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USING STIMULUS EQUIVALENCE PROCEDURES TO TEACH NAME-FACE MATCHING TO ADULTS WITH BRAIN INJURIES

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On pretests, 3 men with brain injuries matched dictated names of three therapists to written names, but did not match dictated or written names to photos, produce correct names in response to photos, locate offices given written names, or name therapists on sight. Match-to-sample training established conditional relations between dictated names and photos. Posttests showed the emergence of untrained conditional relations involving photos and written names, indicating development of three classes of equivalent stimuli (each containing a dictated name, photo, and written name). For 1 participant, conditional relations involving photos of office nameplates were also examined, but did not emerge pre- or posttraining. Two participants produced names orally when given photos and sorted written names and faces together after training; the 3rd participant was unavailable for these posttests. After training, 1 participant located and named all three therapists in their offices.

DESCRIPTORS: stimulus equivalence, match to sample, brain injuries, adults

A common behavioral outcome of certain brain injuries and illnesses is an inability to match spoken and written words with their corresponding objects, people, or events (Hayden & Hart, 1986; Sidman, 1971a; Sidman, Stoddard, Mohr, & Leicester, 1971; Wilson, 1987; Zahara & Cuvo, 1984). Several techniques based on information-processing models have been used to teach these stimulus-stimulus relations. For example, individuals with brain injuries or disease have been taught to use rehearsal, visual imagery, and verbal mediation strategies to improve short- and long-term remembering of relations among stimuli, with mixed results (e.g., Crovitz, 1979; Crovitz, Harvey, & Horn, 1979; Gianutsos & Gianutsos, 1979; Kudo, Segawa, Ihjima, & Okajima, 1988; Malec & Questad, 1983). The potential for behavior-analytic techniques to remediate such deficits, however, remains largely untested.

A powerful behavioral technology for teaching stimulus-stimulus relations has emerged in recent years from Sidman's analysis of stimulus equivalence (Sidman, 1971b, 1986; Sidman et al., 1982; Sidman & Tailby, 1982). In Sidman's (1971b) first stimulus equivalence study, a young man with severe mental retardation proved capable on pretests of selecting 20 pictures in response to their corresponding dictated names, producing oral names for the pictures, and matching identical printed words. He did not match pictures to printed words, or printed words to spoken words. After he was trained with match-to-sample procedures to select printed word comparisons given corresponding dic-

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tated word samples, the youth demonstrated 40 matching performances that were not trained directly; he was able to match pictures to printed words and printed words to pictures. He also orally produced the correct names for the printed words. These performances suggested that the dictated word, picture, printed word, and oral name for each item were equivalent.

Several years after the first study, Sidman and his colleagues specified behavioral tests for stimulus equivalence based on the mathematical definition of an equivalence relation (Sidman et al., 1982; Sidman & Tailby, 1982). They reasoned that when match-to-sample procedures are used to teach two or more linked conditional relations within sets of stimuli, something more than discrete conditional relations may be established: A general relation of equivalence may arise on each of the sets of stimuli. For example, stimuli labeled A1, A2, and A3 are presented as samples on randomly alternating trials, with stimuli labeled B1, B2, and B3 appearing as comparisons on every trial. Reinforcing responses to B1 in the presence of A1, B2 in the presence of A2, and B3 in the presence of A3 should establish the conditional relations A1B1, A2B2, and A3B3. Similar procedures can be used to establish conditional relations B1C1, B2C2, and B3C3.

To determine whether each set of stimuli related by such training (A1B1C1, A2B2C2, A3B3C3) constitutes an equivalence class, it is necessary to conduct behavioral tests for the three properties that define a relation of equivalence in mathematics. Each stimulus must be related conditionally to itself in order to document the property of *reflexivity*. The usual test for reflexivity is untrained identity matching of the stimuli in the prospective equivalence classes (i.e., demonstrating the conditional relations AA, BB, and CC in each of the three sets). Tests for the property of *symmetry* consist of untrained matching of stimuli with sample-comparison roles reversed relative to training (i.e., demonstrating the conditional relations BA and CA in each of the three sets). If the learner also matches stimuli that were never presented together in training but were linked via a common stimulus (e.g., demonstrating the AC conditional relations after AB and BC were trained in each set, without explicit training to do so), the relation among the stimuli has the property of *transitivity*. In our example, tests for the CA conditional relations evaluate the properties of symmetry and transitivity concurrently; such tests have been called simultaneous (Sidman & Tailby, 1982), combined (Catania, 1984), or global tests for equivalence (Sidman, 1986), or simply tests for equivalence (Sidman, 1990; Sidman, Wynne, Maguire, & Barnes, 1989). If all of the aforementioned untrained conditional relations emerge, as inferred from the learner's performances on tests, the stimuli in each set can be said to form an equivalence class (Sidman et al., 1982; Sidman & Tailby, 1982).

Subsequent to Sidman's first demonstration, stimulus equivalence procedures were used to teach a variety of practical skills to individuals with developmental and other disabilities. Examples include sight-word reading (e.g., Sidman & Cresson, 1973), rudimentary spelling (Mackay, 1985; Mackay & Sidman, 1984), manual signing (Osborne & Gatch, 1989; VanBiervliet, 1977), and basic monetary skills (e.g., McDonagh, McIlvane, & Stoddard, 1984). Although there is ample evidence to suggest that methods based on Sidman's stimulus equivalence analysis would be effective for teaching the types of stimulus-stimulus relations that are often absent from the repertoires of individuals who suffer brain injury or disease, systematic evaluations of the utility of stimulus equivalence methods for brain injury rehabilitation have just begun (Green, 1988, 1991).

