*STIMULUS CLASS MEMBERSHIP ESTABLISHED VIA
STIMULUS-REINFORCER RELATIONS*

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In an arbitrary matching-to-sample procedure, two mentally retarded subjects learned conditional discriminations with two sets of stimuli. Each set included a spoken name (N1 or N2), an object (O1 or O2), and a printed symbol (S1 or S2). One subject selected conditionally (a) O1 upon N1, and O2 upon N2, and (b) S1 upon O1, and S2 upon O2. The other subject selected conditionally (a) S1 upon N1, and S2 upon N2, and (b) O1 upon S1, and O2 upon S2. For both subjects, selections of O1 and S1 produced one type of food, F1; selections of O2 and S2 produced a different type of food, F2. Both subjects also learned identity-matching performances, selecting O1, O2, S1, S2, F1, and F2 conditionally upon those stimuli as samples; F1 followed selections of O1, S1, and F1; F2 followed selections of O2, S2, and F2. Matching performances consistent with stimulus class formation involving the names, objects, symbols, and foods were demonstrated on probe trials, even though these performances had not been taught explicitly. Next, new objects, X1 and X2, were presented on identity-matching trials, producing F1 and F2, respectively. Without further training, X1 was selected conditionally upon N1, S1, and O1, and X2 was selected upon N2, S2, and O2. When the contingencies were changed so that selections of X1 and X2 were now followed by F2 and F1, respectively, X2 was selected conditionally upon N1, S1, and O1, and X1 was selected upon N2, S2, and O2. Class membership of X1 and X2 had apparently changed. This study provides evidence that reinforcers may become members of stimulus classes, and that new stimuli may become class members through relations with reinforcers.

Key words: conditional discrimination, matching to sample, stimulus classes, stimulus-reinforcer relations, pointing, mentally retarded adults

In a three-term programmed contingency, a reinforcing stimulus follows a specified response in the presence of a specified discriminative stimulus. The relation among the two stimulus terms and the response term is a contingency because the reinforcer is not presented if (a) the response is not emitted or (b) the response is emitted but in the absence of the discriminative stimulus. Through discrimination training, the subject's behavior becomes consistent with the three-term contin-

gency; responses are emitted only in the presence of the discriminative stimulus and not at other times. A controlling stimulus-response-reinforcer relation, a three-term behavioral unit, is established. Functional analysis requires the specification of a behavioral unit, because an operant response cannot be defined independently of its consequences nor of the stimuli that set the occasion for it (Skinner, 1935).

The present study concerned stimulus-reinforcer relations, in the context of the four-term programmed contingencies and behavioral units defined recently by Sidman (1986). Four-term contingencies bring three-term behavioral units under the control of other environmental events (see Cumming & Berryman, 1965). The arbitrary matching-to-sample procedure provides a good illustration. In this procedure, two (or more) discriminative stimuli, comparisons, are simultaneously displayed along with a conditional stimulus, the sample. The upper portion of Table 1 shows four-term contingencies in the matching-to-sample procedure. A1 and A2 represent sam-

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Table 1

Four-term contingencies in the arbitrary matching-to-sample procedure. A1 and A2 represent samples, B1 and B2 represent comparisons, R represents a response to the indicated comparison, and F1 and F2 represent food items. Transected lines following some response terms indicate behavior that goes unreinforced. Upper portion: contingencies in which the same food item follows all correct responses. Lower portion: reinforcer-specific contingencies in which different correct responses are followed by different food items.

A1 — B1 — R — F1
A1 — B2 — R — /—
A2 — B1 — R — /—
A2 — B2 — R — F1
A1 — B1 — R — F1
A1 — B2 — R — /—
A2 — B1 — R — /—
A2 — B2 — R — F2

ples, and B1 and B2 represent comparisons; none of the stimuli are similar to each other. In the presence of samples A1 and A2, responses to comparisons B1 and B2, respectively, are followed by food, F1; responses to B2 in the presence of A1 or to B1 in the presence of A2 are followed only by an intertrial interval.

