. All other aspects of the ability testing, assignment to conditions, and crossmodal task remained the same as in Experiment 1.

Name Quality: To provide an estimate of name quality, 10 adult volunteers matched the stimulus shapes to names that had been used for the shapes by children in a pilot study. A name was categorized as a good name if at least 5 of the 10 adults matched it to the shape for which it had originally been used. The number of good names used by each child in Experiment 2 was then determined.

Results and Discussion

Descriptive statistics and correlations for the Experiment 2 predictor variables and dependent measures are shown in the lower portion of Table 1. Following assignment to strategy conditions, there were no significant differences among the three groups on age, MPFB scores, or PPVT-R scores.

Effects of Strategy Instructions and Ability Variables: Analysis of variance with the ability variables omitted again revealed no significant main effect of strategy instructions on crossmodal recognition accuracy, although instructions affected overt naming $F(2, 62) = 22.40, p < .001$. As in Experiment 1, naming subjects gave significantly more names ($M = 19.50$) than imagery ($M = 3.91$), or control subjects ($M = 12.57$). Unlike Experiment 1, however, control subjects used significantly more labels than imagery subjects, consistent with the suggestion that control subjects tend to adopt a naming strategy.

The lower portion of Table 2 presents the results of the within-condition regression analyses. In the imagery condition analysis, MPFB visuospatial ability again provided a significant increment (14% of the variance) to prediction of crossmodal accuracy at the second regression step, $F(1, 19) = 7.51, p < .05$. This improvement attributable to MPFB scores occurred despite the much larger initial contribution of age to imagery condition performance in Experiment 2 than in Experiment 1. MPFB again added uniquely (9% of the variance) to the prediction of imagery condition performance even after age and PPVT-R scores were forced to enter, $F(1, 18) = 4.98, p < .05$.

As in Experiment 1, naming condition crossmodal performance was associated

with verbal referential ability (PPVT-R), but not with visuospatial ability (MPFB). The PPVT-R accounted for an additional 23% of the variance when it entered at the second regression step, $F(1, 19) = 8.15, p < .05$. When entered after both age and the MPFB, the PPVT-R still uniquely accounted for 21% of the total variance, $F(1, 18) = 7.09, p < .05$.

Control group performance correlated more highly with the PPVT-R (.57) than with the MPFB (.30); but, unlike Experiment 1, PPVT-R ability did not predict cross-modal performance after the significant effect of age, $F(1, 19) = 12.80, p < .01$, was statistically removed. As in Experiment 1, MPFB scores did not affect control condition performance once age was taken into account.

The distinct ability-performance relations for the imagery and naming strategies were again evident across conditions, where the pattern of standardized regression coefficients in Experiment 2 (see Table 2) replicated that for Experiment 1. The MPFB again showed larger beta weights in the imagery equation (.333) than in the naming (.045) and control equations (.018). The PPVT-R also had a larger weight in the naming (.620) and control equations (.260) than in the imagery equation (.225).

Supplementary tests revealed that age was more highly correlated with crossmodal performance in Experiment 2 than in Experiment 1 for both the imagery, $z = 2.87$, and control conditions, $z = 1.65, p < .05$. Since Experiment 2 children averaged 7 months younger than those in Experiment 1, these results could reflect a larger actual contribution of age to the performance of younger children, or could be the result of sampling differences between the two experiments.

Tests for Ability-Strategy Interactions. The interaction results replicated those from Experiment 1. Regression slopes in the naming and control conditions did not differ significantly for the MPFB or PPVT-R ability measures. MPFB visuospatial ability again interacted with instructions, as reflected by the steeper slope in the imagery equation [$\hat{y} = 2.92 + 1.62(\text{MPFB})$] than in the combined naming/control equation [$\hat{y} = 12.57 + .52(\text{MPFB})$], $t(59) = 1.90, p < .05$. The PPVT-R regression slopes for the combined naming/control equation [$\hat{y} = 2.85 + .18(\text{PPVT-R})$] and the imagery equation [$\hat{y} = -4.36 + .24(\text{PPVT-R})$] did not differ significantly.

Name Quality. The number of good names used by children varied as a function of strategy condition, $F(2, 62) = 23.04, p < .001$. Naming ($M = 9.91$) and control ($M = 7.38$) subjects used significantly more good names than did imagery ($M = 1.91$) subjects. Naming and control subjects did not differ significantly.

