JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1984, 42, 1-18 NUMBER 1 (JULY)

CODING RESPONSES AND THE GENERALIZATION OF MATCHING TO SAMPLE IN CHILDREN

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Two experiments studied the conditions of stimulus control necessary for the generalization of relational matching to sample. Matching required the selection of comparison shapes rotated 90° clockwise from the orientation of the corresponding sample. In Experiment 1, five children were taught to: (a) code the orientations of samples, (b) transform sample codings to account for the 90° rotation, and (c) repeat the transformed sample coding response to a comparison. High levels of generalization occurred with a set of novel stimuli for which stable sample-coding responses were initially available. In another novel set, where stable sample-coding responses were not initially available, low levels of generalized matching were recorded. Matching performance improved after stable coding responses were trained. In Experiment 2, two children and three adults were trained in a form of the matching task that produced poor generalization despite the presence of stable sample-coding responses. Retraining to modify the stimulus control exerted by these coding responses produced an immediate improvement in generalized matching to sample. Results suggest that the generalization of matching is dependent on the structure of stimulus control that the component responses exert on each other.

Key words: matching to sample, generalization, stimulus control, coding responses, children

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In a relational matching-to-sample task a constant relation, such as oddity or identity, exists between each sample and the correct comparison. The generalization of relational matching is demonstrated by maintenance of the trained relation with novel stimuli. Typically, demonstrations of generalized relational matching have been accounted for in terms of the operation of cognitive constructs such as concepts of identity (Farthing & Opuda, 1974; Zentall, Edwards, Moore, & Hogan, 1981; Zentall & Hogan, 1978) or of applications of a rule (Bucher, 1975).

Inferred constructs, like rules or concepts, are used to explain behavior when the environmental antecedents cannot be specified. In order to identify the antecedents of generalized relational matching to sample, the present research developed a set of overt responses capable of mediating generalized matching, and then demonstrated the dependence of generalization on these mediators. Finally, data were collected to see if these overt mediators might be the precursors of covert forms of mediation.

One type of generalized identity matching can be described by the response-mediation model suggested by Cumming, Berryman, and Cohen (1965) (panel A, Figure 1). Their model accounts for generalized matching to sample only as a result of generalization along the physical dimensions of the stimuli. Generalization is independent of any constant relation between samples and comparisons. As a result, the model accounts equally well for generalization in the

I would like to thank Marie Harvey, Director of the Anna Bing Arnold Children Center, and Joan Ross, Lead Teacher, for their unfailing help and cooperation in coordinating the participation of the children in this research. I would also like to thank William Bernhardt, James Brunner, Patricia Comerford, Ann Kelley, and Alison Stanley for their help in the laboratory, especially in observing and recording data. I am indebted to David Weiss, William Buskist, and Carole Zuckerman for their helpful comments on an earlier version of the manuscript. Reprints may be obtained from Barry Lowenkron, Department of Psychology, California State University, Los Angeles, Los Angeles, California 90032.

symbolic-matching task, where no constant sample-comparison relation, like identity, may exist (Eckerman, 1970).

In this model a specific coding response is made to each sample, as in pressing different keys when presented with different levels of sample brightness (Parsons, Taylor, & Joyce, 1981) or pecking the sample key at different rates in the presence of different sample colors (Cohen, Brady, & Lowry, 1981). All comparisons are responded to with a single, common response such as a button press or a key peck. Thus, in the presence of Sample 1 (SA1), a coding response (CR1) unique to that sample is emitted. Performance of CR1 in turn produces the unique cue S1. As a result, on each trial the comparison selection response (R) is controlled by an arbitrarily composed stimulus compound comprised of the appropriate comparison stimulus (CO1) and S1 (Paul, 1983). The stimulus compound is arbitrarily composed because its two elements (S1 and CO1) share no common, distinguishing properties—either physically or in the existing contingencies of reinforcement. Since CO1 and S1 bear only an arbitrary relation to each other, the identity relation between SA1 and CO1 is not represented in the structure of stimulus control over R. The model thus treats a relational matching task as nonrelational, symbolic matching. Generalization of relational matching with specific combinations of novel comparison and sample stimuli can be predicted only to the extent that CR1 generalizes to novel samples and then only if the comparison stimulus set is appropriately constituted (Cumming et al., 1965).

A model that does incorporate the sample-comparison relation is illustrated in panel B of Figure 1. Here a consistent, rather than arbitrary, relation between CO1 and S1 controls identity matching. There is no common response to all comparisons. Rather, (a) comparison stimuli are responded to by repeating the sample-coding response made on that trial, and (b) the same coding response is made for any particular stimulus whether it is a sample or a comparison.

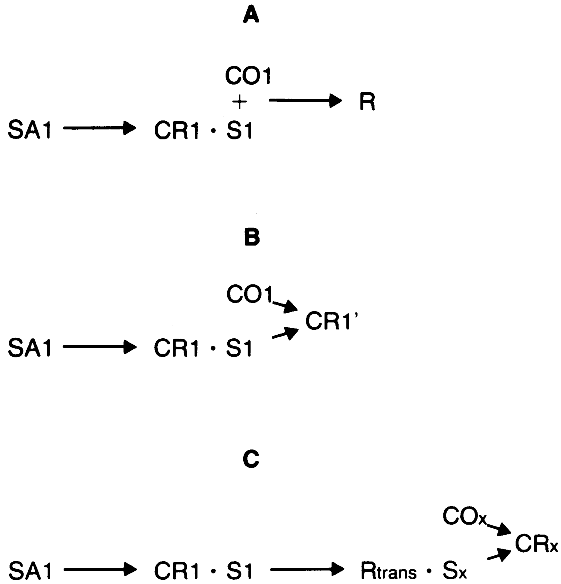

Fig. 1. Three coding-response models of matching to sample.

Repetition of the sample-coding response requires that each response generate a unique cue (S1), which specifies which coding response to repeat. Convergently, the constraint to make the *same* coding response to a particular stimulus, regardless of whether it is a sample or a comparison, limits the comparison stimulus to which CR1′ can be made to only the one that matches the sample. There exists in this case a consistent, rather than an arbitrary, relation between a comparison stimulus and S1. They exert joint discriminative control over the same comparison-coding response. This pattern of behavior intrinsically represents the identity relation in its structure of stimulus control. If repetition of coding responses generalizes, it should produce generalized relational matching with all novel stimuli for which stable sample-coding responses are available—either as a result of training or through generalization from other stimuli.

In a similar fashion, if the pattern of stimulus control were altered so that subjects were taught not to repeat the sample-coding response to S1, oddity matching would result.

In the present research with children, a type of matching more complex than simple identity or oddity was studied in order to eliminate the effects of informal pre-experimental training. Reinforcers were delivered when children selected, from a set of four alternatives, the comparison shape that was rotated 90° clockwise from the orientation of the sample.

A model is shown in panel C of Figure 1. Given Sample 1, children code the orientation of the sample (CR1), and transform (Rtrans) the resultant cue (S1) in a way that corresponds to an orientation 90° clockwise (Sx) from that which controlled the sample-coding response. They then select a comparison stimulus (COx) by making the comparison-coding (CRx) at that stimulus. The response (CRx) is not a duplicate of CR1, but rather, being under the control of Sx, is appropriate for a comparison rotated 90° clockwise from the orientation of the sample. Again, there is a consistent relation between Sx and COx; they are discriminative stimuli for the same comparison-coding response. And again, generalization of matching is expected wherever stable sample-coding responses are available.