Exposure to these four-term contingencies brings the subject's behavior into conformity with them. A1 controls the unit B1 — R — F1 and A2 controls B2 — R — F1. Moreover, recent studies have shown that four-term contingencies may establish the potential for the emergence of derived behavioral units not described by the original four-term contingencies. After establishing two units,

A1 — B1 — R — F1
A2 — B2 — R — F1,

two more may emerge,

B1 — A1 — R — F1
B2 — A2 — R — F1.

B1 and B2 as samples control selection of A1 and A2, respectively, as comparisons, although the subject has never been exposed to the four-term contingencies that would produce the latter two units. Symmetry of the first two stimulus terms in each unit is shown (Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982; Sidman & Tailby, 1982).

Other derived units may emerge when two

sets of four-term units share a common stimulus term. After establishing the following four units,

- (1) A1 — B1 — R — F1
- (2) A2 — B2 — R — F1
- (3) B1 — C1 — R — F1
- (4) B2 — C2 — R — F1,

the following units may occur without further training,

- (5) A1 — C1 — R — F1
- (6) A2 — C2 — R — F1.

This is transitive stimulus control (e.g., Sidman, Cresson, & Willson-Morris, 1974; Sidman & Tailby, 1982).

Additional derived units may emerge after establishing Units 1 through 4 above:

- (7) B1 — A1 — R — F1
- (8) B2 — A2 — R — F1
- (9) C1 — B1 — R — F1
- (10) C2 — B2 — R — F1
- (11) C1 — A1 — R — F1
- (12) C2 — A2 — R — F1.

This indicates that Units 1 through 6 are symmetrical with respect to the first two stimulus terms. If programmed four-term contingencies establish Units 1 through 4 and if Units 5 through 12 are then displayed, the contingencies have established stimulus equivalence with respect to the first two terms of each behavioral unit, provided generalized identity matching, showing reflexivity, has previously been displayed (Sidman & Tailby, 1982).

Demonstrations of derived behavioral units after training on programmed four-term contingencies have become commonplace (e.g., Lazar, 1977; Lazar, Davis-Lang, & Sanchez, 1984; McDonagh, McIlvane, & Stoddard, 1984; Sidman & Tailby, 1982; Stromer & Osborne, 1982; Wetherby, Karlan, & Spradlin, 1983). However, all such demonstrations have involved only the first and second terms of the units. Although the fourth term, the reinforcer, is also a stimulus, the possibility of unique derived units involving this term has not been addressed. In previous work, the use of a reinforcer common to all units prohibited relevant analysis. In Units 1 through 4 above, for example, samples or comparison stimuli (A1, A2, B1, B2, C1, and C2) are all involved in stimulus-reinforcer relations with F1. Because the reinforcer stood in the same relation to all

stimuli in the established units, it could not serve as a stimulus for conditional discrimination among them.

Certain four-term contingencies remove this invariance. Such contingencies, diagrammed in the lower portion of Table 1, provide a different reinforcing stimulus to establish each four-term unit. When $A1 - B1 - R - F1$ and $A2 - B2 - R - F2$ are established, no stimulus term is common to these units. Therefore, the potential for derived units involving the reinforcer is established, and potential stimulus-reinforcer relations can be examined using a conditional-discrimination procedure.

Beginning with Trapold (1970), there have been several studies of four-term contingencies of this sort with laboratory animals (e.g., Brodigan & Peterson, 1976; Fedorchak & Bolles, 1986; Honig, Matheson, & Dodd, 1984; Peterson, 1984; Peterson & Trapold, 1980), but only three such studies with humans (Litt & Schreibman, 1981; Saunders & Sailor, 1979; Shepp, 1962), although derived units are typically studied with humans. Litt and Schreibman compared efficiency of the programmed contingencies shown in the upper portion of Table 1 with those shown in the lower portion. They taught autistic children to select either of two comparison objects, conditionally upon different spoken name samples. We will call the contingencies shown in the lower portion of Table 1 reinforcer-specific contingencies. Learning was faster (as measured by trials to criterion) with the reinforcer-specific contingencies, although the effect was not shown in all subjects. Litt and Schreibman did not test for derived units that might result from their training contingencies.

