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TEACHING ARBITRARY MATCHING VIA SAMPLE STIMULUS-CONTROL SHAPING TO YOUNG CHILDREN AND MENTALLY RETARDED INDIVIDUALS: A METHODOLOGICAL NOTE

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Two experiments demonstrated the efficacy of sample stimulus-control shaping programs for teaching arbitrary matching to 4 subjects who did not acquire the performances via standard methods (i.e., differential reinforcement and, in two cases, comparison intensity fading). All 4 had previously demonstrated identity matching with two-dimensional forms. Identity matching performances were then transformed into arbitrary matching by gradually changing the sample stimuli until they no longer resembled the comparison stimuli. Where applicable, these methods may have advantages over others that have been used after the failure of standard techniques.

Key words: matching to sample, identity matching, arbitrary matching, stimulus-control shaping, touching, normally capable children, mentally retarded adults

The growth in research on stimulus equivalence and related phenomena with matching-to-sample techniques has brought to light a methodological problem. Arbitrary matching-to-sample baselines often prove difficult to teach, particularly when subjects are young children or mentally retarded people. When subjects have developmental limitations, even procedures that provide supplemental verbal instructions may prove ineffective (cf. Gollin & Liss, 1962).

Several recent studies (e.g., McIlvane, Dube, Kledaras, Iennaco, & Stoddard, 1990; Saunders & Spradlin, 1989, 1990) have examined alternatives to the standard teaching methods (i.e., differential reinforcement with or without supporting prompts) with mentally retarded subjects who did not learn after more-or-less protracted training. Saunders and Spradlin required subjects to emit different responses to different samples (e.g., naming them), thus requiring ongoing successive discrimination of one sample stimulus from another during training. McIlvane and colleagues first developed consequence-based stimulus classes via repeated yoked reversals of several simple discriminations (i.e., contingency classes; Sidman, Wynne, Maguire, & Barnes, 1989) and then systematically transformed the simple discriminations into arbitrary matching. Although both procedures succeeded, they required scores of training sessions and are not appropriate for certain applications. The present study sought a more rapid and effective training procedure.

Many subjects who have difficulty acquiring arbitrary matching readily learn identity matching (Saunders & Spradlin, 1989), so we sought to take greater advantage of this potentially relevant entry skill. We asked whether stimulus-control shaping methods (McIlvane & Dube, in press; cf. Sidman & Stoddard, 1967) might be used to transform identity matching into arbitrary matching by gradually altering the physical features of the sample. Following the suggestion of McIlvane and Dube (in press), the term *stimulus-control shaping* is used here and throughout as a generic term to describe a program of gradual stimulus changes arranged to transfer stimulus control. It should be differentiated from *stimulus shaping,* which has been used most recently to refer to programs that gradually transform topographical features of a controlling stimulus (Schilmoeller & Etzel, 1977).

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EXPERIMENT 1

The first experiment conducted a preliminary exploration of sample stimulus-control shaping methods with normally capable preschoolers.

METHOD

Subjects

S1 and S2 were females aged 5 years 10 months and 4 years 7 months, respectively. They had no prior experimental history.

Apparatus and Stimuli

The subject sat before a panel of seven windows mounted on a modified SR-400 teaching machine (Behavioral Controls, Inc.). The windows, each 3.86 cm in diameter, were arranged in a circle of six, with the seventh in the center. The display diameter was 13.59 cm (outer edge to outer edge); all windows were separated by 4.88 cm (center to center) from the adjacent and center windows.

Stimuli were presented behind touch-sensitive windows. The stimuli were forms, Arabic numerals and Greek letters, drawn by hand on fan-fold paper that was advanced or stopped by the SR-400 console acting in concert with solid-state control and data-recording circuitry. Embedded within each window was a layer of liquid crystal that was used to make the forms appear and disappear.

The SR-400 was not capable of backing up to earlier program steps, a common feature of automated programming methodology (e.g., Sidman & Stoddard, 1966). Therefore, backups following errors were accomplished by stopping the program and restarting it at an earlier step in the program sequence.

