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GENERALIZATION OF DELAYED IDENTITY MATCHING IN RETARDED CHILDREN

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In an extension of prior research, four retarded children were trained under an identity matching-to-sample procedure containing features previously shown to produce controlled generalization to novel stimuli. They first were taught to relate a particular handsign to the sample shape, then to maintain the handsign over a delay interval, and then to select from an array the comparison shape that permitted the handsign to be maintained (i.e., the shape identical to the sample). An initial test revealed little generalization of matching to novel stimuli, but after handsigns were trained to these stimuli, accurate generalized matching appeared immediately. The results replicated prior findings and demonstrated particular features of stimulus control sufficient to enable generalized matching. A behavioral account of relational matching was supported. The technique used in this study was shown to be effective in teaching abstract relations to nonverbal retarded children.

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

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In a matching-to-sample task the state of the sample determines which comparison must be selected for reinforcement to occur. If the comparison stimuli are arbitrarily assigned to the samples and presented only after the samples are removed (delayed matching), there can be little basis for generalization of the behavior to novel stimuli except stimulus generalization. On the other hand, if the sample-comparison assignments are based on a consistent relation, as in identity matching, the relation may provide a basis for generalization.

Typically, however, where generalized delayed relational matching has been demonstrated in animals, the effect of the identity relation has been ascribed to its representation in cognitive structures such as generalized identity concepts (Zentall, Edwards, Moore, & Hogan, 1981; Zentall & Hogan, 1978), or relational learning (D'Amato & Salmon, 1984). Demonstrations with children have evoked similar explanations phrased in terms of relational attending responses (House, 1964; House, Brown, & Scott, 1974) and rule learning (Bucher, 1975).

Behavioral models have not explicitly treated this particular issue. The principal behavioral account of performance and generalization in a delayed conditional discrimination (Cumming, Berryman, & Cohen, 1965; Eckerman, 1970; Parsons, Taylor, & Joyce, 1981) is illustrated by the first model in Figure 1. The model has also seen service in the description of acquired distinctiveness (Dollard & Miller, 1950; Goss, 1955). As discussed in an earlier article (Lowenkron, 1984), this model is not suited to the description of generalized matching based on any consistent relation between samples and comparisons because it describes all such tasks as if the samples and comparison stimuli were assigned arbitrarily.

In identity matching, for example, according to the model a unique coding response is acquired for each sample (e.g., children pressing different keys for different sample brightnesses or pigeons pecking at different rates for different colors). Comparison stimuli, however, are selected with a common response; pointing with a finger or pecking. Thus, with Sample 1 (SA1) a corresponding coding response (CR1)

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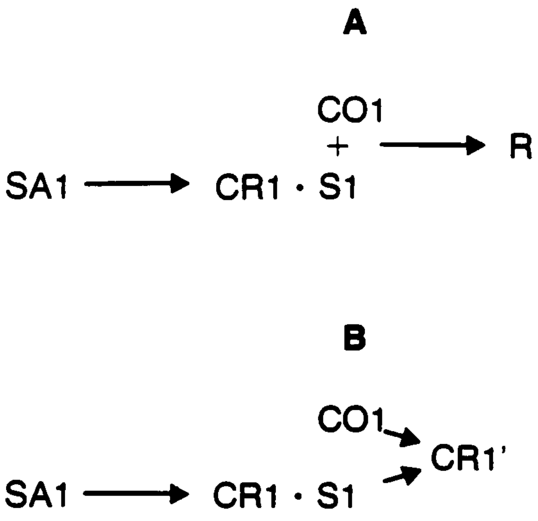

Fig. 1. Two models of identity matching. SA1, Stimulus 1 as a sample. CR1, coding response to Stimulus 1. S1, stimulus cues produced by CR1. CO1, Stimulus 1 as a comparison stimulus. R, the selection response common to all comparisons. + indicates a compound stimulus composed of S1 and a comparison. CR1′, coding response to Stimulus 1 made in the absence of a sample but in the presence of the comparison stimuli.

is emitted that produces the unique stimulus cue S1. With the removal of the sample and presentation of the comparison stimuli, the comparison-selection response R is controlled by the resulting stimulus compound—arbitrarily composed of S1 and the appropriate comparison stimulus, CO1 (Paul, 1983). The compound is composed arbitrarily in that its two elements, S1 and CO1, share no distinctive common characteristics, either physically or in the existing contingencies. Thus, the model does not recognize the identity relation, but treats the sample and comparison as if they were paired arbitrarily.