Some individuals with brain injuries have particular difficulty matching names with faces, even those of persons who were very familiar to them before their injury. This phenomenon has been described in considerable detail (e.g., De Haan, Young, & Newcombe, 1987; Flude, Ellis, & Kay, 1989; Grafman, Salazar, Weingartner, & Amin, 1986; Newcombe, Young, & De Haan, 1989; Tranel, Damasio, & Damasio, 1988; Young & Ellis, 1989). However, few studies evaluating techniques for remediating this deficit have been published. Case studies suggested that instructions to use visual imagery to remember face-name pairs were successful with 1 subject (Glasgow, Zeiss, Barrera, & Lewinsohn, 1977) but not with another (Wilson, 1987). In the latter case, the subject remembered more names when instructed to relate a movement to each face than he did in the visual imagery condition. In another study, brain-injured subjects in a treatment group and subjects in a noninjured control group showed immediate recall after being trained to use "ludicrous" visual imagery to remember name-face pairs, but recall after 1 week was not improved significantly over pretraining performance for either group (Lewinsohn, Danaker, & Kikel, 1977).

The purpose of the present study was to test the effectiveness of stimulus equivalence methods for teaching equivalences among faces and names to individuals with brain injuries. Clients in a brain injury rehabilitation program participated in a variety of therapy sessions with several different therapists each day. A written schedule indicated which therapists they were to see at appointed times each day. Some therapy sessions were conducted in offices that had nameplates on the doors; others were located in therapy rooms or certain areas of the facility. We reasoned that for clients to locate the appropriate therapists, they had to match several stimuli that corresponded to each therapist: his or her spoken name, face, and written name (in one or two forms). Our goal was to teach these potentially useful equivalence classes to 3 men with brain injuries by replicating Sidman's (1971b) original study.

METHOD

Participants

Three adult males participated in the study. Bob, age 45, suffered a stroke that resulted in frontal lobe damage 8 years prior to the start of this study. Ed, age 30, had been in an auto accident 11 years earlier that resulted in extensive, diffuse brain damage. Sam, age 57, had been in an auto accident 2 years prior to the study, in which he sustained frontal lobe injury. Neuropsychological test reports indicated that all 3 men had severe short- and long-term memory deficits. Progress reports also described Ed and Sam as dependent on a written schedule to recall therapists' names, dates, and appointment times. All 3 men were referred by staff because they had difficulty matching therapists' names with faces, despite having worked with many of the same therapists continuously for several months (Bob and Sam) or years (Ed). Records indicated that unspecified instructions to use visual imagery and mnemonics to remember names had produced no improvements for Bob, and verbal prompts (also unspecified) to help Sam locate and name therapists in the facility were described as ineffective. No prior systematic efforts to teach Ed to match names and faces had been documented. Staff members were observed to use a variety of prompts and consequences to have each man say the names of familiar people he encountered.

Stimuli

The following types of stimuli were used to test and train relations among names and faces: (a) dictated names (dictated by the experimenter) (A stimuli), (b) faces (color photographs of head and shoulders) (B stimuli), (c) written names (in participant's handwriting as written on his daily schedule) (C stimuli), and (d) nameplates (color photographs of nameplates on office doors) (D stimuli; these were used for Bob only).

Visual stimuli were mounted and laminated on cards (10 cm by 15 cm). Each stimulus was coded with a letter and a number (e.g., B1, B2, and B3 were photos of three different therapists). For ease of reference, conditional relations were described by the alphanumeric codes for a sample and its corresponding correct comparison. For example, A1B1 named a conditional relation between a dictated name and the corresponding face. Possible conditional relations among stimuli in these sets are illustrated in Figure 1. Successful training and testing were expected to establish three equivalence classes, each consisting of a therapist's dictated name, a facial photograph, written name, and (for Bob) a nameplate photograph.

Experimental Plan

A pretest-train-posttest experimental sequence was followed with each participant. Pretesting was necessary to determine which conditional relations in the prospective equivalence classes were in each participant's repertoire and which relations should