In a recent unpublished study, we attempted to replicate systematically the Litt and Schreibman results with 5 mentally retarded adults. Three subjects did not learn any conditional discriminations. The other 2 learned the discriminations quickly, and showed only order-of-teaching effects; that is, successive discriminations were learned in fewer trials regardless of whether training was conducted with reinforcer-specific contingencies. With 1 subject who did learn, we tested for derived units by assessing whether the subject would select the reinforcers in response to the spoken names in each unit; she did not. However, behavioral prerequisites for engaging in this

latter behavior (visual discrimination of the foods, selection of foods as comparisons, etc.) were not verified before the tests. These limitations were corrected in the present study.

In Experiment 1, units like those numbered 1 through 4 above were established, but F1 terminated Units 1 and 3 and F2 terminated Units 2 and 4. Then, we tested for the emergence of derived behavioral units, including those in which the reinforcing stimulus was the first or the second term. Subsequent experiments examined other training procedures that might result in derived units through reinforcer-specific contingencies.

EXPERIMENT 1

In this experiment, four-term behavioral units were established by matching-to-sample procedures. Four sets of two stimuli each were used in training. The stimuli were two spoken names (N1 and N2), two printed symbols (S1 and S2), two objects (O1 and O2), and two food items (F1 and F2). In an arbitrary auditory-visual matching-to-sample procedure, 2 subjects were taught to select comparison stimuli conditionally upon spoken names. For example, 1 subject learned to select S1 and S2, conditionally upon N1 and N2, respectively. In an arbitrary visual-visual matching-to-sample procedure, the subjects also learned to select comparison stimuli from one set, conditionally upon samples from the other. For example, 1 subject learned to select O1 and O2, conditionally upon S1 and S2, respectively. Finally, in a visual-visual identity-matching procedure, the subjects learned to select all the visual stimuli, including F1 and F2, conditionally upon identical stimuli as samples. In these matching-to-sample procedures, correct selections of S1, O1, and F1 were followed by F1; correct selections of S2, O2, and F2 were followed by F2.

For both subjects, one set of auditory-visual and one set of visual-visual arbitrary conditional relations were trained directly. Then, probe trials tested for derived four-term units based on symmetry and transitivity. Additional probe trials assessed whether stimulus-reinforcer relations had been established on conditional-discrimination training trials, which would then serve as the basis for derived units in which F1 and F2 were either the first (sample) or second (comparison) term.

METHOD

Subjects

Two mentally retarded adults served as subjects. Both had participated in our earlier unsuccessful attempt to replicate the study by Litt and Schreibman (1981). Subject DL was a 23-year-old moderately retarded man (Peabody Picture Vocabulary Test age equivalent: 4.7 years), who attended a day program for behaviorally disordered adults and lived in a group home. He spoke in a stylized, distorted voice, and could answer simple questions about his daily activities. DL exhibited ritualistic, autistic-like behavior such as carefully aligning furniture or repeatedly touching spots on the wall or floor. Prior to this study, DL had been taught identity matching with printed words (MEN, STOP, etc.) and with arbitrary forms. He had also learned to select those stimuli as comparisons conditionally upon spoken name samples.

Subject MC was a 43-year-old severely retarded Down Syndrome woman (Peabody age equivalent: 2.7 years) who lived at a large state institution. She could follow simple spoken instructions and approximately echo words, but much of her speech was unintelligible. MC had learned identity matching with food items and common objects (cracker, key, etc.), and had also learned to select those stimuli conditionally upon spoken names.