Model B in Figure 1 explicitly recognizes the identity relation. In this model, too, subjects learn a coding response for each sample and then rehearse that response (CR1) under the discriminative control of S1, through any delay interval and into the choice phase. That is, the stimulus cue S1, produced by CR1, specifies which coding response to repeat. Thus, if the sample were a dog, the stimulus product of the vocal coding response "Dog," would specify subsequent repetitions of "Dog" during the delay interval.

Initial training must also establish that the sample and comparison contexts are not discriminative, so that the same coding response will be made to a particular stimulus regardless of whether it is a response to a sample (CR1) or a response to a comparison stimulus (CR1′). As a result, S1 and CO1 both become discriminative stimuli for the same coding response, CR1′. Thus, the actual sample-comparison identity relation is described in the model by *joint control* over the same comparison-coding response (CR1′) by S1, the coded version of the sample stimulus, and CO1, a comparison stimulus. The subject, repeating the sample coding "Dog," can select only the particular comparison stimulus that evokes yet another repetition of "Dog," necessarily producing an identity match with the sample. The model thus describes how matching may be controlled by the sample-comparison identity relation, rather than relegating such control to cognitive intermediaries (Skinner, 1957, 1974).

After training young children in accordance with a variant of this model, Lowenkron (1984) reported generalized matching of a spatial relation, in which novel shapes were matched to their 90° clockwise rotations. In the present study a simplified task was used to extend the account to generalized identity matching.

METHOD

Table 1 contains a general overview of the procedure. Subjects were first errorlessly trained to match samples to identical comparison shapes presented simultaneously. Then a delay interval between the removal of the sample and the presentation of the comparison stimuli was introduced, and that delay was increased until accurate matching deteriorated to chance level performance. This baseline level of delayed-matching performance was demonstrated in Test 1. Next, coding responses, in the form of handsigns, were trained for each of the shapes in the training set. Test 2 examined the effect of this training on delayed-matching performance. Next, subjects were taught with errorless training procedures to maintain handsigns over the delay interval and to select the comparison that did not require an alteration of the handsign so maintained. The next test (Test 3) measured delayed identity matching with the training set and generalization to the transfer set. Then, handsigns for shapes in the transfer set were trained and

Table 1

Outline of training procedures.

Procedure	Stimulus set
1. Train simultaneous matching	Training set
2. Introduce delay interval	Training set
3. Test 1	Training set
4. Train sample coding	Training set
5. Test 2	Training set
6. Train comparison coding	Training set
7. Train response retention	Training set
8. Train simultaneous matching	Transfer set
9. Test 3	Training and transfer sets
10. Train sample coding	Transfer set
11. Test 4	Training and transfer sets

the effect of this training on generalized matching was assessed in Test 4.

Subjects

Four teenage subjects with IQs below 40 participated. Two of these, one male (GB) and one female (TA), were from the habilitation unit at a state institution for the retarded; neither had a vocabulary of more than 10 to 15 words. Two other subjects with larger vocabularies, a male (SJ) and a female (IL), were from a day school for the retarded.

Stimuli

Shapes. As illustrated in Figure 2, two sets of shapes were used, each with a corresponding handsign. In different stages of training, shapes appeared as black figures drawn on pairs of 3 by 5 in. (7.62 by 12.80 cm) cards and on 5 by 7 in. (12.8 by 17.9 cm) cards, and as images projected from 35-mm slides. When drawn, the figures averaged 3 in. (7.68 cm) on their longest side. When projected, the size of the overall slide image was 22 by 24 in. (56 by 62 cm), with figures averaging approximately 3 in. (8 cm) on their longest side.