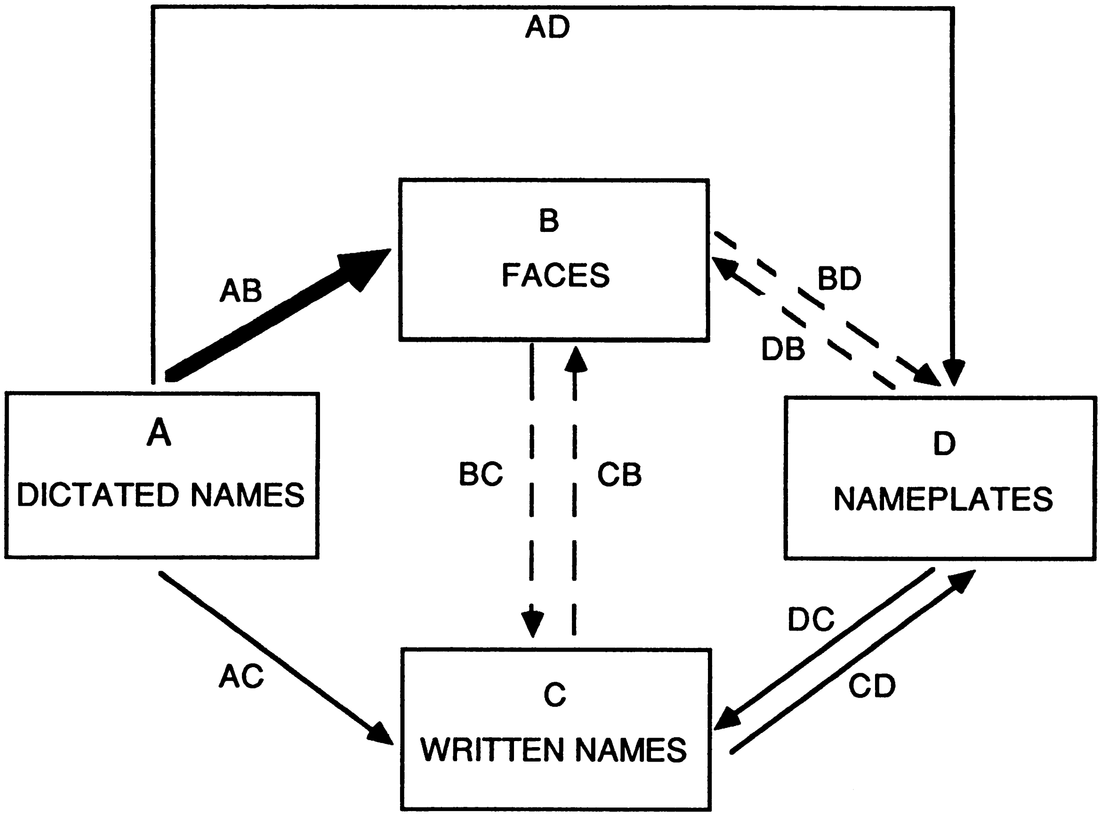

Figure 1. Schematic representation of conditional relations demonstrated on pretests (solid arrows), those trained (bold arrow), and those posttested (broken arrows). Arrows point from stimuli used as samples to stimuli used as comparisons in match-to-sample procedures.

be trained to establish equivalence classes (see Figure 1). Repeated pretesting, however, can be problematic for stimulus equivalence research, because even without reinforcement humans tend to respond consistently on repeated match-to-sample trials. This can establish unintended conditional relations that may later prove resistant to modification by contingencies (Harrison & Green, 1990; R. Saunders, Saunders, Kirby, & Spradlin, 1988). For this reason, we considered designs that required repeated pretesting (multiple baseline, multiple probe) inappropriate. Instead, we administered enough match-to-sample pretest trials to obtain a valid assessment without prolonging conditions that might have set the occasion for participants to make unreinforced, incorrect conditional selections. Naming, sorting, and application pretests (described below) provided additional data about the participants' entry-level skills. The conditional relations necessary to establish stimulus equivalence were then trained, match-to-sample tests for stimulus equivalence were administered, and naming, sorting, and application tests were repeated. The sequence of experimental conditions, which was the same for all 3 participants, is shown in Table 1.

Setting and Sessions

Sessions were conducted in an office containing a desk and two chairs. Occasionally sessions were held in another similar office or in the subject's dormitory room. The experimenter sat on one side of the desk opposite the participant. Only the experimenter, the participant, and occasionally a second observer were present during sessions. Sessions generally lasted 30 to 50 min, and were conducted

Table 1
Sequence of Experimental Conditions

	Samples	Comparisons
Pretests		
1. Oral naming		
1.1 B (faces)		
1.2 C (written names)		
1.3 D (nameplates)		
2. Sorting		
3. Match to sample	Samples	Comparisons
3.1 BB/CC/DD	B. Faces	B. Faces
	C. Written names	C. Written names
	D. Nameplates	D. Nameplates
3.2 AB	A. Dictated names	B. Faces
3.3 AC	A. Dictated names	C. Written names
3.4 BC/CB	B. Faces	C. Written names
	C. Written names	B. Faces
3.5 CD/DC	C. Written names	D. Nameplates
	D. Nameplates	C. Written names
3.6 BD/DB	B. Faces	D. Nameplates
	D. Nameplates	B. Faces
3.7 AD	A. Dictated names	D. Nameplates
4. Application Test		
Training		
AB match to sample (as above)		
Posttests		
1. Match to sample		
1.1 BC/CB (as above)		
1.2 BD/DB (as above)		
2. Oral naming, B (faces)		
3. Sorting		
4. Application test		

3 to 5 days a week. Often the participants' therapy schedules made it necessary to conduct multiple sessions on the same day. When this occurred, sessions were separated by at least 15 min. Bob, Ed, and Sam participated in the study for 12 weeks, 13 weeks, and 8 weeks, respectively.

General Procedures

Table-top match-to-sample methods were used for most training and testing (exceptions are described below). Samples were either visual stimuli or words dictated by the experimenter. Comparisons always involved three visual stimuli. Trial configurations (i.e., specific combinations of samples and comparisons) and sequences were determined prior to each session and were coded on a data sheet, on which the participant's responses and interobserver reliability data were recorded. The experimenter started each session by giving the participant the following instructions. (Bracketed words were conditional on whether the samples were visual or were dictated by the experimenter).

> I am going to [put a picture or a printed word on the board] [say a word]. Please [point to the picture or word] [listen to the word, then point to the blank] (experimenter pointed to the sample position), and then point to the picture or word below that goes with it.

The experimenter arranged the stimuli for each trial on a cardboard mat outside the visual field of the participant before placing the mat in front of the participant. Dictated samples were repeated every 5 s until the participant selected a comparison.

There were 24 trials in each set of identity matching pretest trials for Ed and Sam (BB and CC relations) and 36 trials per set for Bob (BB, CC, and DD relations). Most other training and testing sets consisted of 30 trials (variations are described in the training description). The order of trial configurations within a set was unsystematic, with the restriction that the same sample did not appear on more than three consecutive trials. The position of the designated correct comparison (left, center, right) varied unsystematically from trial to trial. In any given set of trials, each conditional relation was presented on an equal number of trials. For example, an AB training set included 10 trials each of the A1B1, A2B2, and A3B3 relations (i.e., A1, A2, and A3 were presented as samples on 10 trials each in quasi-random order, with B1, B2, and B3 as comparisons on every trial). When six conditional relations were tested in a set, each relation was presented five times (e.g., in a BC/CB test set, B1, B2, and B3 were samples on five trials each with C1, C2, and C3 as comparisons, and C1, C2, and C3 were samples on five trials each with B1, B2, and B3 as comparisons). The number of training or testing sets completed in each session varied across subjects. Bob typically completed two sets per session, whereas Ed and Sam each completed three to four sets per session.

