JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1974, 22, 261-273 NUMBER 2 (SEPTEMBER)

ACQUISITION OF MATCHING TO SAMPLE VIA MEDIATED TRANSFER[1]

MURRAY SIDMAN, OSBORNE CRESSON, JR., AND MARTHA WILLSON-MORRIS

NORTHEASTERN UNIVERSITY AND THE EUNICE K. SHRIVER CENTER AT THE WALTER E. FERNALD STATE SCHOOL

Two severely retarded Down's-syndrome boys learned a matching-to-sample performance through mediated transfer. The transfer paradigm involved three sets of stimuli, one auditory set (A) and two visual sets (B and C). The subjects were taught directly to do B-A and C-B matching, but experienced no direct association between C and A. They acquired the ability to do C-A matching without having been taught that performance directly. They also learned indirectly to name some of the visual stimuli, but naming was apparently not the mediator in the emergent C-A matching. The use of words and letters as stimuli highlighted the possible relevance of mediated associations in the indirect acquisition of elementary reading comprehension and oral reading. The acquisition of matching via mediated transfer also raised some new considerations concerning the role of coding responses in arbitrary matching to sample.

In his germinal paper on mediated association, or mediated transfer, Peters (1935) cited early associationist philosophers and psychologists in his description of this phenomenon: ". . . the successive appearance of apparently unrelated ideas in consciousness can be accounted for only on the basis of a third idea which is definitely related to both of them. . . . the term 'mediate association' refers to an indirect associative connection between two items of experience, ideas, or mental acts, as opposed to a direct type of associative connection. And this indirect associative connection is one supposedly mediated by a third item that has been directly associated with both of them. When we find two ideas A and B appearing in succession with no possibility of their previous, direct association, we will usually find that both A and B have formerly been associated with an item C. Thus, the connection A-B is the result of two other connections, A-C and B-C" (Peters, 1935, pp. 20-21).

Subsequent experimentation, usually using paired-associate techniques in the verbal learning tradition, has amply confirmed the existence of mediated transfer, although the descriptive language has tended away from ideas and mental acts to stimuli and responses (Jenkins, 1963).

We have recently demonstrated mediated transfer by using matching-to-sample procedures with retarded subjects (Sidman, 1971; Sidman and Cresson, 1973). In these earlier experiments, the subjects first learned to match sets of 20 pictures and 20 printed picture names to corresponding dictated names. They then proved able for the first time to match printed words to the corresponding pictures, with word-picture matching never having been taught directly.

The relation of the matching-to-sample experiments to the familiar mediated-transfer, or mediated-association paradigm, can be seen in Figure 1. A, B, and C are three sets of stimuli. Arrows point from comparison to sample stimuli. Subjects first learned to match B to A, and C to A; they were then able to match B to C, and C to B.

In this example, matching printed words to pictures and pictures to printed words may be regarded as simple reading comprehension; matching pictures to dictated words as simple auditory comprehension; and the matching of printed to dictated words may be called "auditory receptive reading". The earlier studies thus had some relevance both to the principles and practicalities of teaching elementary reading.

[1]This research was supported by Grants HD 05124 and HD 04147 from the National Institute of Child Health and Human Development. We are indebted to F. Garth Fletcher for his technical assistance, and to Nan Haar for performing the IQ evaluations. Reprints may be obtained from Murray Sidman, Department of Psychology, 440UR, Northeastern University, Boston, Massachusetts 02115.

The present experiment, however, was concerned with the nature of the mediated-transfer process itself. One interpretation of the original finding is that the subjects' emergent ability to match printed words to pictures was mediated by their previous training to match both of these sets of stimuli to the same auditory stimuli. For example, in the course of learning the crossmodal matching, they had learned to match the picture of a car and the printed word *car* to the dictated word "car"; they were then able to match the picture to the printed word through the mediation of the dictated word.

A second interpretation is also possible. Before they learned the visual-auditory matching tasks, the subjects had some proficiency in naming the pictures, but could not name the printed words. After they had learned the crossmodal matching tasks, they proved able for the first time to name the printed words—to read them aloud. The emergence of oral reading raised the possibility of a different mediation path for the indirectly learned word-picture matching. This path is illustrated by the triangle on the right of Figure 1. For example, subjects had learned to say "car" in response to pictures of cars (B-D) and to the printed word car (C-D); they were then able to match picture with printed word (B-C and C-B) through the mediation of the spoken word.

Was the subjects' emergent reading comprehension (matching printed words to pictures) mediated by the dictated words spoken *to* them? Or did names spoken *by* the subjects, either aloud or implicitly, mediate their word-picture matching? The first possibility would imply stimulus mediation via receptive channels. The second would require response mediation, and would be consistent with stimulus-response models of mediated transfer (Jenkins, 1963; Schoenfeld and Cumming, 1963). To emphasize the distinction, the mediation triangle on the left side of Figure 1 has been labelled, "receptive", and the triangle on the right, "expressive".

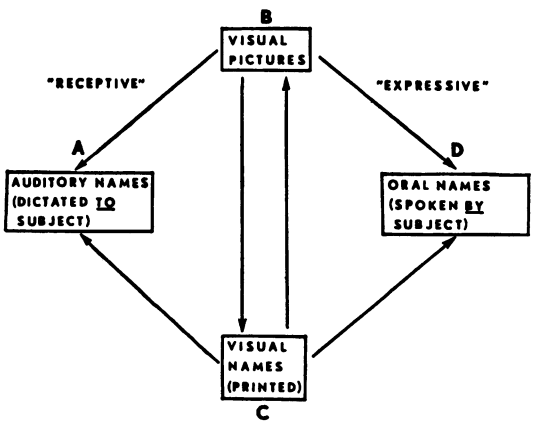

Fig. 1. Stimuli, responses, and mediated-transfer paradigms for Subject J.C. In the "receptive" triangle, arrows point from comparison to sample stimuli. On the "expressive" side, arrows point from visual stimuli to oral naming responses.

A major purpose of the present experiment was to determine whether mediated transfer, demonstrated within the context of matching to sample, requires a response as the mediator or whether stimulus mediation is sufficient to carry the explanatory burden. Are the prerequisites for the emergence of B-C and C-B to be specified as B-A and C-A, or as B-D and C-D (Figure 1)?