Training media. To train handsigns for coding the eight shapes in the training and transfer sets, eight corresponding sequences of training devices were used. Grasping the device at the first step of each sequence fully formed the handsign. In the successive steps of each sequence, parts of the device were removed or reduced in size. Thus, as illustrated in Panel B of Figure 2, a fist was shaped as the handsign for the black circle as the device to be grasped, a dowel at the center of a black circle, diminished in height and diameter over the steps of the sequence until it vanished, leaving only the circle.

Each of the eight sequences of training devices consisted of four to six steps, depending on the complexity of the handsign. The devices to be grasped at each step in a sequence were on 5 by 7 by 0.5 in. (12.8 by 17.9 by 1.3 cm) white wooden plaques with the shape painted in black. Parts of the grasping devices inside the perimeter of the shape were also black, and any parts extending outside were white. The final step in each sequence was a 5 by 7-in. card with only the shape drawn on it. All shapes averaged 3 in. (8 cm) on their longest side, the same size as the projected images.

On the 35-mm slides used in the various phases of training and testing to be described, the sample always appeared at the center, either alone or with one or more comparison shapes at the corners. Other slides contained one or more comparison shapes with no sample at the center.

Training- and transfer-set slide series. To maintain the behavior of matching with the training set and to test for the generalization of matching to the transfer set, two series of 35-mm slides were used, one for each set. Each series consisted of 12 pairs of slides to provide 12 delayed-matching trials. The first slide of each pair contained only the shape serving as the sample for that trial. The second slide of each pair contained all four shapes of the set as comparison stimuli. A blank slide between each sample and comparison provided an interstimulus interval for delayed matching. In each series each of the four shapes appeared as a sample three times in a randomized order. The locations of comparison shapes were counterbalanced across the four corner locations.

Apparatus

Two Kodak Carousel® projectors were used to project images on the screen from the rear. The screen was 22 in. wide by 20 in. high (56.3 by 51.2 cm) and was surrounded by a 3 in. (7.5 cm) frame. Two rails, 1 in. (2.6 cm) wide, ran horizontally across the screen dividing it into three equal areas each 22 by 6 in. (62 by 15.4 cm). Each of these areas was further divided into three independently movable panels 7.25 by 6.0 in. (18.6 by 15.4 cm). The panels were translucent plastic, which transmitted images projected on them from the rear. Two inches below the display screen, centered across the bottom of the frame in a horizontal row 1 in. (2.6 cm) apart, were five red and white lamps. A tone generator attached to the back of the frame operated with the lamps to provide a conditioned reinforcer. The projectors and reinforcement were manually controlled by the experimenter.

Setting

A small room was used. A chair for the second data recorder was located behind the subject, who faced the display screen on a table. The experimenter sat next to the subject. The projectors were placed behind the screen in the same room. Although operation of the projectors was audible to subjects, the projectors were not visible because of the size of the frame around the screen. When necessary, the screen was pushed back to allow space for working with the other training media.

Contingencies of Reinforcement

All correct responses were followed by 2 s of tone with the red and white lights flashing. Small, edible reinforcers (potato chips, popcorn, Crackerjacks®, small cookies) were presented at the end of the tone and lights, approximately after every fifth correct response. The various consequences for errors are described below.

Procedure

Twice-weekly training sessions were conducted, each lasting 45 min. All training began with a review of previously acquired repertoires by reinstating the last steps of the respective training procedures.

Simultaneous matching to sample. A 3 by 5 in. comparison card with one of the shapes of the training set was placed on the table 40 cm from the edge nearest the subject. A sample with the same shape was placed directly below the comparison card, 20 cm from the table's edge. Prompts and demonstrations were used as needed to teach the subject to touch the sample and then hand the comparison card to the experimenter. Compliance was followed by reinforcement. Over trials with all four shapes, the prompts were gradually eliminated until six consecutive trials were completed with no prompts.