Pretests and Posttests

Pretests were administered in the order shown in Table 1. All match-to-sample pretests were administered once, and then any match-to-sample pretest on which performance was below criterion (see below) was administered once more. Pretesting had three general purposes: (a) to assess the participants' ability to read written stimuli; (b) for each participant, to identify from a pool of all their therapists three therapists whose names and faces he did not match reliably and whose faces he did not name reliably; and (c) to evaluate pretraining performances on all the conditional relations shown in Figure 1 with the stimuli corresponding to three selected therapists. Oral naming and sorting pretest items came from a pool of 10 therapists for Bob, seven therapists for Ed, and 10 therapists for Sam. The match-to-sample pretest results were used to determine which conditional relations to teach to make three equivalence classes possible. After training, performances that did not meet criterion on pretests were retested. No differential consequences followed any responses on pre- or posttest trials; participants were merely praised at the end of the session for concentrating and trying hard. Test sessions did not include any training trials.

Oral naming. Oral naming tests were conducted by presenting each stimulus from the B (faces), C (written names), and D (nameplates, for Bob only) sets on three trials in random order and asking the participant, "Who is this?" The participant's response on each trial was written on a data sheet. The total number of correct naming responses was divided by the total number possible and multiplied by 100% to yield an overall score on the naming test. Criterion was no more than one naming error per stimulus. This criterion was applied to pretest results to determine whether participants could read each written stimulus and to identify individual therapists whose faces the participant did not name reliably. It was applied to posttest results to evaluate whether oral naming of faces emerged as a result of training.

Sorting. This test provided another context in which to assess equivalence of stimuli that corresponded to the same therapist pre- and posttraining. All of the relevant B, C, and D stimuli were handed to the participant in a random group. The participant was instructed to "Put all the cards that go together in stacks." Three such sorting trials constituted a test. The codes for the stimuli the participant grouped together were recorded on a data sheet. Correct sorts by the participant (e.g., B1, C1, and D1 grouped together, with no other stimuli included) were divided by the total number of possible correct sorts and multiplied by 100% to yield an overall score on the sorting test. Criterion was no more than one incorrect sort per therapist in three trials. Pretest performances below this criterion identified individual therapists whose names and faces the participants did not sort together reliably.

Match to sample. In addition to generalized identity matching with the relevant visual stimuli (B, C, and D), all 3 participants were pretested on all conditional relations shown in Figure 1 for three prospective equivalence classes. Pretest sets included 24 trials of BB and CC for Ed and Sam; 36 trials of BB, CC, and DD for Bob; and 30 trials of AB, 30 trials of AC, and 30 trials of BC/CB for all 3 participants. Bob also completed pretests for AD, BD/DB, and CD/DC. Criterion on the pretests was no more than one error on each conditional relation in a set of 30 trials. Performances that met this criterion were considered to be in the participant's repertoire and were not trained or tested further.

Based on the pretest results, all 3 participants were taught the AB (dictated name and face) conditional relations with stimuli corresponding to three therapists. Match-to-sample posttests then comprised the tests for stimulus equivalence: BC/CB for Ed and Sam and BC/CB and BD/DB for Bob. Criterion on posttests was no more than one error per relation over two consecutive 30-trial sets. Performances that met this criterion were considered evidence for the emergence of stimulus equivalence. If performance on a posttest was above chance (33%) but below criterion, the posttest was simply readministered until criterion was met (a maximum of six times).

Application test. One application test was planned before training and one after training. This test involved giving the subject a list of therapists' names (in his own handwriting) and a verbal request to find each person on the list. The experimenter accompanied the participant around the facility. When the participant indicated that he had located a listed therapist, the experimenter asked "Whose [office] [room] is this?" and, if the therapist was in sight, "Who is this?" Each response was recorded on a data sheet. Separate scores for finding and naming therapists were calculated by dividing the number correct by the number possible and multiplying by 100%. Criterion was no more than one error overall.

Interobserver Agreement and Procedural Reliability

A trained independent observer was present for 21% of all testing and training sessions. This observer recorded the participant's response as well as the experimenter's behavior (i.e., stimulus presentations and consequences provided to the participant) on every trial. The experimenter's and observer's data on participant responses were compared trial by trial, and the percentage agreement on scoring both correct and incorrect responses was calculated. The percentage of trials on which the experimenter adhered to procedures was also calculated. Interobserver agreement for participant responses averaged 99% overall (range, 92% to 100%). The trainer presented stimuli correctly on an average of 99.4% of trials overall (range, 96% to 100%) and provided consequences (praise, correction, or none) appropriately on 99.8% of trials (range, 97% to 100%).

Training

All participants were taught three AB conditional relations (see Figure 1) via standard trial-and-error match-to-sample training with correction (Carter & Werner, 1978; Ferster, 1960). Most training sets consisted of 30 trials, 10 of each conditional relation in unsystematic order. After every correct response, the experimenter provided verbal praise, such as "Good choice" or "That's right." When the participant made an incorrect response, he was instructed to "Try again." This was repeated until the correct comparison was selected, and verbal praise was provided (correction procedure). Then the next trial was presented. Only the participant's first response on a trial was scored correct or incorrect to determine whether criterion was met and to calculate interobserver agreement. Criterion performance was defined as no more than one error on any conditional relation over two consecutive sets. When criterion was met, the participant proceeded to posttesting.