Reinforcers were pennies or pieces of candy delivered in a tray to the right of the stimulus display apparatus. Reinforcer type was constant within sessions but could vary across sessions according to subject preference.

Matching-to-Sample Procedures

Matching-to-sample sessions lasting about 30 min were typically conducted daily. Every trial began when a sample and two comparison stimuli were displayed on the center and two outer keys, respectively. Only four of the six outer keys were used. The sample stimuli and the positions of the correct and incorrect comparison stimuli varied unsystematically across trials. A correct comparison selection was followed by delivery of a reinforcer and a 3-s intertrial interval (ITI). A response to the incorrect comparison stimulus, a blank key, or the sample was followed by a buzzer and the ITI. Trials had no time limit. Any responses during the ITI postponed the next trial for 3 s.

Preliminary training. Identity matching to sample was established using Arabic numerals. On the first trial, numeral 1 was the sample stimulus, and numerals 1 and 2 were the comparison stimuli. The experimenter said "Look at the button in the middle. Find the other . . . (pause). Now, touch it." The numeral 2 was the sample on the second trial. Thereafter, 1 and 2 varied across a 20-trial set as the sample. When subjects met a 90% accuracy criterion, a 24-trial set of identity matching trials with the numerals 3 and 4 assessed generalized identity matching. Subjects were then given identity matching tasks involving Greek letters used as stimuli in subsequent experimentation.

Arbitrary matching pretest/teaching assessment. Next, subjects were given the opportunity to learn arbitrary matching via differential reinforcement ("trial and error"). The matching tasks (Tasks A, B, and C) are shown in Figure 1. Subjects received at least two 24-trial training sets per task, and qualified for the sample stimulus-control shaping procedure if accuracy scores did not rise above chance levels. All Task A pretesting and subsequent training came first and were followed in succession by Tasks B and C.

Sample stimulus-control shaping programs. Two-phase programs were developed to teach the arbitrary matching tasks. As is typical in the initial stage of developing a stimulus-control shaping program, the gradual stimulus changes were dictated merely by experimenter judgment as to where they might prove necessary (cf. Sidman & Stoddard, 1966). The program to teach Task A is shown in Figure 2. The baseline was identity matching involving Δ and Φ. In the first phase of the Task A program, the Δ sample stimulus was changed gradually in nine steps into Σ; the Δ comparison stimulus was correct on all program trials. To maintain control by the sample stimulus, shaping trials were interspersed among an approximately equal number of identity matching trials that presented the Φ sample. The first program phase ended with a test that re-