Due to the small number of names used by imagery subjects, an additional analysis focussed only on the naming and control subjects. To determine whether the use of good names was an important component of the relation between PPVT-R ability and crossmodal performance, partial correlations were computed. With the effect of good names partialled out, the correlation between PPVT-R ability and crossmodal scores changed minimally for the naming subjects (.67 to .62) and substantially for the control subjects (.55 to .35).

GENERAL DISCUSSION

The overall pattern of ability-performance relations in Experiments 1 and 2 is consistent with the original dual coding analysis of the tactual-to-visual crossmodal

recognition task. Imagery instructions induced children to implement a visual imagery strategy that depended primarily on visuospatial ability, whereas naming instructions promoted use of a naming strategy that depended relatively more on verbal referential ability. When children were given no specific instructions on how to perform the crossmodal task, they apparently used a verbal/naming strategy similar to that used by naming subjects. The pattern of results is more difficult to reconcile with an alternative class of cognitive models which assume that verbal and nonverbal information are ultimately transformed into abstract, amodal (e.g., propositional) representations (cf. the contrast drawn and tested by MacLeod et al., 1978).

The MPFB, a visuospatial ability measure, was the major ability correlate of imagery condition crossmodal performance in both experiments, but it did not predict naming or control group performance. This strong relation between the MPFB and imagery condition recognition accuracy is particularly notable and nontrivial in light of frequently reported failures to find correlations between visuospatial ability scores and tasks presumed to require visual imagery (Ernst, 1977; Katz, 1983; Paivio, 1971, 1986; Slee, 1980).

In both experiments, the mean crossmodal accuracy of children instructed to use imagery was no better than that of children given naming or control instructions. This result, however, does not indicate that the imagery subjects ignored instructions. Rather, it reflects the interaction between visuospatial ability and instructions, whereby imagery instructions improved crossmodal recognition performance only for those children who were high in the visuospatial ability measured by the MPFB. Imagery instructions hindered the crossmodal performance of children who were low in visuospatial skill.

Visuospatial tests such as the MPFB may measure skill in a variety of component processes, including generation of accurate representational images, maintenance of images in short-term memory, and mental transformation of images (Katz, 1987; Paivio, 1986). Children's initial success in applying an imagery strategy in crossmodal recognition may depend especially on the development of image maintenance and transformation processes. These components appear more critical to performance on the MPFB than on the PMA-SR (K-1), a putative visuospatial measure that shared little variance with the MPFB. Further study of individual differences in visuospatial ability, particularly via the techniques of componential analysis (Katz, 1987; Pellegrino & Goldman, 1983), should improve our understanding of the developmental transition into proficient use of imagery memory strategies.

In line with the dual coding task analysis, verbal referential ability was a consistent correlate of crossmodal performance in the naming, but not the imagery, conditions in both experiments, suggesting that effective use of a naming strategy depended on abilities distinct from those needed to apply an imagery strategy. Naming instructions did not improve overall recognition relative to no-strategy control instructions. This result is not surprising if, as we suggest below, control subjects were already employing a covert naming strategy. Under instructions to name, children may simply have said aloud the names they would otherwise have used covertly.

The bulk of the evidence from both experiments supports the interpretation that

control children spontaneously used a strategy, sometimes involving covert naming, that was similar to that of the naming subjects and distinct from that of the imagery subjects. In Experiment 1, comparisons of regression coefficients within and between groups showed that verbal referential ability predicted performance in both the control and naming conditions, but not in the imagery condition. Visuospatial ability, on the other hand, did not predict crossmodal accuracy in either the control or naming conditions, but did so in the imagery condition. Also, the relatively high number of overt labels used by the control children in Experiment 2 supported the view that they spontaneously applied a naming strategy. The single result that was inconsistent with this interpretation was that the PPVT-R did not contribute uniquely to prediction of control performance in Experiment 2 after the effects of age were statistically removed.

Spontaneous use of a naming strategy by young children has also been observed in other recognition memory tasks involving familiar stimuli (Mowbray & Luria, 1973; Perlmutter & Myers, 1976). From a dual coding perspective, uninstructed subjects would not always be expected to choose a naming strategy for crossmodal recognition. With amorphous stimuli, an imagery strategy would be the expected choice. Taken together, our results with familiar, relatively nameable shapes and those of Ford (1973) and Stoltz-Loike and Bornstein (1987) with unfamiliar, less nameable shapes support this expectation.