Variations on these general training procedures

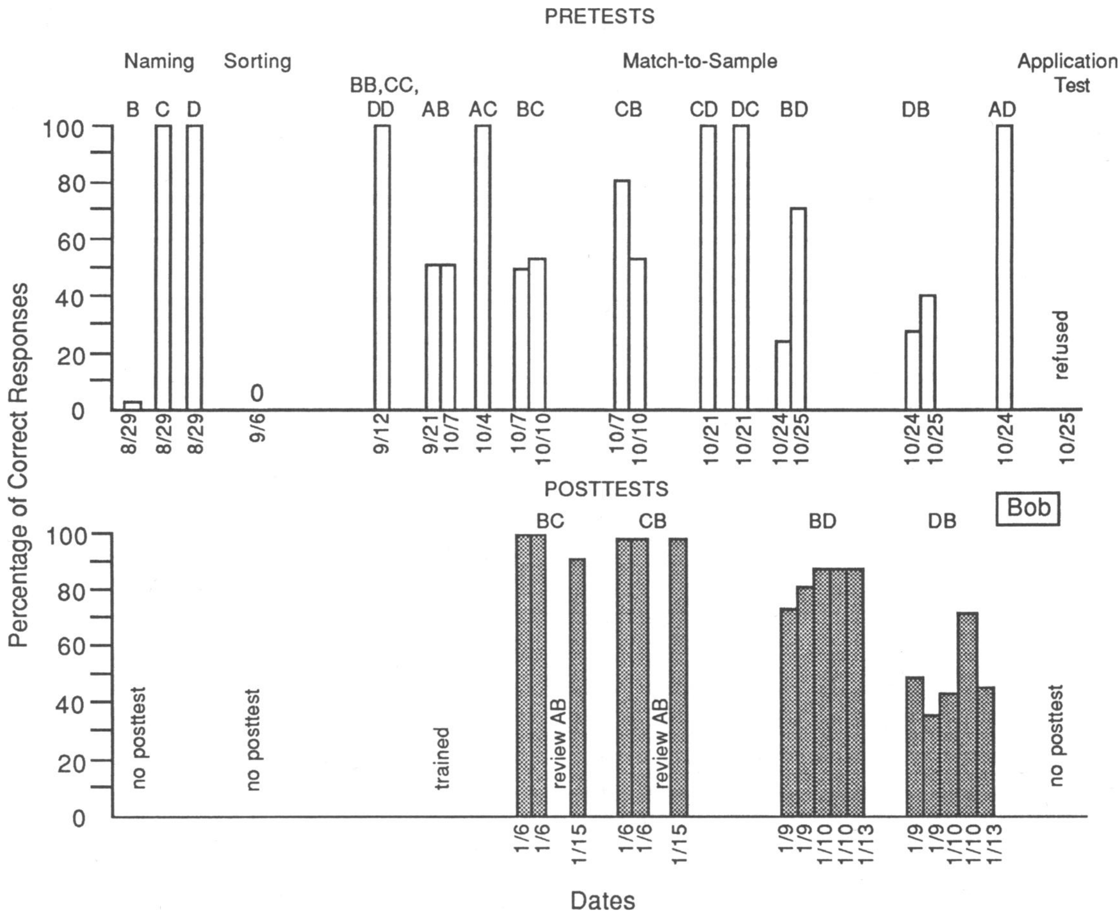

Figure 2. Overall percentage of correct responses on pretests (top panel) and posttests (bottom panel) for Bob.

were required for 2 participants. After 17 sets, Ed was performing with 100% accuracy on one AB conditional relation but was not making progress on the other two. Training sets were modified to 10 trials of each of those two relations, and training continued until Ed achieved a score of 20 correct out of 20 possible (see Results). The third trial type was added and the next two scores were 20 and 25 correct out of 30 trials. At this point it became apparent that verbal praise was not an effective reinforcer. Program staff members were consulted, and they reported that the opportunity to play a card game had been an effective reinforcer for Ed's behavior in the past. Ed was then instructed that if he attained a specified score the experimenter would play a card game with him for 10 min. The criterion was set initially at 26 correct out of 30 trials, and was increased by one when the criterion was met twice consecutively. Ed's scores showed improvement but were variable. After further consultation, the reinforcer was changed to money (50 cents for reaching the criterion score), which could be exchanged at the end of the session for ice cream. Ed's scores reached criterion under this contingency after 18 additional training sets.

Sam left the facility for 2 months after completing initial training and one BC/CB posttest. When he returned, he was given two more BC/CB posttests, but scores were well below criterion (see Results). He was then given a set of 30 AB trials without feedback to test maintenance of those relations. His score was 18 correct out of 30 trials. The AB performances were retrained to criterion. He then completed all posttests.