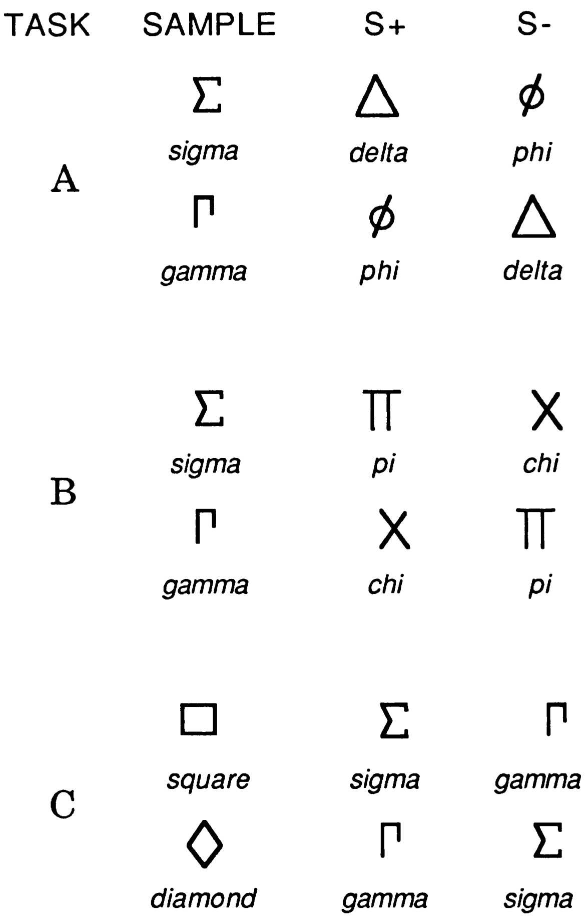

Fig. 1. Stimuli and arbitrary matching tasks (A, B, and C) presented in Experiment 1. Each trial displayed a sample, a correct comparison stimulus (S+), and an incorrect comparison stimulus (S−).

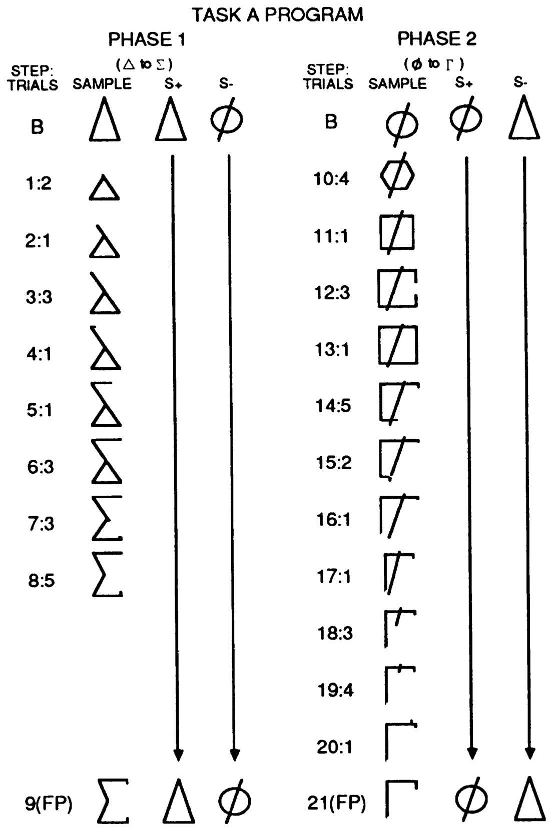

Fig. 2. Sample stimulus-control shaping program to teach Task A. The baseline identity matching and final performance arbitrary matching trials are designated B and FP, respectively.

quired the subject to match Δ to Σ and Φ to Φ on 12 trials each. S1 was also given an additional 60-trial session that reviewed these performances after an unanticipated delay of several days between testing.

In the second program phase, Φ was changed in 11 steps into Γ; Φ was the correct comparison stimulus on program trials. Sample control was maintained by interspersing stimulus-control shaping trials among trials that maintained the performance learned in the first phase.

Only S1 was given the Task B and Task C sample stimulus-control shaping programs. The Task B program sought to teach her to match X to Γ and Π to Σ. The Task C program sought to teach her to match Σ and Γ to geometric forms, square and diamond, respectively. The programs were similar to the Task A program but differed in the number of shaping steps. In the Task B program, there were 11 steps in the first phase and 14 in the second. In the Task C program, there were seven steps in each phase.

Arbitrary matching posttests. After subjects completed each of the sample stimulus-control shaping programs, a posttest was given. The posttest consisted of 24 trials, 12 of each arbitrary matching trial type.

RESULTS

Both subjects acquired the identity matching baseline virtually without error and went on to display generalized identity matching.