If naming mediated word-picture matching in the earlier experiments, it becomes necessary to explain how word naming itself emerged. A possibility was suggested (Sidman and Cresson, 1973) when one subject's picture naming improved as a consequence of learning auditory comprehension (matching pictures to dictated words). Could he also have learned oral reading (naming printed words) simply as a consequence of learning auditory receptive reading (matching printed to dictated words)? If so, printed-word naming and picture naming might then have mediated reading comprehension (picture-word matching).

Although the conditions under which receptive training facilitates expressive speech are still unknown (Guess, 1969; Guess and Baer, 1973), it seems reasonable to suppose that the subjects learned to read the words aloud because of their receptive training in matching printed words to dictated names. In the present experiment, we eliminated this avenue for the learning of oral reading, in the hope that we could assess the likelihood of receptively mediated transfer.

By proceeding around the receptive triangle (Figure 1) in another direction, we prevented the subject from experiencing any direct association between printed words and their auditory counterparts. He was taught auditory comprehension (B-A) and reading comprehension (C-B) directly, and was then tested for the emergence of auditory receptive reading (C-A)

and oral reading (C-D). If the absence of direct C-A training prevented the subject from learning to name the printed words, but C-A itself still emerged from the B-A and C-B training, the possibility of receptive mediation would have to be seriously considered.

Attainment of this objective involved the assumption that the outcomes of the mediation paradigm used in the previous studies (B-A, C-A, test for B-C) and in the present experiment (B-A, C-B, test for C-A) would be similar—that mastery of the first two stages would result in mastery of the third. On the basis of paired-associate experiments (Jenkins, 1963), this assumption appeared reasonable, but its test in the contexts of matching to sample and crossmodal associations was a second objective.

A third objective was to use another set of stimuli, upper- and lower-case letters, to test the generality of mediated learning of matching to sample. Two experiments are described; each used different stimuli and differed in certain procedural features.

METHOD

Subjects

The subjects were two institutionalized Down's-syndrome boys, one (J.C.) 14 yr and 9 months and the other (P.A.) 18 yr old at the start of the first complete test session. Both were participants in a behavior modification project (Mackay and Sidman, 1968; Sidman, 1970), but received no reading instruction during the period covered by the experiment. Their experimental sessions were scheduled so as not to interfere with their project activities, and the pennies and tokens they earned were spent in accord with contingencies prevailing in the project. Approximately two months after the experiment was completed, Subject J.C. achieved a mental age of 3-4 on the Peabody Picture Vocabulary Test, 4-11 on the Stanford-Binet L-M Intelligence Test, and 6-9 on the Leiter Performance Scale. Subject P.A. did not undergo such formal testing, but all who were acquainted with him during the 8 yr of the project judged him considerably less advanced than Subject J.C. in all areas of functioning.

General Experimental Design

The subjects were to be taught two legs of the receptive mediation triangle, the crossmodal matching task B-A and the visual matching task C-B. They were then to be tested for the emergence of the third leg, the crossmodal matching task C-A. Also to be tested was the effect of the teaching on the two oral naming tasks, C-D and B-D. First, the subjects' pre-experimental capabilities were assessed by pretesting them on all these tasks. They were also pretested on, and if necessary, were taught identity matching (Subject J.C.: printed picture names to printed picture names; Subject P.A.: printed upper-case to upper-case, and lower-case to lower-case letters) in order to ensure that they could discriminate the visual stimuli. The left columns of Figures 3 and 4 list the types of stimuli and the responses required of the subjects in each kind of test. This test battery, administered before, during, and after the teaching (see below), provided the experimental data.

After the pretests, teaching was accomplished gradually, first one leg of the receptive transfer triangle (B-A) and then the other (C-B). Tests interspersed at various stages of the teaching evaluated the requisite baseline behavior, and evaluated nonspecific transfer effects arising from the teaching procedures themselves, apart from the associative transfer with which the experiment was concerned. Variations in this general procedure are described below.

Apparatus and General Test Procedures

The subject sat before a panel of nine translucent windows onto which stimuli were projected from the rear. The windows, each 7.32 cm in diameter, were arranged in a circle of eight with the ninth in the center (Figure 2). The display diameter, from outer edge to outer edge, was 32.72 cm; the center-to-center distance was 9.53 cm between adjacent windows on the perimeter, and 12.7 cm between the center window and each of the others.

Each trial began with a sample stimulus. Visual samples (black letters, words, or line drawings on a white background) appeared on the center window. With auditory samples, words or letter names were dictated and repeated through a speaker at 2.0- to 2.5-sec intervals by a continuous-loop tape system (Fletcher, Stoddard, and Sidman, 1971); the center window was illuminated but blank. Each sample, visual or auditory, remained

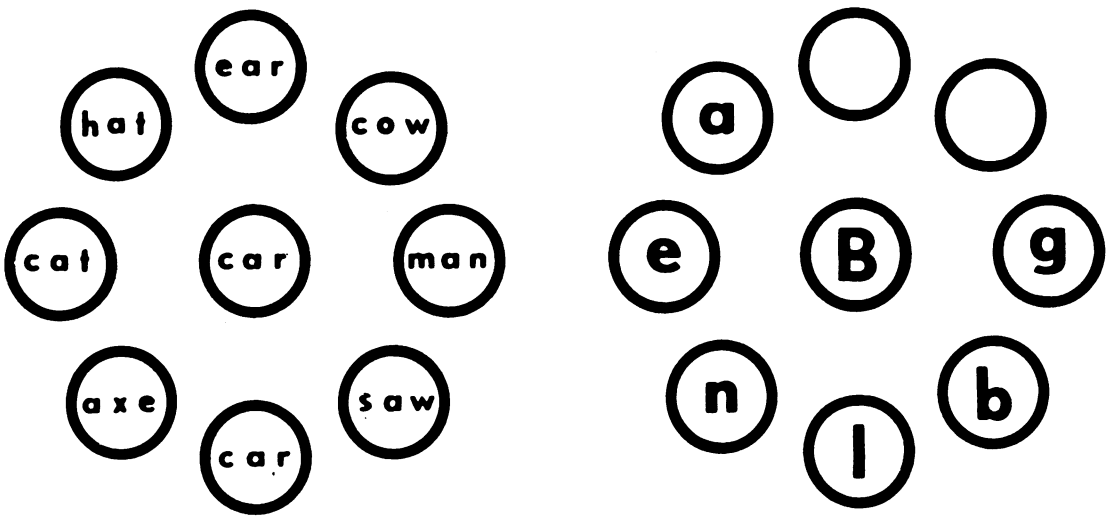

Fig. 2. Schematic diagrams of the display matrix, illustrating one trial from the identity word-word matching test, and one trial from the test of matching lower-case to upper-case letters. In other kinds of tests, the sample window (center) or the comparison windows (periphery) contained pictures or were blank.

present throughout the trial, and trial durations had no time limit.