Next, a second (nonmatching) comparison shape was placed 40 cm from the table's edge and 10 cm to the side of the correct one. The sample was again placed directly below the correct comparison shape and the subject was permitted to select. After four consecutive trials with correct responses, a third and then a fourth comparison shape was added. Training continued with all four shapes until four successive correct selections were made with the correct comparison stimulus in each of the four positions. Then, over subsequent trials, the sample card was moved in approximately 1-in. (2.6-cm) increments along the 20-cm latitude, out from under its correct comparison stimulus and toward the center of the array. The basis of selection thus faded from location to the identities of sample and comparison shapes (Hively, 1962).

Following four successive correct selections (one with each shape) with the sample card at the center of the array, fading was repeated with images projected on the display screen. The sample card was first held by the experimenter in a corner of a blank screen. When the subject touched it, the comparison stimuli appeared as projected images.

Initially, pairs of comparison shapes were shown, one in each of the two lower corners of the screen, with the sample directly adjacent to the correct comparison shape. The subject was prompted and guided to touch the correct comparison. Over successive trials with all shapes, the sample was moved in 1-in. (2.6-cm) increments toward the center of the display. The procedure was then repeated with the comparison shapes in the upper corners of the display and repeated again with comparisons in all four corners.

After four successive correct selections, one

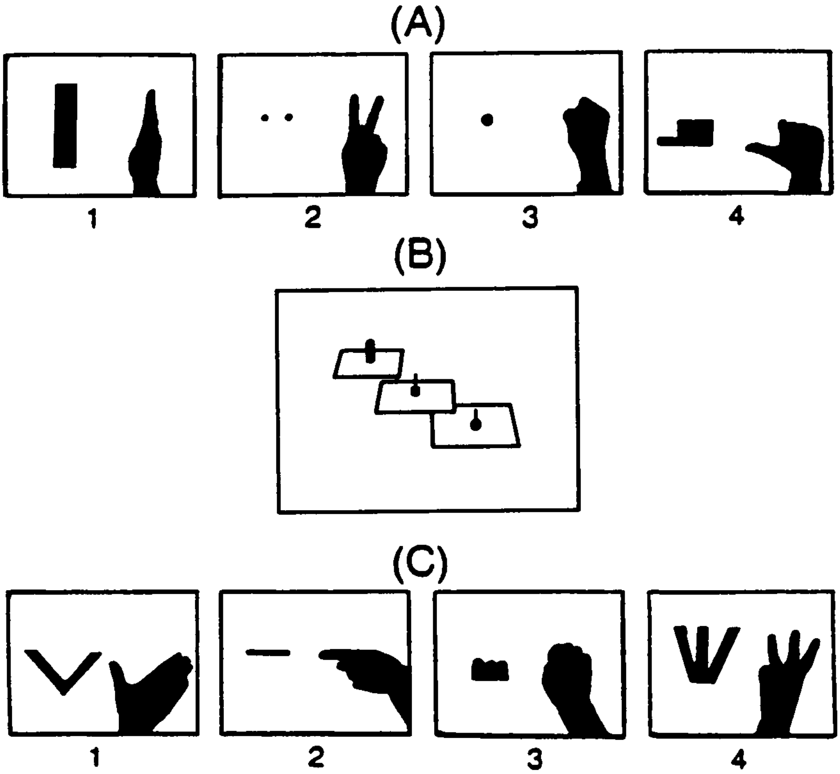

Fig. 2. (A) Shapes in the training set and their designated handsigns. (B) Three members of the series of devices for training the handsign for Shape 3 of the training set. (C) Shapes in the transfer set and their designated handsigns.

to each of the shapes with the sample card at the very center of the display, the card was replaced by a projected shape at the center location, which the subject was also required to touch in order to produce the comparisons. Training continued to a criterion of 18 correct out of 20 in two successive sessions.