Arbitrary matching pretest/teaching assessment. S1 was given 10, two, and four 24-trial sets on Tasks A, B, and C, respectively. Figure

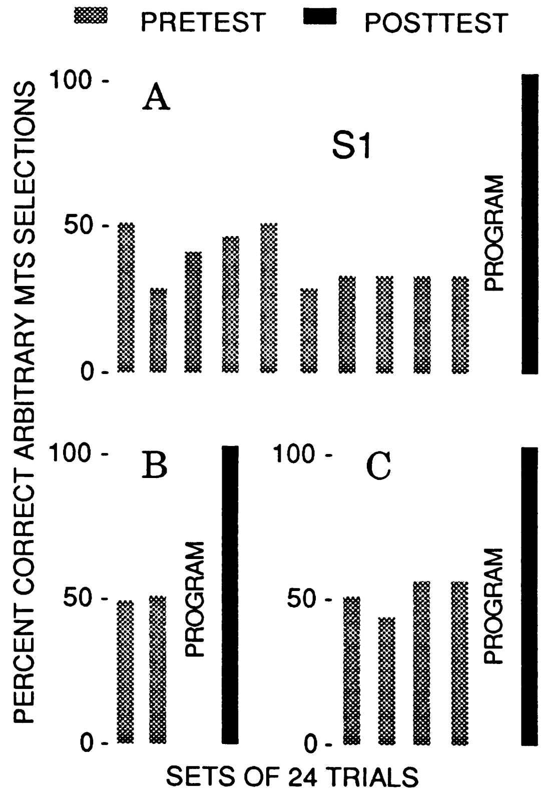

Fig. 3. Performance of S1 during the pretest/training assessments (lighter bars) and posttests (darker bars) in Experiment 1.

3 shows that accuracy scores never rose above chance levels. S2 was given two 24-trial sets on Task A, achieving 50% accuracy scores in both. On the Task B and Task C pretests, however, the differential reinforcement contingency sufficed to teach her the arbitrary matching tasks. She made few pretest errors, and thus did not require the sample stimulus-control shaping procedures.

Sample stimulus-control shaping programs. With S1, the Task A program was implemented over 442 trials, about half of which were sample stimulus-control shaping trials. She made a total of 46 errors during the program. With S2, the program was implemented over 440 trials, and she made a total of 33 errors. Most errors occurred on sample stimulus-control shaping trials during predictably critical stimulus transitions. During Phase 1, that transition occurred when the Δ-like triangular shape was eliminated. During Phase 2, the transition occurred when the diagonal was eliminated. The Task B and Task C programs were implemented over 109 and 96 trials, respectively. S1 made a total of five and seven errors, respectively.

Arbitrary matching posttests. Both subjects' posttest accuracy scores were near 100%. These arbitrary matching baselines were maintained throughout a subsequent experiment that demonstrated that the conditional relations established by the arbitrary matching procedures were equivalence relations (Sidman & Tailby, 1982).

DISCUSSION

The results of this preliminary study were encouraging. Both subjects acquired arbitrary matching via the sample stimulus-control shaping programs. Results with S1 on Task A were particularly noteworthy. During 240 pretest trials, she made 148 errors, and her behavior had apparently stabilized at chance accuracy levels. Given the Task A sample stimulus-control shaping program, however, she was able to learn Task A with relative ease. Given her performance during the Task A pretest, it seems unlikely that continued exposure to the pretest conditions would have led to comparable accuracy gains.

Both children also demonstrated a "learning-to-learn" phenomenon like that reported by Saunders and Spradlin (1990). After acquiring arbitrary matching via programmed training on Task A, the children mastered subsequent problems more rapidly. S2 did not require programmed training after Task A; differential reinforcement alone then sufficed. Although S1 did receive all three programs, she made many fewer errors on the latter two.

EXPERIMENT 2

This experiment examined a sample stimulus-control shaping method to teach arbitrary matching performances to mentally retarded subjects. The subjects' levels of functioning were comparable to those of subjects who have participated in other recent studies of methods for teaching arbitrary matching baselines (e.g., McIlvane et al., 1990; Saunders & Spradlin, 1989, 1990).

METHOD

Subjects

S3 was female, 32 years old, severely retarded (Leiter IQ score: 35), and had a profound hearing loss; she signed to communicate.

S3 had lived in a state institution for most of her life. S4 was male, 16 years old, moderately retarded, and had relatively advanced verbal skills (Peabody Picture Vocabulary Test age-equivalent score: 7.5 years). S4 was a student in a residential program for individuals with developmental disabilities.