Reinforcer-Preference Testing

Previous research with normal (Haaf, 1971), autistic (Litt & Schreibman, 1981), and mentally retarded children (Siegel & Forman, 1967; Siegel & Schneider, 1969) has shown that systematic response biases may develop if two different responses produce unequally preferred reinforcers. Therefore, it was important for our study to identify two foods of approximately equal preference for each subject. To do this, we conducted reinforcer-preference tests: Four foods were displayed, two at a time, in all possible combinations, and each combination was presented four times. At each presentation the experimenter said "Take one," and the subject took one of the foods and consumed it. The frequency of selecting each food was tallied; in each case, there were two items chosen about equally often. For DL, these items were one-half ounce of cola (F1) and a miniature marshmallow (F2);

for MC, they were a piece of Cheez Doodle (F1) and a grape (F2).

Apparatus and Setting

Experimental sessions took place in a quiet room containing a table and two chairs. The subject and the experimenter sat at opposite sides of the table, with a display apparatus placed on the tabletop between them. The display consisted of two compartments made of clear Plexiglas (each 15.2 cm by 15.2 cm by 7.6 cm), mounted side-by-side on a base; a hinged, opaque screen could be raised to shield the contents of the compartments from the subject's view. A sample-display platform (10 cm by 17.5 cm) was mounted slightly above and centered between the comparison-stimuli compartments. When not in use, stimulus objects were placed out of the subject's view, on a tray on the experimenter's lap.

Sessions of 40 to 48 trials were conducted 3 or 4 days per week; each lasted approximately 30 to 35 min. A different experimenter worked with each subject.

Procedure

Auditory-visual and visual-visual matching-to-sample procedures. Before each trial, the experimenter placed the two comparison stimuli in the display, behind the raised screen. Trials began only when the experimenter judged that the subject was looking at the display.

When the sample was a spoken word, the experimenter began the trial by first lowering the screen to reveal the comparisons; after a brief period (2–8 s), the sample was spoken. This "waiting baseline" was used to verify that the subject's responses were occasioned by the spoken name, and not just the comparison stimuli (see Dixon, 1977; McIlvane & Stoddard, 1981). The discriminative response was that of touching the Plexiglas face of one of the compartments that held the comparison stimuli. If the subject responded before the sample was presented (a rare event), the experimenter waited an additional 5 s before speaking the name. Both subjects responded almost immediately after a sample was spoken, and it was not necessary for the experimenter to repeat it. When the sample was a visual stimulus, the experimenter began the trial by placing the sample stimulus on the display platform. The subject was required to point to it, after which the experimenter then

revealed the comparison stimuli by lowering the screen. Again, subjects selected a comparison by touching one of the compartments. All comparison selections were recorded on a prepared data sheet. Intertrial intervals were approximately 15 s.

Reinforcement procedures. Two different reinforcement schedules were used at different points in the experiment. In one (continuous reinforcement, or FR1), the experimenter said "Good" after every correct response, raised the comparison compartment screen, removed the sample (on visual-visual trials), and then placed the food reinforcer on the table in front of the subject. All samples and comparison stimuli were removed from the subject's sight before a food reinforcer was delivered. The experimenter waited until the subject consumed the reinforcer before beginning the next trial. Thus, food reinforcers were never simultaneously present with samples or comparison stimuli. If the response was incorrect, the experimenter said "No" and raised the screen to end the trial. The next trial presented a new stimulus display (noncorrection). Intermittent reinforcement was arranged under a variable ratio (VR) 1.33 schedule. After unreinforced correct responses and after incorrect responses (if any), the experimenter said nothing and simply raised the screen to end the trial.

Stimuli

Figure 1 shows the stimuli used in Experiment 1. Unfamiliar names (N1 and N2), symbols (S1 and S2), and objects (O1 and O2) were used so that pretesting was not necessary. Food items (F1 and F2) were described above. Different stimuli were used with each subject, and neither subject had previous experience with the stimuli, except for the foods.