In matching-to-sample tests, the subject pressed the center window to bring comparison stimuli, always visual, onto the outer windows. This "observing response" was always required, even when the sample was dictated. On each trial, one comparison stimulus, the correct one, corresponded to the sample. Subject J.C. had seven incorrect comparison stimuli (words or pictures) on every trial. Subject P.A. had five incorrect comparison stimuli (upper- or lower-case letters) and two blank windows on every trial (Figure 2). Sample stimuli and window positions of correct and incorrect comparison stimuli varied from trial to trial.

After the comparison stimuli appeared, the subject pressed a comparison window. Correct choices caused chimes to ring and a penny (Subject J.C.) or a token (Subject P.A.) to be delivered. Neither chimes nor penny or token followed an incorrect choice. All stimuli disappeared after each choice, and 1.5 to 2.0 sec later a new sample began the next trial (noncorrection procedure). Any window press during the intertrial interval postponed the next sample for 2 sec. Solid-state logic scheduled the procedures and recorded the responses automatically. Test sessions lasted about 1 hr.

In oral naming tests, the subject had simply to name the sample picture, word, or letter aloud. He was asked, "Tell me what you see". He pressed no windows, and no comparison stimuli appeared. Oral responses of both subjects were clear, and there was no ambiguity in determining whether they were correct. After each response, the experimenter pressed a handswitch to activate the reinforcement (if correct), intertrial-interval, and slide-change apparatus.

Visual and auditory samples never occurred together. With dictated samples, the center window was always blank; with visual word, letter, or picture samples, no stimuli were dictated.

Subject J.C.'s tests each had 20 trials. The stimuli, taken from a list of 20 pictures, or the printed (lower case) or dictated names of the pictures, were: axe, bed, bee, box, boy, bug, car, cat, cow, dog, ear, hat, hen, hut, hoe, man, pie, pig, saw, zoo.

Subject P.A.'s tests each had 24 trials. The stimuli were six letters, A, B, E, G, L, and N, presented in upper-case or lower-case form or as dictated letter names.

General Teaching Procedures

Teaching, which took place between each administration of the test battery, always involved matching to sample, sometimes with a correction and sometimes with a noncorrection procedure (see below). On the correction procedure, an error produced the usual intertrial interval, after which the same sample and

comparison display were presented again. On both the correction and noncorrection procedure, chimes and a penny or token followed any response to the correct comparison window.

Each test listed in Figures 3 and 4 had six versions, differing in their sequence of sample presentations and in the arrangements of stimuli on the panel. Also, each test set used a different variation of each picture. For example, the car in one set was a VW, and in another was an MG; the cat in one set was standing, and in another was lying down; *etc.* One version of each test was used only in the test battery. A systematic rotation through the other five sets during teaching prevented the subjects from learning display configurations, irrelevant display features, and sequences of samples or window positions, all of which would have permitted them to achieve high scores without observing the samples. Varied numbers of sets were presented during teaching sessions, which lasted 20 to 65 min and occurred one to five times a week.

Order of Conditions and Detailed Teaching Procedures for Subject J.C.

Table 1 summarizes the subject's testing and teaching sequence. Dates correspond to those at the bottom of Figure 3.

Pretesting. Three and 2 yr before the experiment began, Subject J.C. received the tests of auditory and reading comprehension. During these years he also had considerable matching-to-sample and oral-naming experience with other kinds of visual, auditory, and tactile stimuli, including colors and color names, numbers and number names, nonsense trigrams, and geometric forms. In preparation for the present experiment he received the complete test battery twice. The early scores have been included in order to show that mere exposure to the tests did not appreciably improve his reading and auditory comprehension or his oral reading.

Preteaching. Some of Subject J.C.'s low pretest scores (see Results) might have been caused simply by an inability to distinguish the printed words from each other. He was therefore taught word-word identity matching, selecting each of the 20 printed words from different sets of eight alternatives in response to printed-word samples. A typical display is in the left side of Figure 2. The teaching involved sets of noncorrection trials with all 20 samples, and correction trials with subsets of those samples he found troublesome. After 1240 trials he achieved a criterion of 95% correct in 120 trials of word-word identity matching, and was given the test battery again.

Table 1

Testing and Teaching Sequence for Subject J.C.

Procedures	*Dates*
A. Pretesting	
1. Test: Matching printed words to pictures (C-B) and pictures to dictated words (B-A)	7/07/67
2. Test: Same	9/27/68
3. Test: Complete battery	8/26/70
4. Test: Complete battery	9/10/70
B. Preteaching	
1. Teach: Identity matching of printed words to printed words	9/30/70 to 11/12/70
2. Test: Complete battery	11/15/70
C. First leg of transfer triangle (B-A)	
1. Teach: Matching pictures to dictated words	11/17/70 to 12/04/70
2. Test: Complete battery	12/08/70
D. Second leg of transfer triangle (C-B)	
1. Teach: Matching 9 printed words to pictures	12/09/70 to 12/30/70
2. Test: Complete battery	12/30/70
3. Teach: Matching 14 printed words to pictures	1/05/71 to 1/24/71
4. Test: Complete battery	1/24/71
5. Teach: Matching 20 printed words to pictures	2/03/71 to 2/15/71
6. Test: Complete battery	2/15/71
7. Reteach: Matching 20 printed words to pictures	2/18/71 to 2/24/71
8. Test: Complete battery	2/26/71

First leg of transfer triangle. He next learned auditory comprehension, matching each variation of the 20 pictures to its dictated name. Again, a mixture of correction and noncorrection procedures was used, the correction procedure being applied to special sets of sample stimuli with which the subject had difficulty. He required 540 trials to reach a criterion of 95% correct in 120 trials, and then received the test battery again.