Apparatus

The apparatus has been described previously (Dube, McIlvane, Maguire, Mackay, & Stoddard, 1989). The screen of a Macintosh-Plus® computer (19 cm by 14 cm) displayed five white squares (4.5 cm by 4.5 cm; response "keys") on a gray background. One key was located in the center of the screen, and the others were at the four corners. Black forms, approximately 2 cm by 2.5 cm, were displayed on the keys, and the subject responded by touching them. Data were recorded on disk.

Procedure

Pretraining. Training was accomplished via shaping, modeling, minimal spoken or signed instructions (i.e., "touch" or "point picture"), and differential reinforcement. In a discrete-trial simple discrimination procedure, subjects first learned to touch a key that displayed one of the four forms shown in Figure 4 (upper portion) and to refrain from touching the other keys that displayed no form. Forms appeared in a quasi-random order. Position varied unsystematically on one of the outer keys; the center key was not used during pretraining. The subjects next learned the identity matching-to-sample tasks shown in Figure 4 (middle portion) to a criterion of at least one perfect 36-trial session. Every matching-to-sample trial began when a sample form, either B1 or B2, was displayed on the center key. A touch of that key was followed by the presentation of B1 and B2 as comparison forms on any two of the four outer keys. One form was identical to the sample, and its selection was defined as correct.

In preparation for a later experiment, an outcome-specific reinforcement procedure was used (Dube et al., 1989). All selections of A1 (on S+ alone trials) and B1 (on either S+ alone or identity matching trials) were followed by one food reinforcer; all selections of A2 and B2 were followed by a different reinforcer. Prior to the experiment, a paired-comparison preference test had identified two reinforcers that were about equally preferred. The different foods were also accompanied by a unique visual display on the computer screen and brief sequences of computer-generated tones. Intertrial intervals were approximately 15 s.

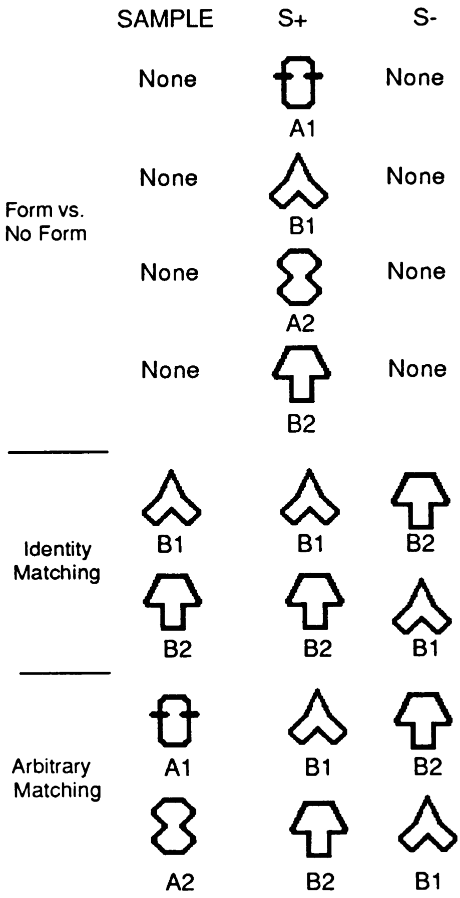

Fig. 4. Stimuli and discrimination tasks presented in Experiment 2. Letter-numeral combinations (e.g., A1) are used merely for convenience in description and did not appear on the trial displays.