EXPERIMENT 1

METHOD

Subjects

Five children from the university day care center participated. All were between 3.5 and 5.5 years old.

Stimuli

Shapes. As illustrated in panel A of Figure 2, three sets of shapes were used. In the training set all shapes were bilaterally symmetrical. In Transfer Set 1 three of the four shapes were symmetrical—Shape 4 was asymmetrical. In Transfer Set 2 only shape 4 was symmetrical.

During various stages of training each shape was presented as a single black figure either cut out from thin cardboard, or projected from a 35 mm slide. Cutouts were 3 in. (7.7 cm) on their longest side. When projected, overall image size was approximately 10 by 15 in. (26 by 38 cm) with shapes averaging about 3 in. (7.7 cm) on their longest side.

Training media. To train sample-coding responses a 3 by 5-in. (7.7 by 12.8-cm) card, with a 3-in. (7.7-cm) arrow (the arrow card), served as a means for subjects to indicate the orientation of shapes (panel B, Figure 2). The tip of the arrow touched a 3-in. side of the card.

In addition, a series of 3-in. arrows (the arrow-fading series) was drawn, with successive arrows diminishing in completeness, on six separate 8 by 8-in. (20.5 by 20.5-cm) cards. The tips of the arrows were at the center of each card. Panel D illustrates this series with the cutout of Shape 2 placed as for training.

To teach clockwise rotation, a series of 3 by 5-in. arrow cards was prepared with a small black tab on the upper right side of each card. The tabs were diminished to a black line on the fifth step and eliminated on the sixth step. These cards were used in coordination with a series of 11 by 11-in. (28.1 by 28.1-cm) background cards marked with 1-in. (2.5-cm) lines at 0, 90, 180, and 270 degrees. The lines were reduced to a dot on the third step and eliminated on the fourth step. Panel E of Figure 2 illustrates both of these series, with the arrow card placed on the background card for training.

Finally, to teach discriminations between orientations of the shapes in Transfer Sets 1 and 2, pairs of 3 by 3-in. (7.7 by 7.7-cm) cards were prepared for each of these eight shapes. The cards had individual shapes drawn in solid black. Shapes were 7.0 cm on their longest side.

On the 35 mm slides used in various parts of training, the shape serving as the sample always appeared at the center, either alone or with one or more comparison orientations of that shape at the corners.

Training- and transfer-set series. The series of 35 mm slides used to maintain behavior in the training set (the training-set series), and to measure generalization to Transfer Sets 1 and 2, were each composed of 12 simultaneous matching trials. On each trial, comparisons appeared in four different orientations, one in each corner. The same shape in the center served as the sample (panel B, Figure 2). In each series of slides, each of the four shapes appeared in three nonconsecutive trials. The orientations of samples and the locations of correct comparisons were counterbalanced across shapes and corners, respectively.

Setting

A small room was used. Chairs for observers were located behind the child, who faced a projection screen installed in one wall of the room. Images were rear-projected on the screen from a separate room. Operation of the projectors was inaudible. To the child's left was a low table for all training tasks involving the use of the cards and cutout shapes. In the latter phases of the experiment, a video camera was located in the room directly behind the child.

Contingencies of Reinforcement

All correct responses during training were followed by a 2-s tone and presentation of a token. After varying numbers of correct responses (variable-ratio 15), children could trade tokens for either small toys or edible reinforcers taken from a constantly visible display on the table. On different days the display contained either toys or snacks, depending on what the child requested that day. Incorrect responses were followed by no tone or token and the word "no" spoken by the experimenter.

Procedure

Training and testing were administered twice weekly in 45-min sessions. Training was administered continuously throughout each session with breaks only for the presentation of earned reinforcers or when the child asked to stop. No interludes were permitted during test sequences. Behavior during training was recorded on prepared forms by a single observer sitting behind the child and the experimenter. Some tests of generalization were recorded by two independent observers for an assessment of recording reliability.

Training was designed to produce three component responses (panel B, Figure 2). They were (a) sample coding—coding the initial orientation of the sample by placing the 3 by 5-in. arrow card in the appropriate orientation, (b) orientation rotation—transforming the sample coding by rotating the arrow card 90° clockwise, and (c) comparison coding—placing the arrow card adjacent to one of the comparison figures so as to repeat the sample coding.

Sample coding. Coding responses were taught separately for each of the four shapes of the training set (panel C, Figure 2). Reviews of all previously taught shapes were given at the beginning of each daily session and before starting training with a new shape. The training procedure was later repeated with the shapes of Transfer Set 2.

At the beginning, the first 8 by 8-in. card of the arrow-fading series (panel D) was placed alone on the table. Children were taught by demonstration and prompting to place their arrow card on top of the fading-series card as the latter was turned to orientations of 0, 90, 180, and 270 degrees. After four consecutive correct placements, the cutout of Shape 1 of the training set was placed on the arrow-fading series card—with the arrow along the shape's axis of symmetry. Such a placement is shown for Shape 2 in panel D. Reinforcement continued for subjects' placements of their arrow card on top of the fading-series arrow, as it was turned with the shape to all four orientations. After every four consecutive correct responses on a fading step, one in each orientation, training proceeded by moving to the next card in the arrow-fading series.

When subjects completed the final fading step in the series, they could position their arrow card along the axis of symmetry of the cutout shape on a blank background. Variations in the distance of the arrow card from the figure were disregarded so long as it was placed on the axis in the correct direction. Following a review of one trial in each orientation, with each previously trained shape, the training procedure was repeated with the next shape.