Second leg of transfer triangle. The critical teaching involved the matching of printed-word comparisons to picture samples. Five

variations of each picture were presented in mixed sequences. The correction procedure was used throughout. Subject J.C. was first taught to match only nine of the printed words to their equivalent pictures. He was initially given sets of 10 trials with only two sample pictures, axe and zoo. When he achieved a score of 100% in a set of 10 trials, he was then given a second pair of pictures, hen and saw, to learn. After achieving 100% with the second pair, he was given variations of all four pictures as samples until he reached a criterion of 19 correct trials in a set of 20. This system of teaching the subject to match new words and then adding those to the previously learned set continued, with the following sequence of pairs: axe and zoo, hen and saw, man and bug, bug and dog (only one new word at this point), hoe and cow. He required 545 trials to meet the criterion for matching the first nine printed words to their corresponding pictures, after which he received the test battery again.

Subject J.C. then learned to match five more printed words to their equivalent pictures. These were taught in the following pairs: hut and hat, bed and bee, bed and boy. Each pair was presented until he achieved perfect performance in a set of 10 trials. He was then given a complete set of 20 sample pictures, including the six he had not yet been taught. If he did not score perfectly on all 14 samples he had been taught, he was given remedial trials with those he had matched incorrectly. When he achieved perfection on the remedial set, he was retested with the complete set of 20 samples. This process of testing with the complete set and then giving remedial teaching on those he had been taught but found difficult continued until, when given the complete set, he correctly matched all the words he had been taught. The subject met this criterion for the 14 samples in 640 trials and received the test battery.

The next teaching phase, carried out in the same manner as the preceding phase, added the last six pictures in the following sequence of pairs: boy and box, cat and car, car and ear, pig and pie. The subject required 380 trials to reach the learning criterion which, by this time, included all 20 samples. He then received the battery of tests again.

The final teaching stage involved special remedial sets of samples the subject sometimes still matched incorrectly. This teaching used all six sets of word-picture matching trials, including the test set, and the subject achieved 100% on all six sets after 380 trials. The final test battery followed this reteaching.

Order of Conditions and Detailed Teaching Procedures for Subject P.A.

For this subject, all six letters were comparison stimuli on every trial. He was taught to match printed upper-case letters to six dictated letter names, and printed lower-case letters to the six corresponding upper-case letters (Table 2).

Table 2

Testing and Teaching Sequence for Subject P.A.

Procedures	*Dates*
A. Pretesting	
1. Test: Complete battery	10/30/72
2. Test: Same	1/23/73
B. Two legs of transfer triangle	
1. Teach: Alternate visual-auditory matching (B-A) and visual-visual matching (C-B) for each letter consecutively	1/26/73 to 5/11/73
2. Test: Complete battery	5/11/73
3. Teach: Review previously taught matching, and teach the other visual-visual matching task (B-C)	5/14/73 to 5/30/73
4. Test: Complete battery	5/30/73

Pretesting. Like Subject J.C., Subject P.A. had considerable matching-to-sample and oral-naming experience with a variety of stimuli other than those used here. He was pretested twice on the complete battery, and did not have to be taught identity matching.

Two legs of transfer triangle. First, the subject learned to match two upper-case comparison stimuli, B and L, to their dictated names. When he reached 100% in a set of 24 trials, he then learned to match the two lower-case letters to their upper-case equivalents. A typical display is in the right side of Figure 2. When he reached 100% in the visual-visual task, he returned to visual-auditory matching. This alternation continued until he went through 96 consecutive trials, two sets of each task, perfectly within a single session.

A third sample, "A", was then added. When all three upper-case letters were matched perfectly to their dictated equivalents, the subject

was given the visual-visual task of matching the three lower-case comparisons to their appropriate upper-case samples. When he reached criterion on each task the other was re-introduced, the alternation continuing until he achieved perfect scores in four consecutive 24-trial sets, two sets of each type, within a single session.

The same procedure then continued, one new letter being added in each teaching step. The final samples to be introduced were "G", "N", and "E". After achieving a perfect performance with all six letters in both matching tasks, the subject had to meet additional criteria before receiving the test battery. First, he had to perform perfectly again on four alternating 24-trial sets, two of each type, within one session. Then, on the day of the test battery, he had to perform perfectly on one 24-trial set of each type. He required 5768 trials to meet these criteria.

In the final teaching phase, Subject P.A. received additional experience with the two tasks he had been taught. He also learned to match upper-case comparison letters to lower-case samples. With all six letters and letter names as samples, the teaching proceeded as before, with the addition of the third matching task. The subject again had to proceed errorlessly through a 24-trial set before going on to the next task. He also had to perform errorlessly on six consecutive 24-trial sets, two of each type, within a single session. Then, in the same session as the final test battery, he had to perform three 24-trial sets perfectly, one of each type. This teaching phase required 1824 trials.

RESULTS

Subject J.C.

Pretests. The sequence of teaching procedures and test results can be followed by scanning the dated columns in Figure 3. The subject's test scores before explicit teaching are in the four left columns of bars. In 1967 and 1968 (the first two columns), he matched pictures to dictated and printed words poorly, although he did somewhat better in auditory than in reading comprehension. His poorest performances on the complete test battery (8/26/70 and 9/01/70) were in the four tests at the top, all involving printed words. He did better, although short of perfection, in picture naming and auditory comprehension, which did not involve printed words. In identity matching of printed word to printed word, he scored no higher than 70%.

Tests after teaching identity matching (preteaching). After being taught visual word-word matching (9/03/70 to 11/12/70), the subject displayed his new skill by scoring 100% on the identity matching test (11/15/70). The other scores changed little; his poor reading did not reflect an inability to discriminate the printed words.