Introduction of delay. To find a delay interval for each subject that produced random selection (25% correct) performance, simultaneous matching was changed to zero-delay matching so that the sample disappeared when the subject touched it and before the comparison stimuli appeared. Following the second correct response in each block of four trials, the delay interval was increased by 1 s on the next trial, which counted as the start of a new block. In blocks where more than two errors occurred, the delay was not increased but was repeated in the next block. The final delay interval was the one in which the subject made three or more errors in two successive blocks.

Baseline (Test 1). To provide a stable baseline of delayed-matching performance, a series of 12 trials was presented with the four training-set shapes counterbalanced for frequency and position. The delay interval was the previously determined value for each subject.

Sample coding-response training. The handsign-training devices were used to teach subjects to make the specified handsign for each of the shapes when they appeared as samples. Subjects were taught first, through prompting and demonstration, to grasp the handsign-training devices so as to make the proper handsign for Shapes 1 and 2 of the training set. Training proceeded by alternating between the two shapes. With each shape, training advanced to the next training step in the sequence after four correct responses. Approximately midway through the sequence for Shapes 1 and 2, training began on the third shape. When training was concluded on Shapes 1 and 2, it was begun on the fourth shape. Training ended when the handsigns could be made to each of the shapes presented on the 5 by 7 in. cards with no cueing devices present.

The shapes were then projected as samples on the screen. The 5 by 7 in. card was then placed over the projected image. As the subject reached up to place a handsign on the card, it was removed, revealing the projected image. The subject was then verbally prompted and physically guided by the experimenter to place the handsign on the image. The trial was then repeated without the card. Training continued over sessions until at least 12 successive correct handsigns were made to each shape.

Effects of sample coding on matching (Test 2). The effect of sample coding-response training on delayed matching was measured in a series of 12 test trials. Each trial began with a sample on the display screen. Production of the appropriate coding response to the sample initiated the delay interval. Incorrect codings were followed by a 2-s removal of the sample, a verbal "no," and a reappearance of the sample.

Comparison coding-response training. To develop control over the selection of comparison stimuli by subjects' handsigns, a 5 by 7 in. card with one of the training-set shapes was held approximately 12 in. (31 cm) in front of the screen. As soon as the subject made the correct handsign on the card, the same shape appeared as a projected image in one of the corners of the screen as a comparison stimulus, and the card was moved toward it. The subject was then verbally prompted ("Where is it?") and physically guided to place the handsign on the comparison shape.

Correct placements of handsigns were reinforced. Any changes in handsigns before touching the comparison stimulus were followed by a 2-s blackout of the image, a verbal "no" from the experimenter, and a repetition of the sample for that trial.

Training proceeded with single shapes occurring, one at a time, in all four corners. After eight successive correct trials without guidance, an incorrect comparison shape was presented along with one correct comparison on each trial. Selections of the incorrect comparison were immediately followed by a verbal "no" and a blackout of the image. Subsequently, after every eight successive correct trials, an additional comparison shape was added until all four were present. Training continued to a criterion of 35 correct trials out of 40 in a single session.

Coding-response retention. To teach each subject to retain the sample coding response over the delay interval, sample coding training was reinstated. After making a handsign to the sample, subjects were guided and prompted to rest their hands, in the handsign, on the wooden railing below the sample panel until the lights and tone provided reinforcement. Over trials the length of the interval until reinforcement increased in 1-s increments.

When subjects held the coding response for 3 s, the sample vanished from the display. The interval for retaining responses was further lengthened in 1-s increments so that ultimately coding responses were maintained for 3 s after the comparison stimuli appeared at the end of the delay interval. Failures to maintain the coding response resulted in a prompt ("no"), reappearance of the sample, and repetition of the trial.