After the above training was completed,

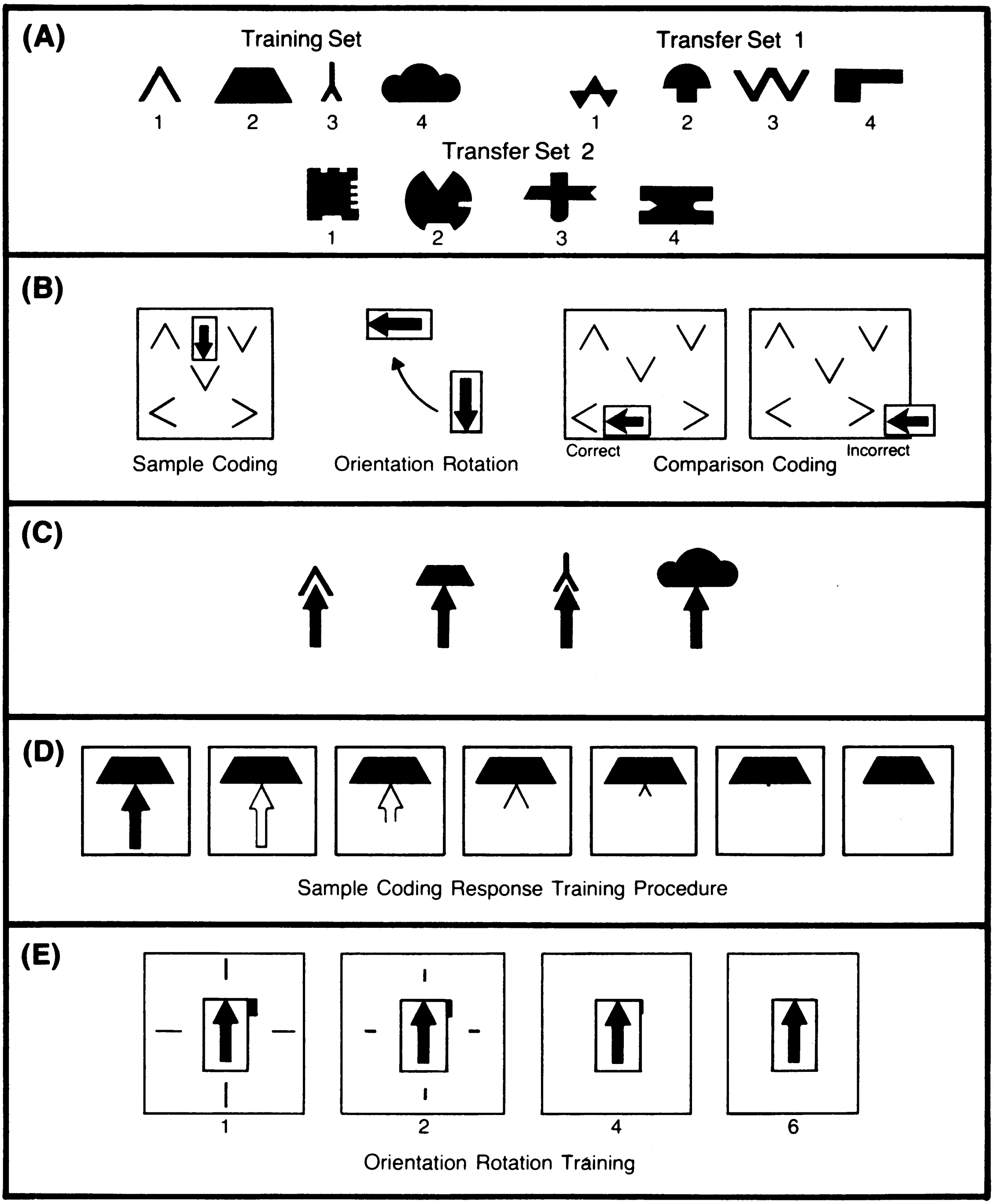

Fig. 2. Stimulus sets and training procedures. (A) Stimulus sets used in training (the training set) and generalization (Transfer Sets 1 and 2). (B) The three component responses: sample coding, rotation of the arrow card, and comparison coding. Both a correct comparison coding, which is a repetition of the sample coding, and an incorrect comparison coding are shown. (C) Sample-coding responses for the training set. (D) The arrow-fading series to train sample coding shown with a cutout of Shape 2. Subject placed the arrow card over the illustrated arrow. (E) Arrow cards, with black tabs, on the background cards.

all shapes were presented in a final review. The criterion was two successive correct placements of the arrow card with each cutout shape in each orientation. Any failures were followed by a repetition of the last fading step with shapes on which errors were made.

In the next step of training the shapes were projected, in interspersed order, at the center of the screen. Subjects were prompted ("Where does it go?") to place their arrow card in the appropriate orientation next to the projected shape. Training continued to a criterion of 16 consecutive correct trials, one with each shape in each orientation.

Next, the comparison shapes were added, one after every fourth trial, to the corners of the screen. Any coding responses to them, rather than to the samples, were followed by a verbal "no," a 5-s blackout of the display, and a repetition of the trial. Training ended after correct sample codings were made on four consecutive trials, one with each shape, with all four comparisons present.

Comparison coding. A comparison shape was presented in one corner of the screen. The subject was handed the arrow card in an orientation appropriate for the orientation of the comparison as defined in sample-coding training. The prompt "Where is it?" was given, and reinforcement was contingent upon the subject's placing the arrow card adjacent to the comparison shape without changing the card's orientation. Following four successive correct trials, one to each of the shapes in a different corner, trials with two comparisons were presented. Here the subject had to select the correct comparison based on the orientation of the arrow card as it was handed. Any attempts by the subject to rotate the orientation of the arrow card were followed by an immediate "no," a 5-s blackout, and a return of the arrow card to its initial orientation while it was still in the subject's hand. Incorrect comparison selections were followed by the "no" and the 5-s blackout.

After eight successive correct trials with two comparisons, the number of comparisons was increased to three, and after eight more successively correct, to four. The verbal prompt was then omitted over an increasing proportion of trials. A final criterion of two correct selections, with each shape in each of the four orientations, was met with no prompting.

Orientation-rotation training. Children were taught the relevant transformation, rotating the arrow card 90° clockwise, in a series of fading steps (panel E, Figure 2). The first arrow card of the training series was placed on the first card of the series of 11 by 11-in. background cards marked with the beginning and end points of a 90° rotation. The black tab on the arrow card and the 90° rotation marks on the background card were pointed out to the children and the behavior of turning the arrow card clockwise, to the next rotation mark, from any initial placement on the background card was demonstrated. The prompt "How do you turn it?" was used on each trial.

After every four consecutive correct trials, the tab and rotation marks were faded out by successive steps until the child rotated the arrow card in the correct direction and amount without these supplementary cues (Step 6). After each error, the tabs and marks were pointed out and the behavior was demonstrated again.

One subject (JT) failed to meet the Step-5 criterion after two sessions of training at Step 4. Fading was terminated and the Step 4 tab was left on the upper right corner of the arrow card for the remainder of training and testing with this subject.

After training with cards was completed, each shape was projected alone in the center of the screen. Children were prompted ("Where does it go?") to code the orientations of these samples with their arrow card, and then transform ("How do you turn it?") the sample coding by rotating the arrow 90° clockwise. Over trials the verbal prompts were gradually eliminated, by increasing the proportion of trials on which they were omitted, until the response was performed correctly with no prompts in 16 consecutive trials.

Final training. To integrate the three component responses, a final series was presented. In the first phase, trials began with the sample projected alone on the screen. After a correct sample coding and rotation, the comparisons were added and the verbal prompt "Where is it?" was given. Selections of the correct comparison shapes were reinforced. Errors in sample coding or in rotation produced an immediate 5-s blackout of the display and a verbal "no" from the experimenter. Any changes in the orientation of the arrow card after a correct rotation were manually prevented by the experimenter reaching over, returning the card to its prior position, and saying "no," but allowing the trial to continue.

After six successive correct trials, comparisons were added immediately after a correct sample-coding response, but before rotation. After six more successive correct trials, samples and comparisons were introduced together by presenting the 12 simultaneous-matching slides of the training-set series. Training in this phase continued until the prompt could be eliminated and children completed 12 successive correct trials.

Following an error in any phase, two successive correct trials were required in the prior phase with prompts used as necessary to facilitate performance.

Training-set baseline. Practice continued with the training-set series to a criterion of 22 trials out of 24 in the first 48 trials of a daily session.

Transfer Set 1: Test for generalization. To ensure that children could initially discriminate different orientations of the shapes in Transfer Set 1, pairs of each shape were presented in different orientations on the 3 by 3-in. cards. Turning one card to match identically the orientation of the shape on the other was reinforced. Training continued to a criterion of eight successive correct trials with each of the shapes of Transfer Set 1.

Subsequently, the 12-trial training-set and Transfer Set 1 slide series were interspersed. The 24 slides were presented twice to provide a 48-trial test of generalization. All correct responses were reinforced in both training and transfer trials. Errors on training-set trials produced an immediate 5-s blackout and a verbal "no" followed by a repetition of the trial. Errors on Transfer Set 1 trials were followed only by omission of the reinforcer.