Tests after teaching auditory comprehension (first leg of transfer triangle). After he had learned auditory comprehension, Subject J.C. scored 100% on his newly taught skill (12/08/70). Learning to match pictures to dictated words also seemed to improve his picture naming slightly, although he did not consistently do as well in later tests. The change in auditory comprehension was not accompanied by appreciable increases in any of the reading scores. Learning one leg of the mediation triangle (B-A) did not cause the other legs to emerge. In the three matching tests of reading, his scores were close to the chance level for eight comparison stimuli per trial, and oral reading remained at zero. These poor scores apparently did not stem from an inability to distinguish the pictures from each other, or the dictated or printed words from each other. Although some difficulty in oral reading may have stemmed from an inability to say the words aloud, the subject's picture naming indicated that this problem could have been only minor and could not have accounted for his complete lack of oral reading.

Tests after teaching reading comprehension (second leg of transfer triangle). Would the establishment of this performance, matching printed words to pictures, cause the emergence of the third leg of the triangle, matching printed words to dictated words?

Double bars in the four reading tests (12/30/70) distinguish the scores for the nine words he was first taught to match to pictures (+) and the scores for the 11 words he had not yet been taught (−). The direct effect of the teaching was a large increase in the subject's accuracy in matching the nine printed words to their equivalent pictures, an increase not reflected in his score for the 11 untaught words. The reason for his less-than-perfect score on the nine critical words is unclear.

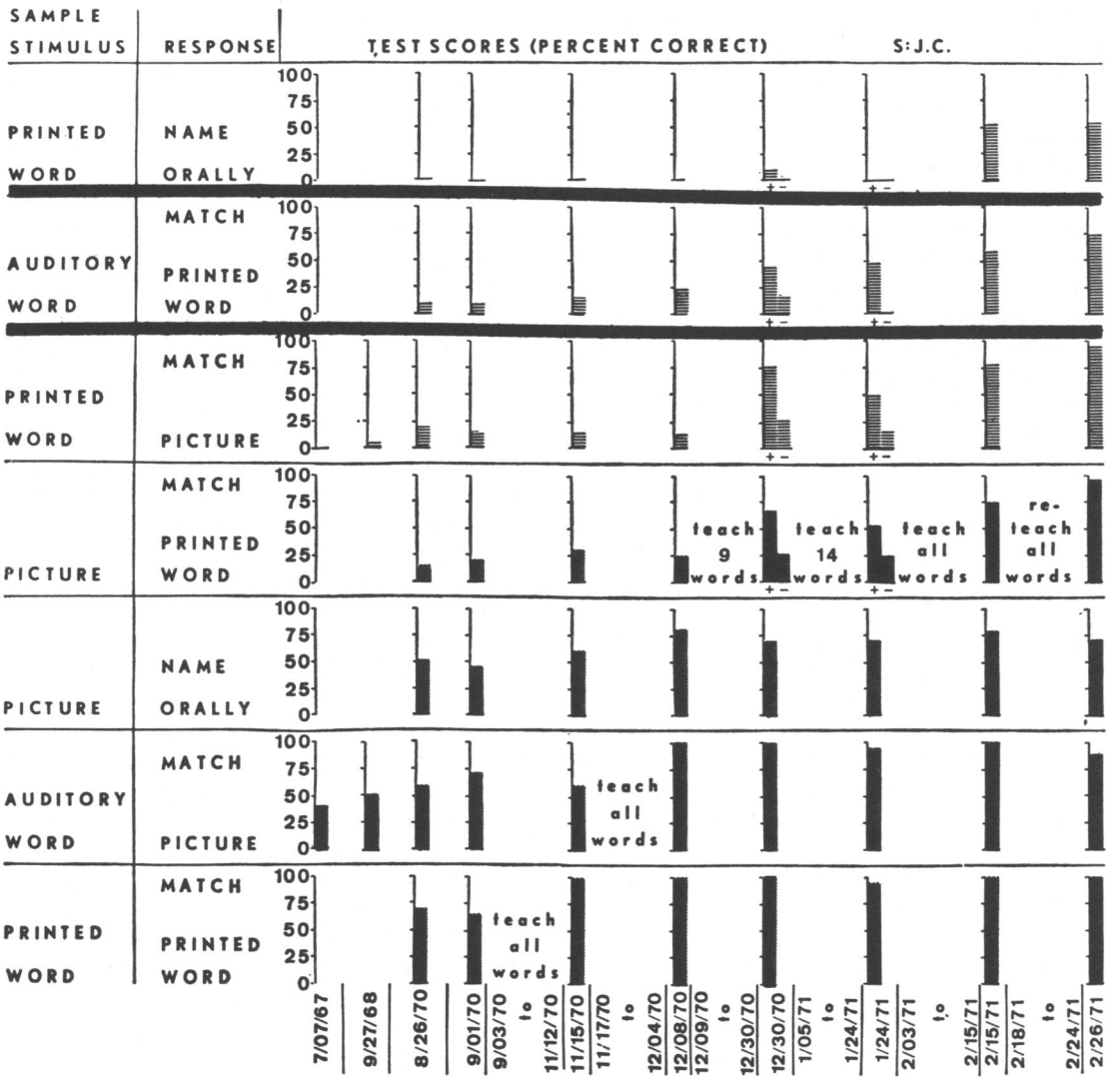

Fig. 3. Subject J.C. The two left columns identify the sample stimuli and responses that comprised each type of test. The row of bars to the right of each test represents the subject's scores in successive administrations of the test. The dates of each test, and of the interpolated teaching, are given below the columns of bars. In some test series, each of the four reading tests has two scores: the bars marked + represent the subject's performance with words he had been taught to match in the word-picture matching task; the bars marked − represent his performance with words he had not yet been taught.

Accuracy also improved considerably in matching picture-comparison stimuli to printed-word samples, although he had not received explicit training on this task.

In matching printed to dictated words, the subject improved modestly on the nine critical words. This improvement did not extend to the 11 untaught words, and the selectivity of the change provides evidence that the improvement was a transfer effect from the previous teaching.

In oral reading, the subject named one of the printed words aloud for the first time, but his score did not show an improvement comparable to that of the matching tasks.