Arbitrary matching teaching assessment. Immediately following pretraining, both subjects received two sessions of an intensity-fading procedure that had been used in prior work to teach arbitrary matching performances to other mentally retarded subjects (Dube et al., 1989). The arbitrary matching tasks are shown in the lower portion of Figure 4. At the start of each trial, a sample stimulus, A1 or A2, was displayed on the center key. After the subject touched it, the comparison stimuli, B1 and B2, appeared on two of the outer keys. If the sample was A1, selecting B1 was defined as the

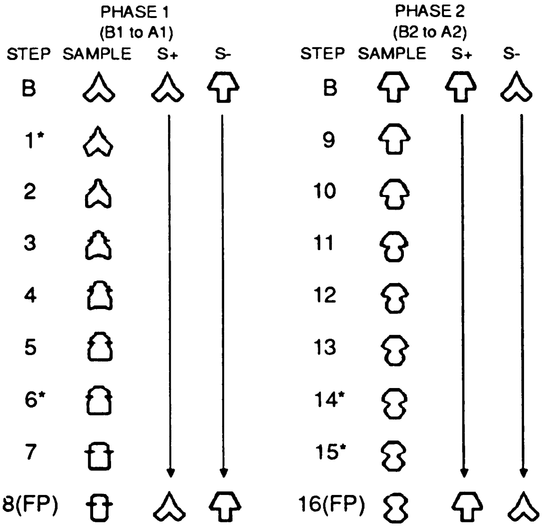

Fig. 5. Sample stimulus-control shaping program presented in Experiment 2. Program steps marked with asterisks were added to the program during or after S3's participation. B and FP indicate the baseline identity matching and arbitrary matching final performance trials, respectively.

correct behavior. If the sample was A2, however, then selecting B2 was correct.

During the intensity-fading program, the S− comparison stimulus was gradually faded in by progressive increases in its apparent intensity. The S+ stimulus was always displayed at full intensity. Two consecutive correct responses advanced the program to the next step, and one error backed the program to the previous step. Pretesting was limited to two sessions because past study of subjects with moderate-to-severe disabilities has shown that lengthy pretesting may produce error patterns that require dozens of training sessions to eliminate, if they can be eliminated at all (e.g., Stoddard, Brown, Hurlbert, Manoli, & McIlvane, 1989; Stoddard, de Rose, & McIlvane, 1986; cf. Stoddard & Sidman, 1967).

Teaching arbitrary matching via sample stimulus-control shaping. The baseline for the sample stimulus-control shaping procedure was identity matching with B1 and B2 (Figure 4, middle portion). A stimulus-control shaping program gradually transformed sample stimuli B1 and B2 into the arbitrary matching sample stimuli, A1 and A2. Originally, six-step sequences were designed to transform each sample. However, steps were subsequently added (see below), and the programs ultimately had eight steps. Figure 5 shows the program that was used with S4. Exceptions with S3 will be noted along with the results. Each correct response at a given program step advanced the subject to the next step. Each error returned the subject to the previous program step.

During the first phase of the program, B1-to-A1 sample stimulus-control shaping trials alternated irregularly with B2 identity matching trials. When the B1-to-A1 sequence was completed (Figure 5, Step 8), the subjects were required to meet a criterion of at least eight of eight correct trials at the final performance before advancing. During the second phase of the program, B2-to-A2 shaping trials alternated irregularly with arbitrary matching trials that displayed A1 as the sample. When the B2-to-A2 shaping sequence was completed, maintenance of the performance was assessed in subsequent sessions that presented only the arbitrary matching trial types shown in the lower portion of Figure 4. If 90% or greater accuracy was not maintained, subjects were given further program trials to recover it.

RESULTS

Pretraining. Both subjects learned the form versus no-form discrimination to a criterion of 36 consecutive correct unprompted trials in one session. Both subjects also displayed virtually errorless identity matching. S4 did so immediately, and S3 did so after two sessions of response shaping devoted primarily to slowing down initially very rapid selections.

Arbitrary matching teaching assessment. During the intensity fading, both subjects responded accurately when the S+/S− intensity disparity was great, but accuracy broke down when the disparity was reduced. In her two fading sessions, S3 never advanced beyond Step 14 of the 16-step program. In his fading sessions, S4 advanced rapidly through the program, but accuracy dropped immediately to chance levels (33% correct) at the final performance.