Coding-response prevention. In a subsequent session, performance with the training set was retested. Following 10 correct trials out of 12, the arrow card used by the subject was removed and the 48-trial test of generalization was repeated with no further instructions. All questions by children were answered by phrases such as "Where is it?" or "Where is the right answer?" Performance in this phase was recorded on video tape.

Transfer Set 2: Test for generalization. All procedures described for Transfer Set 1 were repeated with the shapes of Transfer Set 2.

Transfer Set 2: Retest for generalization. Sample-coding responses were trained for the shapes of Transfer Set 2 using the sample-coding procedure described for the training set. Then the Transfer Set 2 test for generalization was repeated.

RESULTS

Figure 3 summarizes performance in all three transfer tests. Where sample-coding responses were not trained to the shapes of Transfer Set 1 or 2, no particular responses could be designated in advance as correct. Because of this, generalization of sample coding was measured as the stability of responses to these stimuli. For each shape the stability of sample-coding behavior is reported in Figure 3 as the numbers of trials the arrow card was placed in each orientation. The orientations of the arrows in Figure 3 are in relation to the orientations of the shapes in Figure 2.

Thus, with Shapes 1, 2, and 3 of Transfer Set 1, Subject RU positioned the arrow in the same direction on all trials, relative to each shape's orientation. The arrow was always placed on the wide side of Shape 1, along the stem of the mushroom in Shape 2, and at the center peak of Shape 3. With asymmetrical Shape 4, the arrow was positioned against the short base of the figure on three trials and along the long axis on three trials.

Sample-coding behavior with the training-set stimuli is not reported because training trials did not continue until a correct sample-coding response had been made. In no case did more than two sample-coding errors occur with these stimuli during tests for generalization.

Figure 3 also describes arrow rotation, comparison coding, and matching in the 18 trials with the three symmetrical shapes, the 6 trials with the asymmetrical shape (Shape 4) of Transfer Set 1, and with the three asymmetrical and one symmetrical shape of Set 2.

On each trial an arrow rotation was recorded as correct if it was a 90° clockwise rotation, and as a direction error if it was rotated 90° counterclockwise. Any other behavior, including failure to rotate at all, was scored as incorrect. A comparison coding was scored as correct if it was a reproduction of the sample-coding response that began the trial (see panel B, Figure 2).

The last measure, matching, was partially redundant on the rotation and coding-response scorings: A correct rotation of the arrow, followed by a correct comparison coding (a reproduction of the sample coding), necessarily resulted in a correct match. It was entirely possible, however, for the subject to select the correct comparison without accurate mediating responses. Measures of reliability indicated interobserver agreement greater than 90%.

Transfer Set 1

Stable sample-coding responses appeared with the three symmetrical shapes of Transfer Set 1. In all cases the orientations of these samples were coded by a placement of the arrow along the shapes' axes of symmetry. (The variability exhibited by Subject XB with Shape 3 arose from placing the arrow on the axis in one direction on half of the trials, and in the opposite direction on the remaining trials.)

With the asymmetrical Shape 4 all subjects showed variability—placing the arrow in at least two different directions relative to the orientation of the shape.

Orientation rotation also generalized to Transfer Set 1. The single most frequent error was a direction error. Less frequently, a rotation of 180° or some other amount was made. For the most part errors were confined to a single stimulus. Thus, all errors by Subject SS were made with Shape 2. Subject KM made errors on all trials with Shape 3 and two direction errors with Shape 1. Subject JT made four of the six errors with Shape 3, and the remainder with Shape 1.

With Shape 4, three subjects maintained rotation accuracy. Subject JT did not rotate the arrow at all with this shape; Subject SS rotated it in varying directions and amounts.

Accurate comparison coding generalized to the three symmetrical stimuli. All inaccurate comparison selections by Subject SS were again confined to Shape 2. Similarly, KM made errors on all trials with Shape 3, with additional errors on five of the six trials with Shape 2.

With Shape 4, comparison-coding accuracy varied considerably. In some cases high levels were attained even when two or more sample codings were used for this shape. The accurate comparison coding by JT was accompanied by identity matching produced by omission of the rotation with this shape.

Overall, matching depended on generalization of the mediating behavior. Only Subject SS matched without accurate mediation. This occurred once with Shape 2 and twice with Shape 4.

Transfer Set 2

In the first test, stable sample coding was not observed with the three asymmetrical shapes. Rather, in some cases, response stereotypy was observed. Subject KM placed the arrow pointed down, and Subjects XB and RU placed it pointed up, on no less than 14 trials—regardless of the orientation of the sample. Although Shape 4 in this set was symmetrical, only XB and SS made the same sample-coding responses on at least five of six trials.