Although the subject's scores after he had been taught 14 of the 20 words (1/24/71) were similar to those of the preceding tests, the percentages represent a larger number of correct responses. Furthermore, all of his correct choices in response to dictated samples were printed words learned in word-picture match-

ing. In spite of his improvement in matching printed to dictated words, he still showed no ability to read the printed words aloud.

Having learned to match all 20 printed words to picture samples, the subject correctly matched 12 (60%) of the printed words to dictated samples (2/15/71).

Also, for the first time, his oral reading improved distinctly. The way this came about is of interest. In the first seven trials of this test, he responded to the printed words by uttering nonsense syllables or letter names unrelated to letters within the words. On Trial 8, with *bee* as the sample word, he said, "bee-fire". On Trial 9, with *box* as the sample word, he suddenly sat up straight, clapped his hands, laughed, said, "I get it", and responded correctly. A similar "aha" reaction occurred on Trial 10. After failing the first seven trials, he went on to name nine of the next 13 words correctly. The first seven trials were then repeated, and he read three of those words aloud correctly. The correct responses upon retest were included in the score shown in Figure 3.

Although transfer to auditory receptive reading and to oral reading did occur, this transfer was far from perfect. Furthermore, the subject fell short of 100% even on the word-picture matching task he had been taught. Therefore, he was retaught word-picture matching and received the test series once more (2/26/71).

This time, Subject J.C.'s word-picture matching was almost perfect, as was picture-word matching, which had not been directly taught. Along with this improvement was an increased accuracy in matching printed to dictated words. Oral reading, however, remained at its previous level.

Subject P.A.

Pretests. The subject did visual-visual identity matching of upper- and lower-case letters perfectly in pretests, and continued errorlessly in every administration of the test battery. These consistently perfect performances were therefore omitted from Figure 4.

The two initial administrations of the test battery, nearly three months apart (Figure 4; 10/30/72 and 1/23/73), yielded consistent results. His best scores, less than 50%, were on the two tasks he was to be taught directly. The other matching tasks were within the range of chance performance for a display of six comparison stimuli. He showed a slight ability to name upper-case letters aloud, but was completely unable to name the lower-case letters.

Tests after teaching two legs of the transfer triangle. Although the subject maintained an almost perfect performance on the visual-auditory task he had been taught, visual-visual matching deteriorated from the relatively rigorous learning criterion he had attained (5/11/73). On the reverse visual-visual task, lower-case samples and upper-case comparisons, in which he had not received direct training, his performance was still less satisfactory. Nevertheless, he did better on these tasks after the teaching than before, and the improvement was reflected in considerable transfer to the critical visual-auditory task—matching lower-case letters to their dictated names.

Oral naming of upper-case letters also improved considerably over the pretest performances.

Oral naming of lower-case letters was tested twice. For the first time, Subject P.A. named a few lower-case letters correctly, but his score was still quite low, as indicated by the first of the two bars in the uppermost row (5/11/73). This test was administered before the upper-case naming test, and because he did so much better in the latter we suspected that he might have learned something about naming that could help him with lower-case letters. For this reason, the lower-case test was re-administered. His score did improve, as indicated by the second of the two bars in the uppermost row, but was still quite low.

Teaching the subject two matching tasks brought about a much improved performance in the third matching task, as well as in oral naming of both sets of letters. The incompleteness of the transfer might have reflected his less-than-perfect matching of lower- to upper-case, and upper- to lower-case letters. He was therefore retaught the two tasks he had previously learned. He was also taught explicitly to match upper-case comparison letters to lower-case samples.

The final column in Figure 4 (5/30/73) shows Subject P.A. maintaining perfect performances on all three matching tasks he had been taught. In matching lower-case comparisons to dictated samples, he also scored almost perfectly. His oral-naming scores, however, were practically the same as in the preceding tests.