Each stimulus appeared in the left and right position and as the correct (S+) and incorrect (S-) comparison an approximately equal number of times. The position of S+ was varied unsystematically, with the restriction that neither position was the correct one more than three times consecutively. No comparison stimulus was the correct one more than twice consecutively.

Baseline Training

Identity matching to sample. Subjects first received identity-matching trials with all the

visual stimuli (not diagrammed in Figure 1). On these trials, a food, object, or symbol appeared as the sample, and both foods, both objects, or both symbols appeared as the comparison stimuli. Correct choices of O1, S1, or F1 were reinforced with F1, and correct choices of O2, S2, or F2 were reinforced with F2. Identity matching with F1 and F2 gave subjects a history in which foods served as samples, as comparisons, and as reinforcers. Food items used as samples and comparisons were treated like the other visual stimuli, including their removal from the subject's view before the appropriate reinforcer was delivered.

Arbitrary matching to sample. After one (for MC) or three (for DL) sessions of identity matching, subjects were trained on two arbitrary matching-to-sample tasks. The solid arrows in Figure 1 illustrate the trained relations; the arrows point from sample to comparison. DL was trained to select S1 and S2 conditionally upon N1 and N2, respectively, and also to select O1 and O2 conditionally upon S1 and S2, respectively. MC was trained to select O1 and O2 conditionally upon N1 and N2, respectively, and to select S1 and S2 conditionally upon O1 and O2, respectively.

Training was accomplished with a variant of the delayed-prompting procedure (Touche, 1971). On auditory-visual trials, the experimenter pointed to the correct comparison after speaking the sample name; on visual-visual trials, the experimenter pointed to the correct comparison after lowering the display screen. For the first four trials of each new task (two trials per relation), the pointing prompt immediately followed presentation of the sample (for auditory-visual matching) or the comparisons (for visual-visual matching). On the fifth trial, a delay of 1 s was interposed between stimulus presentation and the cue. If the subject waited for the prompt before responding, the delay was increased by 1 s on the following trial. If the subject responded correctly before the prompt was presented, the delay remained the same. If the subject made an error, the delay was decreased by 1 s on the following trial. After the subject responded correctly before the prompt on 10 consecutive trials of a given task, no further prompts were presented on that task.

Both subjects learned the auditory-visual

Fig. 1. Diagram of conditional relations involving spoken names (N1 and N2), junk objects (O1 and O2), and printed symbols (S1 and S2) in Experiment 1. For Subject DL, O1 was a blue IC socket and O2 was a gray din plug; for Subject MC, O1 was an unpainted aluminum bracket and O2 was a blue capacitor. Arrows point from samples to comparison stimuli. The solid arrows represent conditional relations that were established through explicit discrimination training. The dashed arrows represent conditional relations that might emerge without direct training. Unfilled arrows labeled "S^{R+}" show the food items (F1 or F2) that followed selections of the indicated objects and symbols during conditional-discrimination training.

matching task first. The new auditory-visual relations were trained to a criterion of 12 (for DL) or 24 (for MC) consecutive unprompted correct trials. After reaching these criteria, equal numbers of auditory-visual and identity-matching trials were irregularly alternated for one (for DL) or two (for MC) additional sessions. The arbitrary visual-visual task was then introduced. Criteria for mastery were the same as those applied to the auditory-visual tasks. Afterwards, arbitrary auditory-visual, arbitrary visual-visual trials, and identity-matching trials were intermixed.

Ultimately, the proportion of trial types in the baseline was as follows: three-eighths auditory-visual, three-eighths arbitrary visual-visual, and one-quarter identity matching. This will be called the *mixed* baseline. After accurate performance on one mixed-baseline session, intermittent reinforcement was introduced gradually over several sessions.