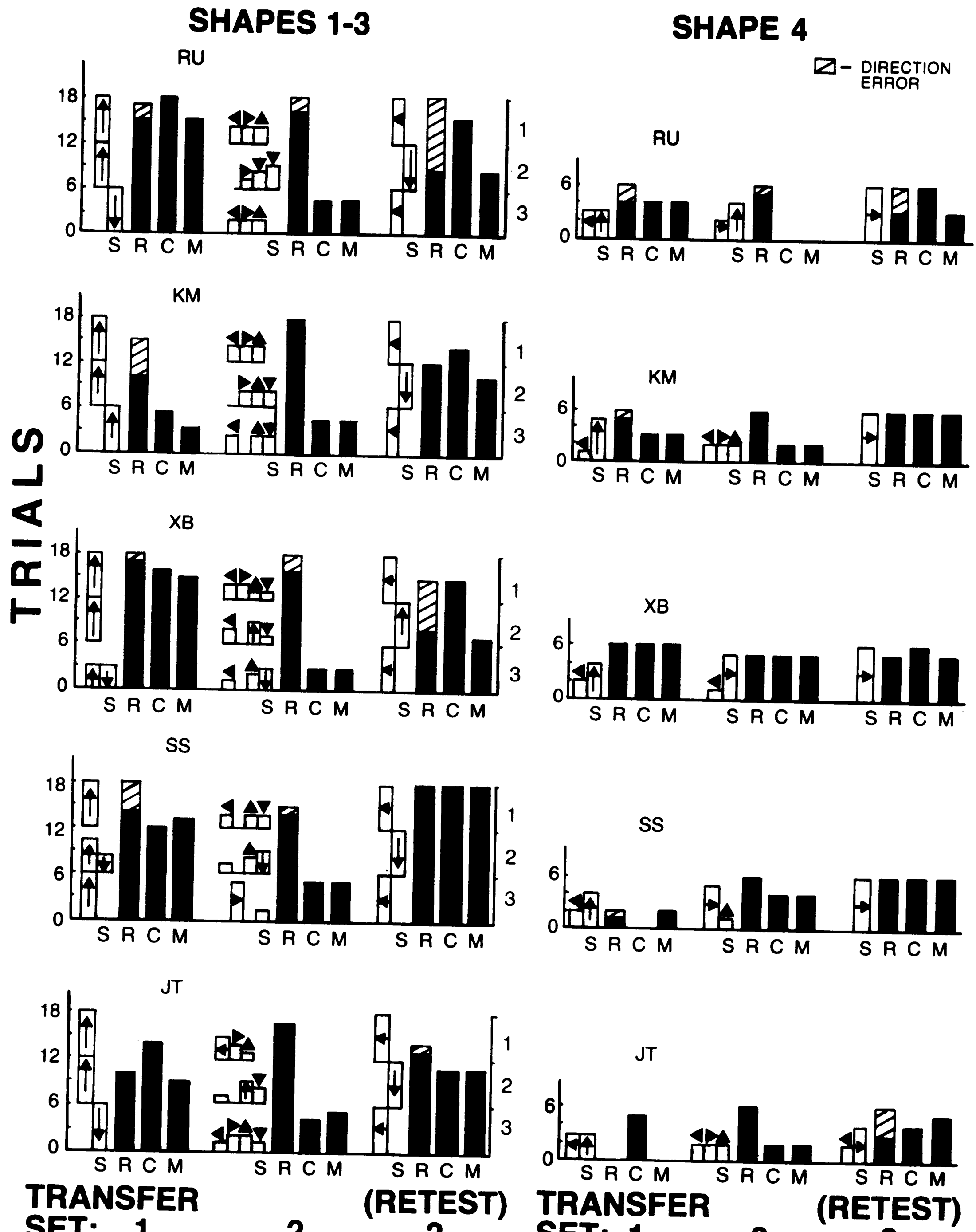

Fig. 3. Five children's performances on component tasks and on matching to sample in Experiment 1. S = sample coding, R = rotation, C = comparison coding, M = matching. 1, 2, 3—Shapes 1 to 3 in each stimulus set. Direction of arrow indicates direction arrow card was placed on samples in terms of the orientations of these shapes illustrated in Figure 2. Direction errors were rotations of 90° counterclockwise.

Orientation rotation did not deteriorate compared to performance in Transfer Set 1. It was maintained at comparable levels both with Shapes 1 to 3 and with Shape 4.

Performance in comparison coding reflected the deterioration in sample coding. Some subjects demonstrated a position preference. Of the 18 trials with the asymmetrical stimuli, Subject RU selected lower left comparisons on 14 trials. Subject KM selected the upper left comparison on 17 trials and Subject XB selected the upper left comparison on 9 trials. JT selected the upper left on 8 trials. With the symmetrical Shape 4, Subject RU maintained the position preference on 5 of 6 trials; JT did so on 4 trials. Matching again reflected its dependence on accurate mediating behavior. Except for one trial with JT, matching was not found in the absence of accurate component responses.

Training stable *sample*-coding responses to the shapes of Transfer Set 2 produced an immediate improvement in the accuracy of *comparison* coding during the retest and a corresponding improvement in the accuracy of overall matching. This improvement in matching was attenuated by a consistent deterioration in the accuracy of the rotation responses with the shapes of Transfer Set 2, although rotation was accurately maintained on the interspersed training-set trials. Why this happened is not apparent.

With the symmetrical Shape 4 a similar relation between sample coding and comparison coding was found. Subjects KM and JT, initially with unstable sample coding, also had inaccurate comparison coding. In the retest, their comparison coding improved as stable sample coding was acquired. In contrast, Subjects XB and SS performed both responses accurately from the start.

The overall dependence of accurate matching on accurate mediation continued. On two trials with Shape 4, however, JT selected an accurate match without performing the mediators correctly.

Coding response prevention. Video tape recordings of subjects' performances with the arrow card removed were examined in slow motion or by single frames. They revealed that coding behavior remained intact, though in modified form, in four of the five subjects (Figure 4). In these cases subjects used their index fingers, in place of the arrow, indicating the orientation of samples by laying their fingers on the samples parallel to the screen and along the axes of symmetry. Subjects then maintained their index fingers extended, rotated their hands clockwise, and then placed their fingers on the correct comparison, thus reproducing the sample coding response. If the rotation had been in the correct direction, this produced a correct match.

As in the previous figure, the sample-coding data in Figure 4 illustrate the numbers of trials in which the same sample-coding response was used with a shape. Arrows specify the direction the index fingers pointed, relative to the orientations of each shape as illustrated in Figure 2.

Subject XB responded to samples by touching them with the fingertip of the index finger while keeping the finger perpendicular to the panel. She was occasionally observed to twist her wrist after making these responses. The rudimentary and stereotyped form of this behavior did not appear to vary in any consistent fashion with the orientations of stimuli and seemingly minimized its function in the control of behavior. Subject SS behaved this way with Shape 4 of Transfer Set 1.

On 7 of the 24 trials in the training set, Subject KM selected correct matching comparisons directly with no measurable mediating behavior. Because of an equipment failure Subject RU saw the training set only once.

Discussion

The generalization of matching varied directly with the availability of appropriate mediating responses. Matching to sample was found where stable sample coding and accurate comparison coding occurred, as in Transfer Set 1, and in the retest with Transfer Set 2 after sample-coding training. No such matching was observed initially in Transfer Set 2, when neither stable sample

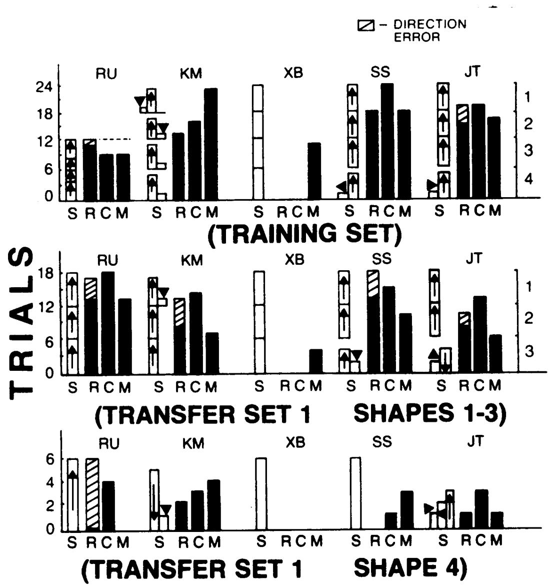

Fig. 4. Performance in Experiment 1 with coding responses prevented. Direction of arrow indicates direction subjects pointed their fingers relative to the orientations of these shapes as illustrated in Figure 2. Blank columns indicate no measurable direction in response.

coding nor accurate comparison coding occurred. The dependence of matching on stable coding responses suggests that generalization could not be readily accounted for in terms of general states of knowledge or cognition acquired merely through successful performance on the training set.

The generalization of sample coding (SA1-CR1) appears to have depended on control acquired by the feature of symmetry. Stable sample-coding responses were made from the start with the shapes of Transfer Set 1, but not Set 2.

The generalization of accurate comparison coding (COx-CRx) depended, in turn, on stable sample coding. Accurate comparison coding accompanied the generalization of sample coding to Transfer Set 1, and occurred with no additional training in Transfer Set 2 after stable sample coding had been trained.

In addition to the specific feature of symmetry, general features also appeared to affect coding behavior. Thus, in Transfer Set 2, stimuli did not have the symmetry feature and initially yielded unstable coding responses. Despite this, sample- and comparison-coding responses occurred on every trial. This consistent sequence suggests that these responses were partially controlled by general stimulus features common to all trials, such as the location of the samples and comparisons. Therefore, in the models of Figure 1, SA1 and CO1 refer to functionally distinct stimuli, though they may include a common shape. Likewise CR1 and CR1′ refer to responses that, although topologically similar, are also functionally distinct.

In a similar fashion, the uniform generalization of the rotation response indicates control by features common to the completion of any sample-coding response, regardless of whether or not the latter was controlled by symmetry.