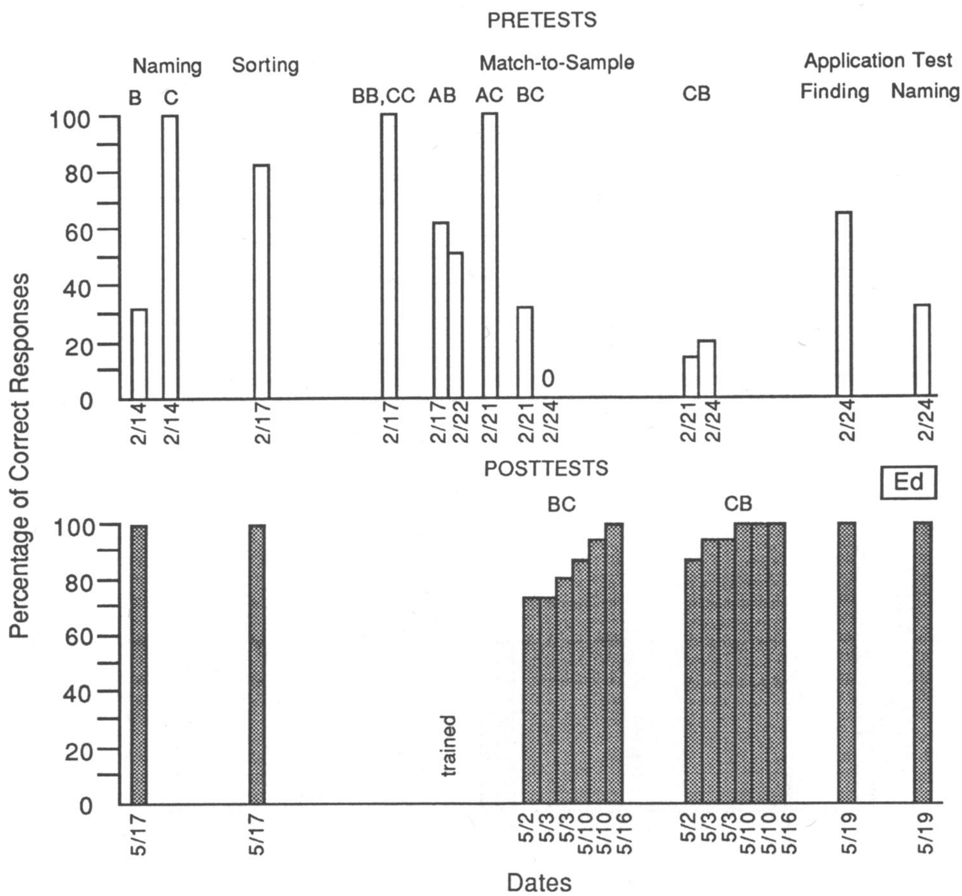

Figure 3. Overall percentage of correct responses on pretests (top panel) and posttests (bottom panel) for Ed.

RESULTS

Pretests

Pretest results for each participant are shown in the top panels of Figures 2, 3, and 4. (Note that BC and CB relations were tested together in the same sets, as were BD and DB relations, but the data for each type of relation are presented separately in Figures 2 through 4.) As anticipated, all participants orally produced names for written name stimuli (C and D) and performed to criterion on match-to-sample pretests of generalized identity matching (BB, CC, and DD) and all relations involving corresponding spoken and written names (AC, AD, CD, and DC). Ed's score on the sorting pretest was 81%, but neither of the other participants sorted stimuli accurately. The three faces (B stimuli) that each participant failed to name on the oral naming pretest were not matched reliably to any other stimuli (A, C, or D) on match-to-sample pretests. Bob refused to try the application pretest, Ed found two of three therapists and named one of three, and Sam neither found nor named any of his three therapists correctly.

AB Training

The course of acquisition of the AB conditional relations varied somewhat across participants. Data are presented in quartile means and ranges for ease of comparison (Figure 5). Bob's performance reached criterion in 37 sets (30 trials per set). Ed required a total of 72 training sets, including three sets in which only two conditional relations were trained in the same set until criterion performance was demonstrated. Sam required 20 AB training