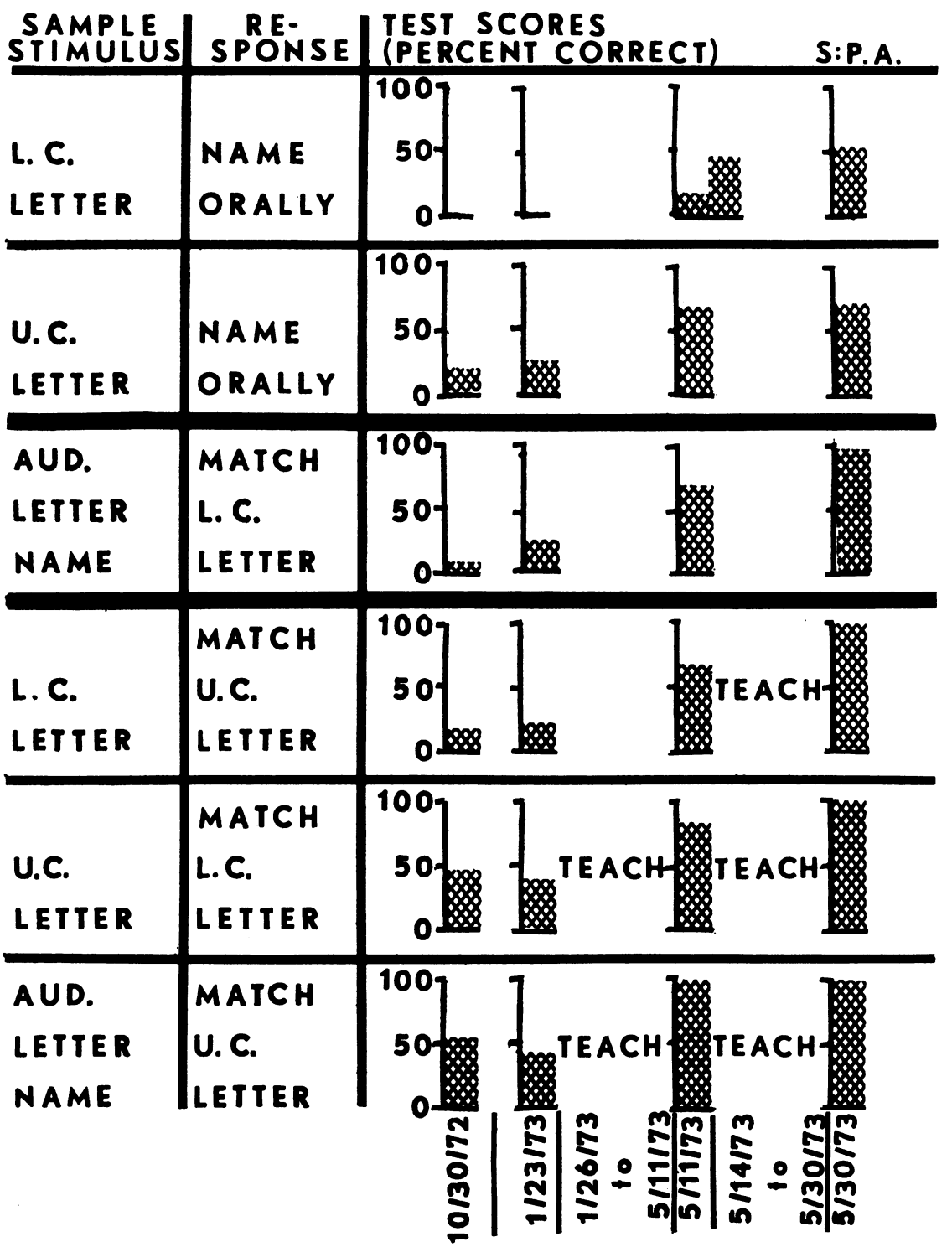

Fig. 4. Subject P.A. The two left columns identify the sample stimuli and responses that comprised each type of test. The row of bars to the right of each test represents the subject's scores in successive administrations of the test. The dates of each test, and of the interpolated teaching, are given below the columns of bars.

DISCUSSION

Matching to Sample

In previous experiments (Sidman, 1971; Sidman and Cresson, 1973), the ability to match printed words with pictures emerged after subjects had learned to match each set of visual stimuli to a set of auditory stimuli, dictated words. This learning sequence was consistent with the commonly observed developmental sequence in which auditory comprehension precedes reading comprehension. It was also consistent with the suggestion that the ability to perform crossmodal tasks is helpful in learning reading comprehension (Birch, 1962; Birch and Belmont, 1964, 1965; Geschwind, 1965; Kahn and Birch, 1968; Wepman, 1962).

The present and the earlier experiments together, however, have shown that the receptive mediation triangle (Figure 1) can be bidirectional. Facilitation can apparently work both ways; the normal developmental sequence is apparently not a necessary sequence.

The present data suggested also that oral naming need not mediate the emergence of visual-auditory matching. After Subject J.C. had learned to match nine and then 14 printed words to pictures, he showed a substantial ability to match printed to dictated words and almost no ability to read words aloud. Oral reading could not at this stage have mediated the emergent matching of printed to dictated words.

After Subject J.C. had learned to match all 20 printed words to pictures, he named a substantial number of words for the first time. His "aha" reaction during the oral reading test suggested that although he had failed to read the words aloud up to that point, he had actually been capable of doing so, and exercised his new capability only in the course of this test. Nevertheless, even though he may have been capable of naming the printed words, he clearly had not been doing so.

Practically all of Subject P.A.'s ability to name upper- and lower-case letters can be attributed to the teaching procedures. After learning the two matching-to-sample performances, his performance improved considerably in matching lower-case letters to their dictated names. Correlated with this improvement in crossmodal matching was a corresponding improvement in upper-case letter naming, but on first testing, only a slight development of lower-case naming. The emergence of crossmodal lower-case matching in the absence of lower-case naming indicates that the emergent matching was not mediated by naming, but was fostered rather by the receptive training in the other two matching-to-sample tasks.

The improvement in lower-case letter naming upon retest was analogous to Subject J.C.'s "aha" experience. Subject P.A. was apparently capable of naming more lower-case letters than he actually did upon initial testing, but he had not been using those letter names to mediate the crossmodal matching of lower-case to dictated letters.

On the second posttest, Subject P.A.'s matching of lower-case letters to dictated names had become almost perfect, but the two naming performances remained at their previous levels. This again indicated that the mediation was independent of oral naming.

The Emergence of Printed-Word and Lower-Case Letter Naming

It was possible for Subject P.A. to learn upper-case names in the course of learning to match upper-case to dictated letters (B-A). None of the subjects' training, however, involved the association of printed lower-case letters with dictated letter names, or of printed with dictated words. The interesting possibility here is that receptively mediated matching (C-A) might, in turn, have fostered oral naming of the words and lower-case letters (C-D); oral naming, rather than mediating the emergent visual-auditory capability (C-A), might itself have been a product of that capability.

This possibility received some support from the data: (1) Oral naming did emerge *after* crossmodal matching. (2) In his test on 2/15/71, Subject J.C. matched 12 dictated words with their appropriate printed words; he also named nine of these 12 correctly. Of the eight words matched incorrectly, five were also named incorrectly. On 2/26/71, 10 of the 15 words that he matched correctly were also named correctly. Four of the five words matched incorrectly were also named incorrectly. These data are consistent with the possibility that the receptively mediated matching of printed to dictated words actually generated oral reading.

On the other hand, oral naming might be explained by the expressive mediation paradigm. For instance, teaching Subject P.A. di-

rectly to match upper-case letters to their dictated names (B-A) partially established B-D in the expressive mediation triangle. Then, teaching him directly to match lower- to upper-case letters established a second side of this triangle, C-B. At this point, the third side of the expressive triangle, C-D, would have emerged, making the subject capable for the first time of naming some of the lower-case letters.

This second possibility was suggested by two of Subject J.C.'s naming errors. He gave the incorrect response, "hammer", both to the picture of an axe and to the printed word *axe;* in response to the picture of a pig and to the word *pig,* he said, "cow". In these instances, he gave the same incorrect name to the picture and to the corresponding printed word. Similarly, Subject P.A. consistently said, "Seh", in response to both upper- and lower-case G during his final test. It is difficult to attribute such naming errors to any process other than that illustrated by the expressive mediation triangle.

Mediation by Stimuli or by Responses?