When trained forms of the coding responses were prevented by removing the arrow card, modified forms of these mediating responses appeared immediately. Apparently, behavior acquired with the training set was adequate, despite the extremely restricted form of the coding response, to generate a class of responses in which alternate members would occur if the primary response was prevented. It is not unreasonable to suspect that increasingly more covert forms of coding and transformation would occur, approximating cognitive events, either as more overt forms of the behavior were prevented or, perhaps, with increased practice.

Finally, performance with the Shape 4 of each transfer set suggests the operation of some intra-set transfer effects, which acted to facilitate sample and comparison coding when an asymmetrical shape was put in a context with symmetrical shapes (as in Set 1) and degrade performance when the relation was reversed (as in Set 2).

EXPERIMENT 2

Experiment 1 demonstrated that the generalization of matching to sample depended on the generalization of sample-coding responses. Besides coding, generalization of matching may have depended also on subjects' understanding of the relation between samples and comparisons. This understanding may have been gained merely through successful matching in the training set. At issue here is the dependence of generalization on a specific transformational response that supplies the relevant relation.

In this experiment, relational matching was first trained with the structure of stimulus control modified so that a transformational response did not supply the relevant sample-comparison relation. Subjects were taught directly which sample went with which comparison, without making the form of the matching relation an explicit part of the behavior. Comparison codings were again repetitions of sample-coding responses, but the rotation behavior was not controlled by sample coding nor did it in turn control comparison coding. Rather, rotation was made to be an incidental result of the matching of specifically trained sample-comparison combinations.

To study the effect of this form of training on subjects experienced with 90° clockwise rotations, adults—presumably with relevant pre-experimental training—were used as subjects along with the children.

METHOD

Subjects

Two children, C. J. (4 years 3 months) and S. R. (4 years 10 months), participated under the conditions described in Experiment 1. In addition, three adults (A1, A2, A3), volunteers from the introductory psychology subject pool, participated in two sessions of 90 min.

Stimuli

Shapes. Modified versions of three shapes from the training set of Experiment 1 were used in the current training set. Each shape, shown as the final forms in panel A of Figure 5, was reached through stimulus-shaping series from alternative initial objects. The stimulus-shaping series for the objects of Shape 1 is shown in panel C. Transfer Set 1 from Experiment 1 was used, unmodified, to measure generalization. All stimulus dimensions were as described in Experiment 1.

Training media. To teach sample-coding responses for the training-set shapes, the arrow-fading series described in Experiment 1 was used again. Instead of the cutout forms used in Experiment 1, the six initial objects shown in panel A of Figure 5 were each drawn (7 cm on their longest side) on 3 by 3-in. (7.7 by 7.7-cm) cards. The arrow card described in Experiment 1 was again used by subjects to code orientations.

To teach discriminations between orientations of the shapes of Transfer Set 1, the pairs of 3 by 3-in. cards described in Experiment 1 were used again.

Specific sample-comparison pairings were trained in a pair-training procedure (panel B, Figure 5). In pair training only the correct comparison was paired with each sample over a stimulus-shaping series. To teach a sufficient number of sample-comparison pairings, two types of stimulus-shaping series were presented: same-object series and alternative-object series. In the same-object series the same object (i.e., the boy) served as both a sample and, in a different orientation, as the comparison. In the alternative-object series the alternative objects for each shape served as the sample and comparison. Thus if the boy were the sample, the fish, in some orientation, was the comparison—likewise for the flower and cat, or the turtle and boat. Each series was made up of six steps, and two identical 3 by 3-in. (7.7 by 7.7-cm) cards were prepared for each step. Figures were drawn individually on each card and measured 7 cm on their longest side.

As shown in Table 1, two same-object series were produced for each of the three shapes in the training set. The two series started with the two different initial objects related to the shape (panel A, Figure 5) and converged on the common, final form of the shape. Panel C illustrates the two series for Shape 1. Similar series were produced for Shapes 2 and 3.

The alternative-object stimulus-shaping

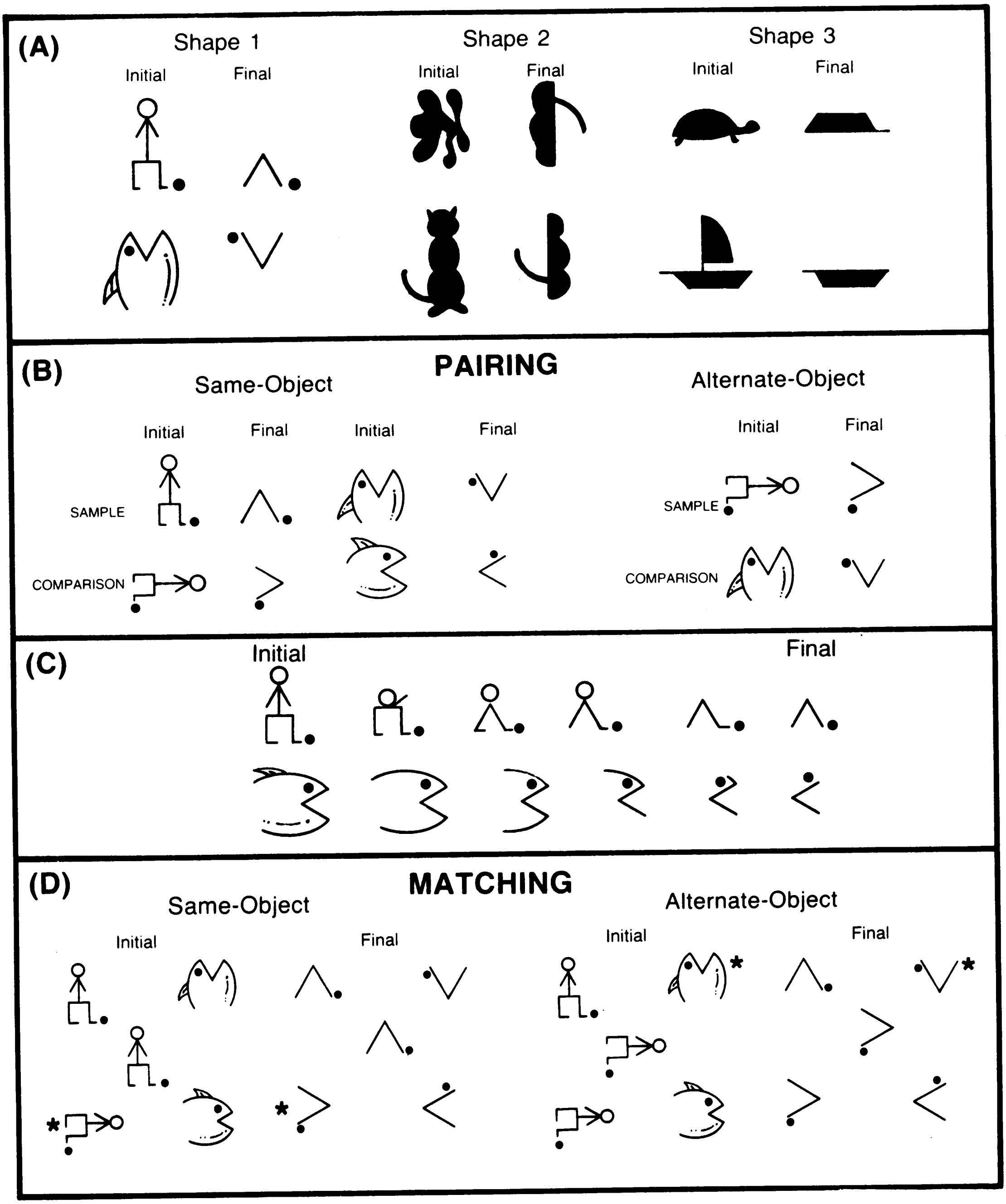

Fig. 5. Training procedures in Experiment 2. (A) The initial and final forms of the shapes of the training set in their orientations as samples. (B) Pair training. The initial and final forms of Shape 1 paired for same-object and alternate-object series. (C) An example of a stimulus-shaping series used to produce the final forms of the training set. (D) Matching-to-sample training. Asterisk indicates correct comparison.