After eight successive trials in which the subject had held the coding response until 3 s after the comparison shapes appeared, the prompt used to train comparison coding ("Where is it?") was presented just as the comparison stimuli appeared. Correct comparison codings were reinforced. Incorrect comparison codings were followed by a brief review of comparison-coding training for that shape. Training continued until 10 correct choices were made in two successive series of 12 trials with no prompts. During these trials, the sample was turned off and the interstimulus interval began as soon as the correct handsign was placed on the resting rail.

In the next session, this training continued to the same criterion. Incorrect sample codings were still followed by a "no," a 2-s blackout of the sample, and a repetition of the trial. Failure to retain the coding response through the interval was followed by a "no" and a reappearance of the sample to restart the trial.

Simultaneous matching in the transfer set. To ensure that subjects discriminated between the shapes of the transfer set, simultaneous matching was taught using the procedure described with the training set. Criterion, however, was 18 of 24 correct in a single session.

Generalization to the transfer set (Test 3). To determine whether accurate matching in the training set could produce generalization to the transfer set, the training- and transfer-set slide series were alternated and presented twice each to provide 24 training- and 24 transfer-set test trials.

Retest for transfer-set generalization (Test 4).

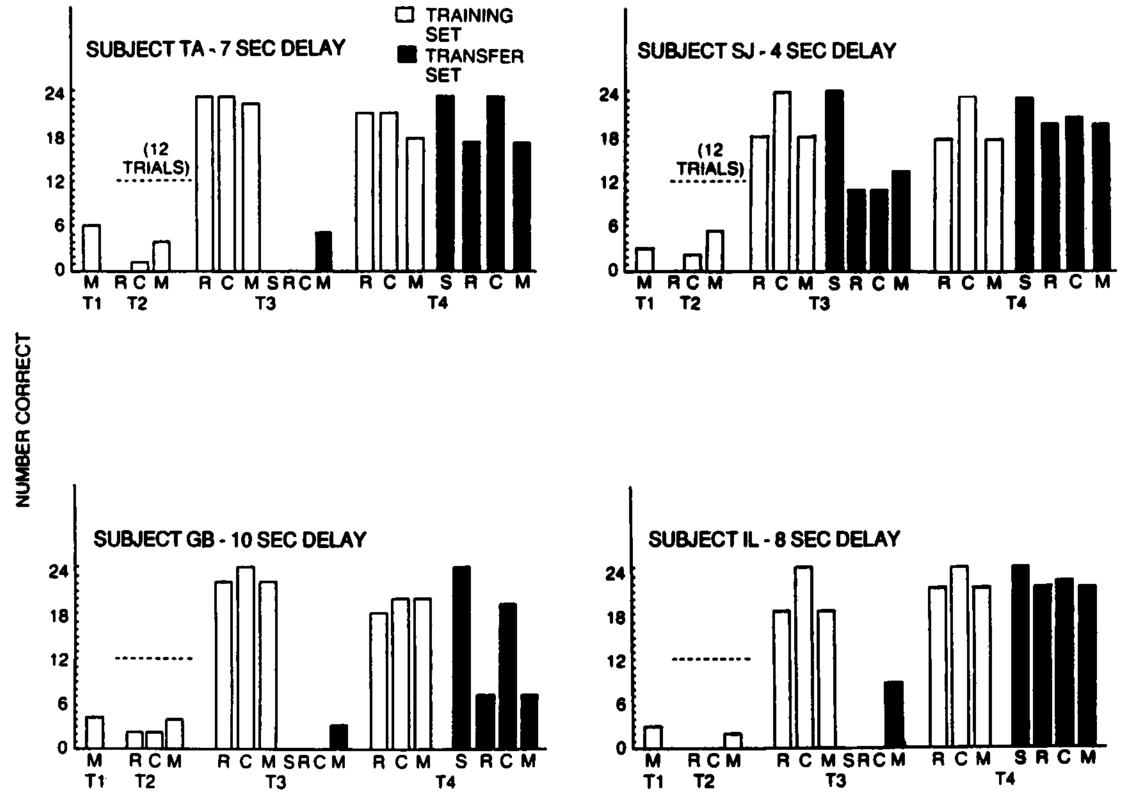

Fig. 3. Accuracy of each component of the trained delayed-matching repertoires, and overall accuracy of matching in the training and transfer sets. S, sample coding; R, retention of coding; C, comparison stimulus selection; M, matching; T1-4, Tests 1 to 4.