From a dual coding perspective, verbal referential ability involves bidirectional mental translation between the nonverbal and verbal representational subsystems. How did proficiency in representational translation influence crossmodal recognition in the naming and control conditions? One possibility we considered in Experiment 2 was that high referential ability subjects used more discriminating labels for the target shapes than did low referential ability subjects. Name quality appeared to be an important component of the relation between verbal referential ability and crossmodal success in the control condition, but not in the naming condition. It may be that specific instructions to name the stimuli increased children's reliance on components of verbal referential skill that were not directly reflected in overt name quality. These additional components might include covert verbal elaboration of specific stimulus characteristics and/or proficient decoding of names to visual images for comparison during recognition.

In conclusion, these studies demonstrate that different abilities underlie children's success in implementing imagery and naming strategies in a tactual-to-visual recognition memory task. The cognitive performance of children who lack the prerequisite abilities may not benefit and may even be harmed by the requirement to use a specific strategy. In particular, imagery strategies require visuospatial abilities, such as those measured by tests like the MPFB, and naming strategies require verbal abilities, such as those measured by the PPVT-R and the EOWPVT. The observed matches between visuospatial abilities and imagery strategies and between verbal abilities and naming strategies are consistent with the dual coding emphasis on distinct imaginal and verbal representational systems. Similar results have been obtained in other cognitive tasks (e.g., mental comparisons, language comprehension; Paivio, 1986) in which dual coding theory predicts specific relations between imaginal or verbal strategies and their corresponding abilities.

REFERENCES

- Cohen, J., & Cohen, P. (1983). *Applied multiple regression/correlation analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
- Cronbach, L.J., & Snow, R.E. (1977). *Aptitudes and instructional methods*. New York: Irvington.
- Dunn, L., & Dunn, L. (1981). Peabody picture vocabulary test — revised. Circle Pines, MN: American Guidance Service.
- Ernest, C.H. (1977). Imagery ability and cognition: A critical review. *Journal of Mental Imagery*, *2*, 181-216.
- Flavell, J.H. (1985). *Cognitive development* (2nd ed.). Englewood Cliffs, NJ: Prentice-Hall.
- Ford, M.P. (1973). Imagery and verbalization as mediators in tactual-visual information processing. *Perceptual & Motor Skills*, *36*, 815-822.
- Forisha, B. (1975). Mental imagery verbal processes: A developmental study. *Developmental Psychology*, *11*, 259-267.
- Gardner, M.F. (1979). *Expressive one-word picture vocabulary test*. Novato, CA: Academic Therapy Publications.
- Gibson, C., & Bryden, M.P. (1983). Dichaptic recognition of shapes and letters in children. *Canadian Journal of Psychology*, *37*, 132-143.
- Guilford, J.P. (1967). *The nature of human intelligence*. New York: McGraw-Hill.
- Johnson, E.S., & Meade, A.C. (1987). Developmental patterns of spatial ability: An early sex difference. *Child Development*, *58*, 725-740.
- Kamhi, A., Catts, H., Koenig, L., & Lewis, B. (1984). Hypothesis-testing and nonlinguistic symbolic abilities in language-impaired children. *Journal of Speech & Hearing Disorders*, *49*, 169-176.
- Katz, A.N. (1983). What does it mean to be a high imager? In J.C. Yuille (Ed.), *Imagery, memory and cognition: Essays in honor of Allan Paivio* (pp. 39-63). Hillsdale, NJ: Erlbaum.
- Katz, A.N. (1987). Individual differences in the control of imagery processing: Knowing how, knowing when, and knowing self. In M. McDaniel & M. Pressley (Eds.), *Imagery and related mnemonic processes: Theories, individual differences, and applications* (pp. 177-217). New York: Springer-Verlag.
- Klatzky, R.L., Lederman, S., & Reed, C. (1987). There's more to touch than meets the eye: The saliency of object attributes with and without vision. *Journal of Experimental Psychology: General*, *116*, 356-369.
- Laurendeau, M., & Pinard, A. (1970). *The development of the concept of space in the child*. New York: International Universities Press.
- Lenhart, R.E., & Schwartz, S.M. (1983). Tactile perception and the right hemisphere: A masculine superiority for imagery coding. *Brain & Cognition*, *2*, 224-232.
- Likert, R., & Quasha, W. (1941). *Revised Minnesota paper form board test (Series AA)*. New York: The Psychological Corporation.
- London, P., & Robinson, J.P. (1968). Imagination in learning and retention. *Child Development*, *39*, 803-815.
- MacLeod, C.M., Hunt, E.B., & Mathews, N.N. (1978). Individual differences in the verification of sentence-picture relationships. *Journal of Verbal Learning & Verbal Behavior*, *17*, 493-507.
- Mowbray, C., & Luria, Z. (1973). Effects of labelling on children's visual imagery. *Developmental Psychology*, *9*, 1-8.
- Paivio, A. (1971). *Imagery and verbal processes*. New York: Holt, Rinehart, & Winston.
- Paivio, A. (1976). Imagery in recall and recognition. In J. Brown (Ed.), *Recall and recognition* (pp. 103-129). New York: Wiley.
- Paivio, A. (1986). *Mental representations: A dual coding approach*. New York: Oxford University Press.
- Paivio, A., & Cohen, M. (1979). Eidetic imagery and cognitive abilities. *Journal of Mental Imagery*, *3*, 53-64.
- Pellegrino, J.W., & Goldman, S.R. (1983). Developmental and individual differences in verbal and spatial reasoning. In R.F. Dillon & R.S. Schmeck (Eds.), *Individual differences in cognition* (Vol. 1, pp. 137-180). New York: Academic Press.
- Perlmutter, M., & Myers, N. (1976). Recognition memory in preschool children. *Developmental Psychology*, *12*, 271-272.
- Piaget, J., & Inhelder, B. (1956). *The child's conception of space*. London: Routledge & Kegan Paul.
- Pressley, M., Borkowski, J., & Johnson, C.J. (1987). The development of good strategy use: Imagery