Teaching arbitrary matching via sample stimulus-control shaping. Both subjects acquired the arbitrary matching baseline. S3's program was accomplished over seven sessions that presented a total of 544 trials (sample stimulus-control shaping and baseline trials combined).

S4's training was accomplished over five sessions that presented a total of 146 trials.

In S3's initial B1-to-A1 shaping session, the program advanced from the step labeled B directly to the one labeled Step 2 in Figure 5. S3's performance broke down immediately, and she responded with only 50% accuracy on 20 Step 2 shaping trials. Step 1 was therefore added to the series on the assumption that the degree of change in the physical characteristics had been too great to allow transfer of stimulus control. In her next session, S3 then advanced rapidly through her program (which omitted the step labeled Step 6 in Figure 5), and she made only seven errors before reaching the final performance in Phase 1. During the final 36 trials of this session, she selected the B1 comparison in the presence of the A1 sample on each of 18 trials; on the remaining 18 trials, she selected the B2 comparison in the presence of the B2 sample.

S3's B2-to-A2 shaping (Phase 2) went smoothly until she reached apparently critical transition points labeled Steps 13 and 16 in Figure 5. Errors became frequent, suggesting that the steps originally designed had also been too big. Therefore, the steps labeled 14 and 15 in Figure 5 were added to the series. S3 then completed the program. She made a total of 43 errors during Phase 2.

S3's subsequent two sessions assessed maintenance of arbitrary matching. Accuracy was high in the first (96% correct) but deteriorated in the second (58% correct). Progression through the B2-to-A2 shaping series once again (with a single error) restored accurate arbitrary matching, and it was maintained with 100% accuracy in two subsequent sessions.

S4 had little difficulty completing the sample stimulus-control shaping programs. He made only three errors during the first B1-to-A1 shaping series. However, he responded inaccurately initially on the final performance trials, making errors on three of seven trials. In S4's next session, he proceeded errorlessly through Step 6, but a computer programming error resulted in the presentation of an impossible discrimination trial and led to four successive errors. When the program was restarted, S4 responded correctly on all program trials and on each of 20 final performance trials.

During S4's first B2-to-A2 shaping session, he made two errors during shaping and two errors on eight final performance trials. His subsequent session began with two errors on four such trials. B2-to-A2 shaping resumed at Step 12, and he advanced without error to the final performance. At this point, he responded correctly on each of 44 arbitrary matching trials (22 with the A2 sample). In three subsequent maintenance sessions, S4 responded correctly on each of 112 such trials.

DISCUSSION

The results of sample shaping with S3 and S4 systematically replicated those of Experiment 1. Both subjects acquired arbitrary matching baselines after only a few sessions of training. These results compare favorably to those reported by Saunders and Spradlin (1989, 1990) and McIlvane and colleagues (1990), in which protracted training over scores of sessions was required to establish the first arbitrary matching performances. The present results suggest that sample stimulus-control shaping may be an important alternative technique for teaching arbitrary matching to subjects with developmental limitations, even though some questions remain to be answered.

First, this experiment did not conduct extensive pretests with the intensity-fading procedure. One might ask whether S3 and S4 could have learned arbitrary matching with more lengthy exposures to that method as well. Although logically possible, that outcome would not be consistent with prior studies in our laboratory (e.g., Rosenberger, Stoddard, & Sidman, 1972). We have found that even protracted exposures to such procedures are not likely to succeed with severely mentally retarded subjects if there is no indication of learning during the initial sessions.

Second, one might ask whether the outcome-specific reinforcement procedure was a variable in our subjects' acquisition of arbitrary matching. It has been suggested that such procedures can enhance mentally retarded individuals' conditional discrimination learning (e.g., Litt & Schreibman, 1981), although the empirical evidence is weak (cf. McIlvane, Dube, Kledaras, de Rose, & Stoddard, in press). Because the outcome-specific reinforcement procedure was also used with the unsuccessful intensity-fading procedure during the teaching assessment, it seems likely that acquisition was due to the stimulus-control shaping and not to the reinforcement procedure.