In the following session sample coding responses were trained for the shapes of the transfer set using the procedures described for the training set. After training, both the training- and transfer-set slide series were again presented in alternation (twice each) to provide 24 trials with each series.

RESULTS

Figure 3 illustrates the overall accuracy of matching and the three independent components of the behavior: sample coding responses, retention of those responses, and selection of comparison stimuli. Data for sample coding in the training set are not displayed because a trial was not started until a correct coding response occurred. Before specific handsigns had been trained for shapes in the transfer set, sample coding responses were recorded (in Test 3) and later scored as correct if they were either one of the handsigns previously assigned to a shape in the training set or a novel handsign that occurred two or more times to the same shape. In Test 4, sample coding responses to the transfer set were scored as correct if they were performed as they had been trained.

A coding response was scored as correctly retained over the delay interval if the handsign made to a comparison stimulus, whether correct or not, was the same as the handsign made to the sample on that trial—that is, if the handsign did not change during the delay interval.

Selection of a comparison stimulus was scored as correct if the shape selected was accompanied by the handsign appropriate to that shape. Again, in Test 3, before handsigns had been trained for shapes in the transfer set, subjects' handsigns were recorded and later scored. In this case a correct selection was scored if the handsign-shape combination had appeared as a sample coding response on that or on any other trial.

The fourth measure, matching, is partially redundant with the first three. Thus, if the sample were coded as trained and if that handsign were retained during the delay interval, and if the comparison stimulus selected were appropriate to that handsign, then the sequence of behavior was scored as a correct sample coding response, a correct retention, a correct comparison selection, and necessarily, a correct identity match. On the other hand, if the subject changed the handsign during the delay interval and selected a comparison stimulus appropriate to the new handsign, the sequence was still scored as a correct sample coding response and an accurate comparison stimulus selection, but with an error in handsign retention and therefore in matching because the selected comparison stimulus would no longer match the sample. Alternately, it was possible, in this case, to make a compensating error in comparison stimulus selection, so that a sample-comparison match was achieved with errors in both retention and comparison stimulus selection. Finally, accurate matching could be achieved by selecting directly, with no evident mediating behavior except the required sample coding response to training-set stimuli. Measures of interobserver reliability (agreements divided by agreements plus disagreements) were higher than 90%.

Training Set

Delayed-matching performance on the training set did not exceed random selection (25% correct) in Test 1. Acquisition of stable sample coding responses did not improve the accuracy of matching or comparison selection (Test 2). Rather, subjects selected comparison stimuli directly and with no discernible handsigns. Because no trial proceeded without a correct sample coding response, this behavior is not reported. No subject made more than one such error.

Transfer Set

After coding-response retention and comparison selection were trained, matching approached high levels of accuracy in the training set (Test 3), but produced no generalization to the transfer-set performance for 3 of the subjects. Rather, on these trials, subjects were observed to make training-set handsigns to the novel samples and comparison stimuli, but with no discernible regularity.

The single subject (SJ) who generalized sample coding responding to the transfer set also showed moderate levels of accurate matching. As the retention and comparison selection data indicate, Subject SJ retained and used the codings to match on 11 of 24 trials.

After coding responses were acquired for the shapes of the transfer set, all behavior involved in this set improved in Test 4 for 3 of the 4 subjects. For Subject GB comparison coding improved, but overall matching accuracy was attenuated by failure of the retention component to generalize to the transfer set. Rather, on transfer-set trials the subject relaxed his hand during the delay interval, then made a new handsign and selected a comparison stimulus appropriate to that handsign at the end of the delay interval. It could not be determined what controlled the selection of the comparison-coding handsign—neither a position nor a stimulus preference was evident. Only on two trials with the transfer set did GB hold the sample coding response through the delay interval and code the appropriate comparison stimulus with it. In contrast, GB retained sample coding responses on 18 of the 24 training-set trials.