Table 1
Same-object and alternative-object pairings for pair training and matching training.

Sample		*Comparison*			
Same-Object Series	*Alternative-Object Series*	*Boy* 0°	*Boy* 90°	*Fish* 0°	*Fish* 90°
Boy 0°			*		
Fish 0°					*
	Boy 90°			*	
		Flower 0°	*Flower* 90°	*Cat* 0°	*Cat* 90°
Flower 0°			*		
Cat 0°					*
	Flower 90°			*	
		Turtle 0°	*Turtle* 90°	*Boat* 0°	*Boat* 90°
Turtle 0°			*		
Boat 0°					*
	Turtle 90°			*	

Note. Degree notations refer to rotations clockwise from the orientations illustrated in panel A of Figure 5. Asterisks indicate sample-comparison pairs trained.

series were generated by pairing each object with the alternative object for that shape at each step of the shaping series.

For matching-to-sample training the three incorrect-comparison orientations were added to the combinations trained during pair training, and the trials were presented on 35 mm slides—with samples at the center and comparisons located at each corner. Again, three stimulus-shaping series were developed for each shape. Two series with each shape (Table 1) required matching 90° rotations of identical objects (same-object series) and one series required matching to the appropriately rotated version of the alternative object (alternative-object series).

Panel D of Figure 5 illustrates the initial and final steps of a sample-object shaping series, and the alternative-object series for Shape 1. The convergence of the shaping series toward common final forms produced a final set of matching trials for each shape in which objects differed only in their orientation.

Training- and transfer-test series. During tests for generalization, maintenance of behavior with the training set was assessed with a series of 12 slides. Each of the three training-set shapes (in their final forms) occurred on four trials, counterbalanced for orientation and location of the correct comparison shape. Only previously trained combinations of samples and comparisons were included. The 12-slide series from Experiment 1 for Transfer Set 1 was reused.

Contingencies of Reinforcement

The reinforcement contingencies described in Experiment 1 were employed with the children. For the adults correct responses were followed by the tone only.

Procedure

Training was designed to develop matching-to-sample behavior overtly similar to that produced in Experiment 1, but with a different structure of stimulus control. Subjects were taught, through stimulus-shaping procedures, to directly select a specific comparison for each sample.

Sample coding. The arrow-fading procedure, described in Experiment 1, was used to train sample coding with the current training set. Arrow cards with the initial forms of each object were placed on the arrow-fading series cards so that coding responses to the final forms of the stimuli would be identical to those taught to subjects in Experiment 1. Therefore, in this phase, subjects were taught to place the arrow pointing to the boy's legs or the fish's mouth; on the side of the cat with the tail, or the stem of the flower; and at the turtle's belly, or the top of the ship. Over trials, the arrow-fading series cues were reduced until subjects were correctly placing their arrow card as each of these initial forms was presented alone in any orientation.

Next, projected images of the forms were presented as samples at the center of the screen. Training continued until subjects correctly coded the orientations of all forms without the prompt ("Where does it go?").

Pair training. In pair training subjects learned to turn the comparison card to the correct orientation (Table 1) as samples were presented in various orientations. Starting with the first step in the shaping series, subjects were shown the objects pictured on pairs of cards. The cards were placed side-by-side on the table, about 8 in. (20 cm) apart, in their only permissible orientations as samples and comparisons. The subjects were given an explanation such as "The boy kicks the ball across [the left card], or the boy kicks the ball down [the right card]." On the first training trial with each pair, the comparison card (the one to the right) was handed to the subject, who was asked to replace it on the table in its correct orientation. Errors were followed by a repetition of the explanation and a demonstration of the correct orientation of the comparison. The trial was repeated until the card was placed in the correct orientation.

On the second and all subsequent trials with each pair, both the sample and comparison cards were handed to the subject. He was asked to restate the explanation and then replace the cards in their proper orientations—sample first—as indicated by the experimenter pointing to that location on the table. Errors were followed by a return to the first training-trial procedure. Following four successive correct placements of the sample and comparisons in Trial 2, the other object of Shape 1, representing the second same-object series for this shape, was introduced. The fish was presented, and the training procedure for Trials 1 and 2 was repeated using the prompt, "The fish swims up or the fish swims across."

A titration procedure then followed, in which subjects progressed to the next shaping step following three consecutive correct placements, and regressed to the prior shaping step after two consecutive errors. Training proceeded, alternating at each step between the same-object series for the boy and the fish, until the forms converged on the final form of Shape 1. At the end of these shaping series, subjects could provide correctly rotated placements of the comparison for two different orientations of Shape 1 when it was presented as a sample: one based on training with the boy (V with vertex up) and one based on the fish (vertex down).

With each shape, pair training was followed by matching-to-sample training before the next shape was trained. After matching training with Shape 3 was completed, the entire cycle was repeated starting again with Shape 1. In the first cycle the two same-object series for each shape were intermixed and trained together. In the second cycle the alternative-object series were trained.

Matching training. During matching training with same-object series, each shaping step was comprised of four trials—two with each object. Thus, with Shape 1 there were two trials with the boy as a sample, and two with the fish. With the alternative-object series, in which only one object served as the sample, there were two trials at each step.

A titration procedure was again used. Errors in selecting the correct comparison produced an immediate return to the prior shaping step. On all trials subjects were prompted as necessary ("Where is the other one?") to use the arrow to code the orientations of the sample and the comparison that had been trained in pair training. The criterion for each shaping sequence was 15 trials correct out of 18 at the final shaping step. After a review on matching, with all previously taught shapes brought to a criterion of 10 correct out of 12, pair training was continued with the next shape.

When training had been completed for all shapes, the 12 slides of the training series were presented until a criterion of 12 successive correct trials was reached. By the end of training, subjects could correctly select rotated comparisons for three different sample orientations of each shape—correctly coding the samples and the comparison shapes. At this stage, behavior was not visibly different from that observed in the training set in Experiment 1.

Transfer Set 1: Test for generalization. Using the 3 by 3-in. cards, subjects were trained with the procedure described in Experiment 1 to ensure that different orientations of the Transfer Set 1 shapes could be discriminated. Then the training-set slide series was interspersed with Transfer Set 1 and both were presented twice to provide a 48-trial test. As in Experiment 1, all correct trials were reinforced. All training-set errors were followed by a 5-s blackout of the picture, a verbal "no," and a repetition of the trial. Errors on Transfer Set 1 trials had no consequence.

Retraining. After the test for generalization, training continued for the children. They were given the rotation training, comparison selection, and the final training procedure from Experiment 1, with the shapes of the current training set.

Set 2 retest. Children were again given the training set interspersed with Transfer Set 1.