GENERAL DISCUSSION

Sample stimulus-control shaping methods taught arbitrary matching performances to normally capable preschoolers and mentally retarded individuals. The results of this first study, however, demonstrate only that the stimulus-control shaping method was sufficient rather than necessary. Although the method succeeded after the failure of simple differential-reinforcement and intensity-fading procedures, the experimental designs do not allow one to conclude that sample stimulus-control shaping is a superior teaching method. The data do demonstrate that the method is feasible, thus illustrating a new and promising approach to developing arbitrary matching baselines.

Previous research and theoretical analysis suggest that the sample stimulus-control shaping method should succeed where other traditional teaching methods fail. In their analysis of conditional discrimination learning, for example, Saunders and Spradlin (1989, 1990) have shown that conditional discrimination is encouraged when the teaching methods establish and maintain both successive discriminations between and among the sample stimuli and the simultaneous discrimination of the comparisons. Their work suggests that teaching procedures that do not explicitly require these discriminations are prone to fail. Proceeding as it does from an already established conditional discrimination (i.e., conditional identity matching), the sample stimulus-control shaping method appears to maintain the critical successive and simultaneous discriminations throughout teaching.

Additional conceptual support for the present methodology can be found in research that has demonstrated the superiority of "criterion-related" over "noncriterion-related" stimulus-control shaping procedures (cf. Schilmoeller & Etzel, 1977). The essential features of the former are (a) establishing control by a stimulus difference that will be present at the final performance and (b) maintaining control by that difference during stimulus-control shaping. In arbitrary matching, the samples are the critical stimuli that must control behavior initially and throughout stimulus-control shaping. None of the other potentially "errorless" programming methods so far reported for teaching arbitrary matching explicitly encourage the subject to observe relevant sample-stimulus features before responding (cf. Lancioni & Smeets, 1986). Indeed, as we have argued previously (McIlvane et al., 1990), those methods direct observing to irrelevant stimulus features, producing an outcome resembling that seen in studies of blocking phenomena (Kamin, 1969; cf. Rescorla & Wagner, 1972).

The fact that the programs employed in the present study did not teach the arbitrary matching performances errorlessly indicates the need for program revisions to refine the steps at critical stimulus transition points. The program deficiencies, however, were valuable in that the errors help to rule out further the possibility that subjects' nominal arbitrary matching continued to be based on common physical features of the sample and comparison stimuli. If those stimuli continued to resemble one another closely, then performance during sample stimulus-control shaping would have been comparable to the virtually errorless performance observed on identity matching baseline trials. As improved sample stimulus-control shaping programs are developed, experimental procedures may have to incorporate more extensive controls for matching performances based on physical features (e.g., large stimulus sets and transitivity tests).

This study can be viewed as part of a larger ongoing effort to analyze and teach the behavioral prerequisites for matching to sample. One result has been clarification of the complexities of this procedure as it is used with both human and nonhuman subjects (e.g., Dube, McIlvane, & Green, in press; Wright, Cook, Rivera, Sands, & Delius, 1988). Through research accomplished in the past 5 years, one can now envision a more complete and possibly more broadly effective program for teaching matching-to-sample baselines to subjects with developmental limitations or disabilities. It would begin by using any of several prompting methods to establish simple form discrimination (e.g., Richmond & Bell, 1986; cf. Sidman & Stoddard, 1966) and perhaps the initial identity matching baseline (Rosenberger et al., 1972). If problems were encountered in teaching the latter, promising remedial approaches have been outlined and empirically validated (Dube, Iennaco, Rocco, Kledaras, & McIlvane, in press; McIlvane et al., 1990). Where appropriate apparatus and/or sufficient technical or graphics skills are available, arbitrary matching can be taught via sample stimulus-control shaping. Alternative procedures that do not have these requirements are also available when technical limitations or stimulus characteristics preclude the use of this method (e.g., McIlvane et al., 1990; Saunders & Spradlin, 1989, 1990).

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