DISCUSSION

Generalization of the identity relation in the current experiment extends previously reported findings (Lowenkron, 1984) regarding generalization of a complex spatial relation. Behavior trained in accordance with Model B in Figure 1 preserved the identity relation during generalization to novel stimuli. This preservation seems to depend on the interaction between stimulus-specific components of behavior and components common to all trials of the task. In the present task, stimulus coding was the sole specific behavior. The components common to all trials include retention of handsigns over the delay interval and use of handsigns to select comparisons.

Evidence of the interaction of these general and specific components may be seen in the pattern of results. In Test 4 matching generalized to the transfer set stimuli, but only after both sample coding responses specific to these stimuli and an initial matching performance in the training set had been trained. Sample coding alone did not facilitate matching, as indicated in Test 2, nor did matching in the training set produce generalized matching to the transfer set in Test 3. Thus, generalization of matching was not an inevitable consequence of accurate matching with the training set, and, symmetrically, stable sample coding supported generalization only if the other, generalizable, components had been acquired.

The crucial role of stimulus-specific coding responses in supporting generalization is further shown by the failure of simultaneous matching with the transfer set to facilitate generalized delayed matching in Test 3. Thus, differentiating the stimuli (Gibson & Gibson, 1955) to allow simultaneous matching produced no generalized matching, but when accurate coding responses were acquired for these same stimuli, matching appeared immediately.

Other investigators suggest that a prior history of differential responding to samples is not adequate to facilitate identity matching, but that differential responding must be part of the current behavior. Thus, Constantine and Sidman (1975) found that simply prompting retarded children to vocally name samples on each trial greatly increased the accuracy of delayed matching. Their subjects could also select the stimuli when given the names. Apparently the subjects had acquired, preexperimentally, those components trained in the present experiment to produce accurate matching after Test 2, so when differential responding was prompted, matching followed.

When nonhumans are the subjects, and therefore preexperimentally acquired behavior relevant to these procedures is absent, differential sample coding only facilitates matching over relatively prolonged tests (e.g., Eckerman, 1970). This suggests that additional unspecified behavior is trained inadvertently during these prolonged tests (Blough, 1959), which ultimately permits the sample coding response to effect matching.

For this reason, and because the purpose of the current research was to study generalization properties implied by a specific model, comparison coding and retention were trained in the present study with no intervening test. Without retention training the response-produced cue (S1) was not reliably available at the end of the delay interval to enter into joint control. Conversely, without the comparison coding behavior the joint control of comparison stimulus selection, and thus the sample-comparison identity relation, was not defined. A prolonged test with feedback for accurate matching would have simply invited the acquisition of unspecified behavior.

The transfer-set performance of Subject SJ in Test 3 replicated the performance of subjects in the study by Lowenkron (1984) with a transfer set designed to foster generalization of sample coding responses and thereby produce generalized matching with no prior training of sample coding. In Test 3, SJ also produced stable sample codings without specific training, and matching again generalized immediately. Overall accuracy with the transfer set was depressed because accurate matching emerged rather late in the 24-trial test.

For Subject GB, accurate matching to the transfer-set shapes was attenuated by a deterioration in coding-response retention, although comparison coding generalized. This is reminiscent of the performance of Subjects XB and RU in Experiment 1 of Lowenkron (1984). There too, a behavior intermediate to sample and comparison stimulus coding did not generalize to the transfer set although it was maintained in the training set. Just why this occurs is not apparent.

Skinner (1969, 1974) has long suggested that the explanatory function of cognitive mechanisms may be replaced by descriptions of environmental contingencies. Model B describes one set of contingencies responsible for generalized identity matching.

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