- and related mnemonic strategies. In M. McDaniel & M. Pressley (Eds.), *Imagery and related mnemonic processes: Theories, individual differences, and applications* (pp. 274-297). New York: Springer-Verlag.
- Pressley, M., Heisel, B., McCormick, C., & Nakamura, G. (1982). Memory strategy instruction with children. In C.J. Brainerd & M. Pressley (Eds.), *Verbal processes in children: Progress in cognitive development research* (pp. 125-159). New York: Springer-Verlag.
- Robinson, J.P., & London, P. (1971). Labelling and imaging as aids to memory. *Child Development*, *42*, 641-644.
- Rushton, J.P., Brainerd, C.J., & Pressley, M. (1983). Behavioral development and construct validity: The principle of aggregation. *Psychological Bulletin*, *94*, 18-38.
- Slee, J.A. (1980). Individual differences in visual imagery ability and the retrieval of visual appearances. *Journal of Mental Imagery*, *4*, 93-113.
- Smith, M.L., & Glass, G.V. (1987). *Research and evaluation in education and the social sciences*. Englewood Cliffs, NJ: Prentice-Hall.
- Snow, R.E. (1989). Aptitude-treatment interaction as a framework for research on individual differences in learning. In P.L. Ackerman, R.J. Sternberg, & R. Glaser (Eds.), *Learning and individual differences: Advances in theory and research* (pp. 13-59). New York: W.H. Freeman & Co.
- Sternberg, R.J., & Weil, E.M. (1980). An aptitude \times strategy interaction in linear syllogistic reasoning. *Journal of Educational Psychology*, *72*, 226-239.
- Stoltz-Loike, M., & Bornstein, M. (1987). The roles of imagery, language, and metamemory in cross-modal transfer in children. *Psychological Research*, *49*, 63-68.
- Thurstone, L., & Thurstone, T. (1965). *Primary mental abilities tests*. Chicago, IL: Science Research Associates.
- Waters, H., & Andreassen, C. (1983). Children's use of memory strategies under instruction. In M. Pressley & J. Levin (Eds.), *Cognitive strategy research: Psychological foundations* (pp. 3-24). New York: Springer-Verlag.
- Witelson, S. (1974). Hemispheric specialization for linguistic and nonlinguistic tactual perception using a dichotomous stimulation technique. *Cortex*, *10*, 3-17.

Received 13 October 1988

Accepted 4 January 1989.