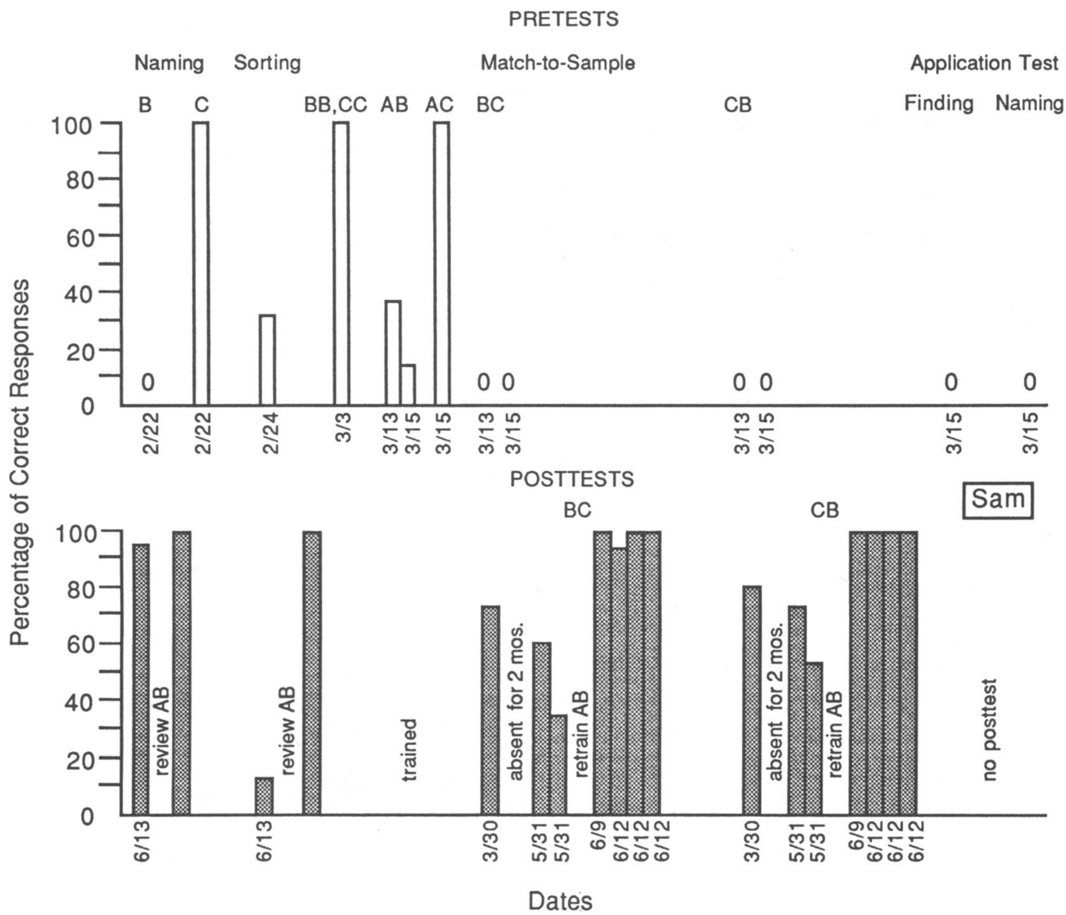

Figure 4. Overall percentage of correct responses on pretests (top panel) and posttests (bottom panel) for Sam.

sets to reach criterion initially, and another nine sets to reattain criterion after a 2-month absence.

Posttests

Posttest results are shown in the lower panels of Figures 2, 3, and 4. All participants demonstrated the AC conditional relations on pretests and were taught the AB conditional relations; thus the BC/CB posttests constituted tests for stimulus equivalence because both evaluated the properties of symmetry and transitivity simultaneously. Bob also demonstrated the AD relations on pretests, making the BD/DB relations possible after AB relations were trained.

Bob's responses on the BC/CB posttests were 100% consistent with stimulus equivalence (see Figure 2, lower panel). His performances on BD trials approached but did not reach criterion, and his scores on DB test trials were variable and well below criterion. After these tests were completed, Bob refused to attempt further tests; it appeared the absence of feedback was having a deleterious effect. He was given 10 trials of reinforced identity matching with the B, C, and D stimuli mixed, but refused to complete any more trials. At that point he refused to participate in any therapy or research sessions for 1 week. When he agreed to resume participation, we reviewed AB training to provide reinforcement and to confirm that the critical AB performances were maintained. His scores were 27, 29, and 29 correct on three AB sets of 30 trials each (data not shown). Two more BC/CB tests were administered, and performances were at or near criterion (Figure 2, lower panel). Bob was

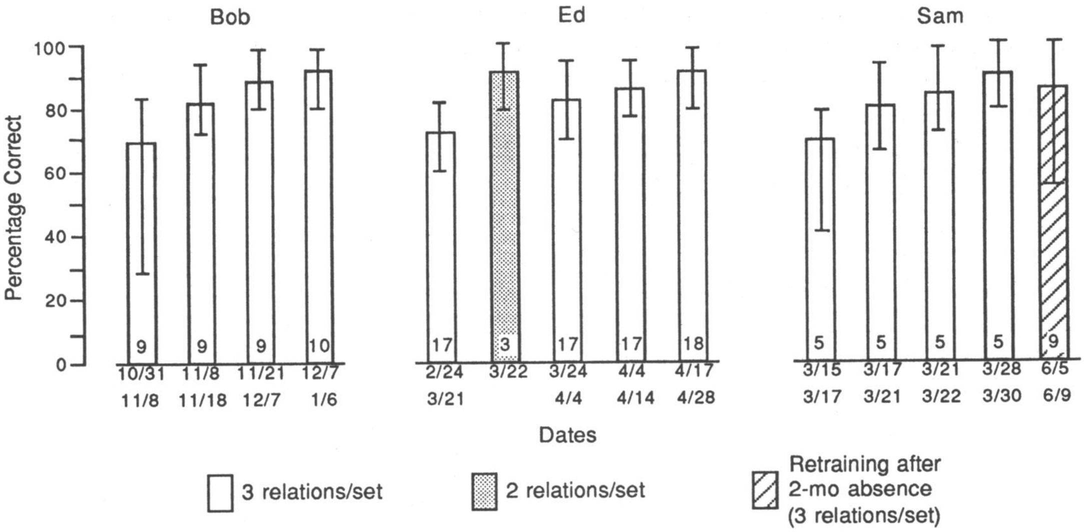

Figure 5. AB training data for all participants. Open bars represent quartile means (in percentage of correct responses); vertical lines indicate ranges. The shaded bar represents Ed's mean and range in a condition in which only two AB conditional relations were trained concurrently. The striped bar represents Sam's reacquisition performance after a 2-month absence. Numbers inside each bar indicate the number of training sets summarized by that bar.

discharged from the facility before completing oral naming and sorting posttests.

Ed's scores on BC/CB posttests were well above chance from the outset and improved steadily with repeated unreinforced testing (see Figure 3, lower panel). On the oral naming posttest, Ed produced the correct names in response to faces on every trial. He grouped all stimuli correctly on the sorting posttest. On the application posttest, Ed located all three therapists' offices, named two of the therapists when he saw them in their offices, and reported accurately that the other therapist had left the facility.

Sam's scores on BC/CB posttests immediately following AB training were above chance (73% and 80%, respectively) but below criterion (see Figure 4, lower panel). After his 2-month absence from the facility, we readministered those posttests without reviewing any of the underlying conditional relations. Either his initial training and testing had been insufficient to establish stimulus equivalence or he did not remember the requisite conditional relations. After the AB relations were retrained, however, his scores on BC/CB posttests were immediately and fully consistent with stimulus equivalence. Sam made one error on the oral naming posttest, and did not sort stimuli correctly on the sorting posttest. We gave him one AB review set with reinforcement for every correct response; immediately thereafter he performed without error on both the naming and sorting posttests. No application posttest was administered because by that time one therapist had left the facility, another no longer worked with Sam, and the third had moved to another building.