The present study has suggested that new matching-to-sample performances, not directly taught, were generated by an apparently receptive mediation process. The suggestion that an untrained association can be mediated by a stimulus is not consistent with stimulus-response theories, which require differential responses to intervene between stimulus terms in the mediated-transfer paradigm (Jenkins, 1963; Schoenfeld and Cumming, 1963). Even stimulus-stimulus association theories postulate intervening representational processes (Estes, 1969) whose functions are difficult to distinguish from those attributed to response processes.

In arbitrary matching to sample, however, no differential responses to the individual stimuli are required. The necessary overt response is pointing, or touching, which is the same for all sample and comparison stimuli. Matching to sample has been accommodated into a stimulus-response framework by hypothesizing that each sample generates a differential coding response; the stimulus consequences of these coding responses then control appropriate comparison responses (Schoenfeld and Cumming, 1963). Without such coding, matching to sample would have to be viewed as a direct stimulus-stimulus association.

Although it is plausible for each sample to generate its own coding response, the transfer tests in our earlier experiments (Sidman, 1971; Sidman and Cresson, 1973) did not involve the original sample stimuli. The stimuli in the transfer tests, B and C, had training histories only as comparison stimuli. To explain the mediated transfer of matching to sample, a coding hypothesis would therefore have to assume that each sample and its correct comparison generated the same coding response. For example, the dictated sample word "boy", the comparison picture of a boy, and the comparison printed word *boy* would all have to be coded the same way. The common coding response could then mediate the matching of the comparison stimuli to each other.

In the present experiments, the mediation of C-A matching via identical sample and comparison coding would require an additional step. In B-A matching, each B-comparison stimulus would have had to generate the same coding response as its corresponding A-sample. In C-B matching, these same B-coding responses would have had to persist and, in addition, transfer to the C-comparison stimuli. Coding responses common to the A-samples and the C-comparisons could then mediate C-A matching.

Names can clearly serve as coding responses and can meet the requirement of identical sample and comparison coding. To maintain the coding hypothesis in the present experiments, however, one must assume some class of coding responses other than names. Then, each comparison stimulus would have to generate the same unknown coding response as its appropriate sample, even though the matching relation was arbitrary.

Schoenfeld and Cumming (1963) presented a strong argument for nonverbal mediating processes, although such processes become difficult to identify in matching-to-sample tasks that involve large numbers of stimuli. The additional assumption of identical sample-comparison coding, required if mediated transfer of matching is to be interpreted as other than stimulus-stimulus learning, does not seem to have been considered, and is under investigation in this laboratory.

Until these issues have been clarified, it would seem desirable to restrict the term *mediation* to its procedural sense. If an association between stimuli B and C is established by their

common association with stimulus A, and we cannot identify actual events or processes that intervene between B and C, the utility of postulating such events or processes will remain debatable. In the procedural sense, the term *mediation* refers to the observation that the B-C association, for example, was brought about by some form of prior learning that involved elements other than B and C. The critical aspects of that prior learning are matters of primary concern.

REFERENCES

Birch, H. G. Dyslexia and the maturation of visual function. In J. Money (Ed.), *Reading disability*. Baltimore: Johns Hopkins, 1962. Pp. 161-169.

Birch, H. G. and Belmont, L. Auditory-visual integration in normal and retarded readers. *American Journal of Orthopsychiatry*, 1964, **34**, 852-861.

Birch, H. G. and Belmont, L. Auditory-visual integration, intelligence, and reading ability in school children. *Perceptual and Motor Skills*, 1965, **20**, 295-305.

Estes, W. K. New perspectives on some old issues in association theory. In N. J. Mackintosh and W. K. Honig (Eds.), *Fundamental issues in associative learning*. Halifax: Dalhousie Univ. Press, 1969. Pp. 162-189.

Fletcher, F. G., Stoddard, L. T., and Sidman, M. A system for unlimited repetitive presentation of auditory stimuli. *Journal of Experimental Child Psychology*, 1971, **11**, 165-169.

Geschwind, N. Disconnexion syndromes in animals and man: part I. *Brain*, 1965, **88**, 237-293.

Guess, D. A functional analysis of receptive language and productive speech: acquisition of the plural morpheme. *Journal of Applied Behavior Analysis*, 1969, **2**, 55-64.

Guess, D. and Baer, D. M. An analysis of individual differences in generalization between receptive and productive language in retarded children. *Journal of Applied Behavior Analysis*, 1973, **6**, 311-329.

Jenkins, J. J. Mediated association: paradigms and situations. In C. N. Cofer and B. S. Musgrave (Eds.), *Verbal behavior and verbal learning*. New York: McGraw-Hill, 1963. Pp. 210-245.

Kahn, D. and Birch, H. G. Development of auditory-visual integration and reading achievement. *Perceptual and Motor Skills*, 1968, **27**, 459-468.

Mackay, H. A. and Sidman, M. Instructing the mentally retarded in an institutional environment. In G. A. Jervis (Ed.), *Expanding concepts in mental retardation*. Springfield: Charles C. Thomas, 1968. Pp. 164-169.

Peters, H. N. Mediate association. *Journal of Experimental Psychology*, 1935, **18**, 20-48.

Schoenfeld, W. N. and Cumming, W. W. Behavior and perception. In S. Koch (Ed.), *Psychology: the study of a science*, Vol. 5. New York: McGraw-Hill, 1963. Pp. 213-252.

Sidman, M. Behavior shaping with the mentally retarded. In N. R. Bernstein (Ed.), *Diminished people: the problems and care of the mentally retarded*. Boston: Little, Brown and Co., 1970. Pp. 263-276.

Sidman, M. Reading and auditory-visual equivalences. *Journal of Speech and Hearing Research*, 1971, **14**, 5-13.

Sidman, M. and Cresson, O. Reading and crossmodal transfer of stimulus equivalences in severe retardation. *American Journal of Mental Deficiency*, 1973, **77**, 515-523.

Wepman, J. M. Dyslexia: its relationship to language acquisition and concept formation. In J. Money (Ed.), *Reading disability*. Baltimore: Johns Hopkins, 1962. Pp. 179-186.

Received 31 October 1973.
(Final Acceptance 15 April 1974.)