RESULTS

Figure 6 illustrates performance during the initial test for generalization to Transfer Set 1. Behavior in the retest is also reported for children. During the initial test for generalization with Transfer Set 1, only Subject A3 showed any significant instability in sample coding with a symmetrical shape. Both A3 and Subject CJ displayed variable coding with the asymmetrical Shape 4. Overall, high levels of correct comparison coding were found. In general, these data replicate the findings of Experiment 1.

Only moderately accurate rotation occurred with the shapes of Transfer Set 1, although the accuracy of these responses remained at a high level on the 24 interspersed trials with the training set. Only one child made as many as three rotation errors in the training set. No other subject made more than one error in the training set.

Again, accurate matching to sample depended on accurate mediating responses. In no case was a matching comparison selected without accurate performance of the precurrent mediators. Retraining children with the procedures from Experiment 1 improved the generalization of matching in the retest. As Figure 6 indicates, the improvement in matching was closely related to improvement in the accuracy of rotation.

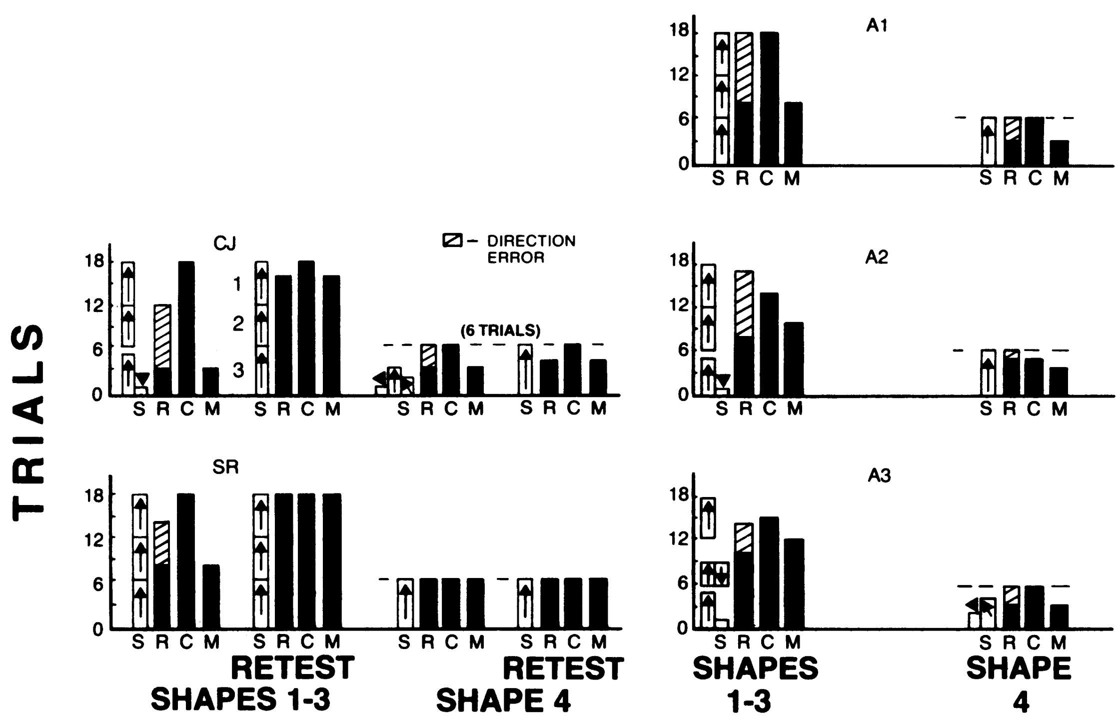

Fig. 6. Performance in Experiment 2 on three component tasks and on matching to sample. S = sample coding, R = rotation, C = comparison coding, M = matching. Arrows in the sample-coding response column illustrate the sample-coding response on each trial in terms of the orientation of each shape shown in Fig. 2.

Discussion

The lack of stable matching in Transfer Set 1, before retraining, illustrates that the generalization of matching is not an inevitable consequence of successful matching in the training set. Rather, it depends on specific features of the structure of stimulus control operating in the behavior.

In this experiment, pair training and matching training brought comparison selection under the direct control of each sample. As a result, arrow rotation was made incidental to the coding of comparisons. It consisted only of turning the arrow so that a repetition of the sample-coding response could be made with the specified comparison. The stimulus control relation was reversed from that produced in Experiment 1. Here the orientation of the selected comparison controlled the rotation of the arrow. Because samples directly specified comparisons, there was no mediating behavior, controlled by general features of the situation, which could aid generalization—even among adults who had presumably practiced this behavior pre-experimentally. The failure of adults to generalize simple relations to novel stimuli has been noted before, even in a situation that was not designed to minimize generalization (Lowenkron, 1969; Lowenkron & Driessen, 1971).

GENERAL DISCUSSION

According to the models described previously (Figure 1), generalization of matching is dependent on joint control of the comparison-coding response by (a) the comparison stimulus and (b) stimulus cues (S1) arising directly from the sample-coding response or from a transformation of it (Sx). Accordingly, deletion of either source of control should eliminate matching and indeed, various aspects of the data demonstrate the dependency of generalized matching on this structure of joint stimulus control.

In Experiment 1, during the first generalization test with Transfer Set 2, unstable sample coding was accompanied by inaccurate comparison coding and hence inaccurate matching, despite the stable rotation. Subsequent strengthening of sample coding in Transfer Set 2 generated accurate comparison coding and matching.

In Experiment 2 the second source of control was studied. Here, control of comparison selection by the aftereffects of rotation (Sx) was lacking and matching also suffered—despite stable sample- and comparison-coding responses. Generalized matching occurred only after training that brought comparison coding under the control of cues produced by rotation.

Because the current task required relational matching, certain features may have enhanced the generalization of coding responses. First, in a relational matching task (i.e., size, number, brightness, etc.), large numbers of stimuli may be coded with relatively few responses if coding corresponds to the dimension defining the relation. In the current case the orientations of the shapes in *all three sets* could be coded with one of four different coding responses. As a result, control of CRx by Sx, established in training, should have transferred intact to the transfer sets. Second, the specific orientation of the arrow card was a permanent product of the rotation response and could be maintained merely by not making any additional rotations.

Under circumstances in which generalization required the production of truly novel coding responses, reliable repetition of the sample-coding response, or of a transformed version of it, might require a different form of training. This would be especially true if the response were vocal (and hence produced only a transitory S1). In this case training a form of self-echoic behavior (Skinner, 1957) might be required to provide a stable and functional S1.

In general, the findings indicate that different programs of training may have the effect of generating complex patterns of behavior which, although seeming identical at the conclusion of training, differ in the structures of stimulus control exerted on the component responses, and thus vary in the degrees to which they generalize.

These differences in generalization are commonly taken to indicate the difference between acting in accord with a concept without understanding it (i.e., not generalizing to novel instances) and acting in a way that does illustrate understanding (i.e., generalizing to novel instances) (Lowenkron, 1969; Lowenkron & Driessen, 1971). But it would seem that variations in the degree to which one "understands a concept" may be accounted for in terms of differences in the structure of stimulus control of the behavior and ultimately in the specifications of the originating contingencies.

It closely follows that such a specification provides an account of the behavior that does not require recourse to cognitive or other nonbehavioral constructs. Identity need not be viewed as a concept residing within the subject, but rather as the identity of the coding responses controlled by cues originating in the sample-coding response and the correct comparison stimulus. Other complex repertoires almost certainly must consist of similar structures of stimulus control.

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Received January 31, 1983
Final acceptance April 27, 1984