DISCUSSION

This study replicated early experiments by Sidman (1971b) and Sidman and Cresson (1973) in which equivalences among spoken words, pictures, and written words developed following auditory-visual match-to-sample training. The course of acquisition of the AB conditional relations (dictated names and faces) in this study suggests that they were functionally as arbitrary for our participants as if the stimuli had been nonsense sounds or forms. Nonetheless, with the AC relations in place to begin with, equivalence classes developed following AB training. All participants demonstrated the formation of three equivalence classes, each including a therapist's dictated name, photo, and written name. For Bob, equivalence did not extend to the nameplate stimuli (see Figure 2, BD/DB posttests). This outcome was surprising, considering that all the conditional relations that should have supported emergence of the BD/DB relations appeared to be in place prior to posttesting. It is possible that those underlying relations had deteriorated by the time of the posttests (although the BC/CB posttests and AB review suggested that most of them were intact), and that testing BD and DB in a context of reinforced training trials or following further training on the underlying relations might have produced different outcomes. Bob's posttest results also emphasize the importance of examining all combinations of stimulus-stimulus relations within linguistic classes with individuals who have brain injuries (cf. Green, 1991; Sidman, 1971a; Sidman et al., 1971).

Bob and Sam demonstrated equivalence on the first posttests (BC/CB posttests, Figures 2 and 4). In Ed's case (Figure 3, lower panel), the gradual emergence of stimulus equivalence simply with repeated testing replicated the performances of some subjects in several other studies (e.g., Lazar, Davis-Lang, & Sanchez, 1984; Sidman, Kirk, & Willson-Morris, 1985; Sidman, Willson-Morris, & Kirk, 1986; Sigurdardottir, Green, & Saunders, 1990; Spradlin, Cotter, & Baxley, 1973). The reason for this gradual emergence is not yet well understood. Some authors (e.g., Devany, Hayes, & Nelson, 1986; Sidman, in press) have suggested that it reflects progressively diminishing stimulus control by sources other than stimulus equivalence (e.g., perceptual similarities among stimuli) because over test trials equivalence is the only consistent source of control (see also Harrison & Green, 1990). Another possibility is that unreinforced testing actually serves to establish untrained conditional relations, and therefore stimulus equivalence (Sidman et al., 1985; Sigurdardottir et al., 1990).

Because we did not use a standard experimental design, the internal validity of our experiment may have been compromised. It is possible that events outside the experiment caused our participants' improved performances during training and posttesting. In addition to our pretest results, however, we had other evidence (albeit largely archival and anecdotal) that our participants had lengthy, stable baselines of inaccurate and unreliable name-face matching. The gradual acquisition of the trained AB relations by all 3 participants suggests that if other variables were contributing to improvements in those performances, they were not very potent. Further, most of the posttest performances represented dramatic improvements over baseline, in the absence of reinforcement or reviews in most cases. The effect of the intervention was replicated for all participants, and was consistent with the results of many other stimulus equivalence experiments. We believe these factors, coupled with continuous objective assessment, strengthen the internal validity of the experiment (see Kazdin, 1982, pp. 92–94), and we are reasonably confident the outcomes we obtained were due to the intervention.

In many cases reported in the literature to date, humans who have been taught certain linked conditional relations have shown the emergence of other, untaught conditional relations on unreinforced tests. Such emergent performances have been inferred to show the development of stimulus equivalence, according to Sidman's paradigm. Some of these subjects were considered severely deficient in behaviors commonly termed cognitive and linguistic (e.g., Mackay, 1985; Mackay & Sidman, 1984; Sidman, 1971b; Sidman & Cresson, 1973). Analogous emergent performances have not yet been demonstrated convincingly by nonhumans, and this has provoked considerable debate about the behavioral processes underlying stimulus equivalence (e.g., Dugdale & Lowe, 1990; Hayes, 1989; McIntire, Cleary, & Thompson, 1987, 1989; K. Saunders, 1989; R. Saunders & Green, 1992; Vaughan, 1988, 1989). Clearly, teaching conditional relations to humans in certain ways somehow generates new conditional relations, and perhaps a general relation of equivalence on each of two or more sets of stimuli. Recently Sidman (1990, in press) concluded that there appears to be no ready explanation for this phenomenon based on known behavioral principles or functions. He suggests that stimulus equivalence may be a fundamental stimulus function selected by phylogenic contingencies. Regardless of whether this or some other explanation proves valid, it seems incontrovertible that teaching methods derived from Sidman's analysis of stimulus equivalence represent a powerful behavioral technology for the remediation of deficits viewed by many as irreversible, including the types of language problems that are a common outcome of brain injury.

We tried to address an issue that has not been investigated adequately in stimulus equivalence research: the extent to which equivalence classes taught in the laboratory or classroom serve any function for the learner in other contexts. Our attempts in this study to assess transfer to the "real world" via our application tests yielded limited but promising data. It is critical that such efforts continue. Another important question that we did not address is whether the equivalence classes our participants demonstrated were maintained. Individuals with mental retardation have been reported to remember equivalence classes for as long as 3 years with no intervening training or practice (R. Saunders, Saunders, & Spradlin, 1990). Two adults with brain injuries who participated in laboratory stimulus equivalence experiments demonstrated relatively intact equivalence classes of abstract figures for up to 10 months with no intervening exposure to the stimuli (Green & Sigurdardottir, 1990). If stimulus equivalence procedures yield accurate remembering as well as efficient acquisition of useful stimulus-stimulus relations, they will be powerful additions indeed to the brain injury rehabilitation armamentarium.

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