Symmetry and Transitivity Probes

Symmetry- and transitivity-probe trials were interspersed among mixed-baseline trials. No reinforcer followed selections on any probe

Fig. 2. Baseline trials and reinforcer probes in Experiment 1. N1 and N2 represent spoken names, O1 and O2 represent objects, S1 and S2 represent printed symbols, and F1 and F2 represent food items. Lines connect samples and pairs of comparison stimuli that were presented together on different trial types. Upper portion: intermittently reinforced mixed-baseline performances. Only selections of comparison stimuli in the columns labeled S+ for each sample were followed by food. S+ selections on the trials on the left were followed by F1; S+ selections on the trials on the right were followed by F2. Lower portion: reinforcer probe-trial types. No probe responses were ever followed by food.

trials. The dashed arrows in Figure 1 illustrate the probed relations; each relation was probed on three trials. On symmetry probes, the samples from visual-visual training trials appeared as comparisons, and the comparisons as samples. For DL, objects (O1 and O2) appeared as samples and symbols (S1 and S2) as comparisons, and for MC, symbols (S1 and S2) appeared as samples and objects (O1 and O2) as comparisons. On transitivity probes, the visual stimuli that were not used in auditory-visual training were presented as comparison stimuli on unreinforced auditory-visual trials. For DL, objects (O1 and O2) were comparisons, and for MC, symbols (S1 and S2) were comparisons, to be selected condi-

tionally upon N1 and N2, respectively. Both subjects received symmetry probes in their first probe session, and after one or two intervening baseline sessions, transitivity probes were presented in a second probe session. The extra baseline sessions were scheduled to verify and review the arbitrary matching baselines when weekends intervened between critical sessions. After these tests, the probed performances were intermittently reinforced and became part of the mixed baseline. The upper portion of Figure 2 shows the subjects' baselines at this point in the experiment.

Reinforcer Probes

New probe trials were then introduced, in which F1 and F2 were presented as samples and comparison stimuli on arbitrary-matching trials. As shown in the lower portion of Figure 2, all possible name-food, object-food, and symbol-food relations were tested. Each potential relation was tested three times. Again, no reinforcers followed selections on any probe trial.

Reliability

Reliability measures were taken in five baseline sessions and seven probe sessions. An independent observer viewed the session and recorded the stimuli presented and the subjects' responses on all trials. Reliability scores (the total number of agreements divided by the total number of agreements plus disagreements) exceeded 99%.

RESULTS

Baseline Training

The results of Experiment 1 are shown in Table 2. For economy of presentation, trained identity conditional relations are abbreviated as OO, SS, FF for both subjects. On half of the OO, SS, and FF trials, the samples were O1, S1, and F1, respectively, and selections of comparisons O1, S1, and F1, respectively, could be followed by F1. On the other half, the samples were O2, S2, and F2, and selections of comparisons O2, S2, and F2, respectively, could be followed by F2. Trained arbitrary conditional relations are abbreviated as NS and SO for Subject DL, and as NO and OS for MC. On half of the arbitrary-matching trials for DL, the sample was either N1 or S1, and selections of comparisons S1 and O1, respectively, could be followed by F1.

Table 2

Training and probe data for the 2 subjects in Experiment 1. Stimuli for trial types are abbreviated as follows: N = Names, O = Objects, S = Symbols, and F = Foods; the first letter refers to the sample, and the second letter to the comparison. Training results are presented as the number of trials correct/number of errors (C/E). Probe results are given as the number of selections of each probe comparison in the presence of each probe sample; the number of selections of each probe comparison follows the colon.

Sessions	Training	C/E	Probes			Probe type
			Sample	Comparisons		
Subject DL						
1–13	OO, SS, FF	182/0				
	NS, SO	327/5				
14–16	OO, SS, FF, NS, SO	132/0				
			O1	S1:3	S2:0	Symmetry
			O2	S1:0	S2:3	Symmetry
			N1	O1:3	O2:0	Transitivity
			N2	O1:0	O2:3	Transitivity
17–27	OO, SS, FF, NS, SO, OS, NO	495/3				
			F1	S1:3	S2:0	Reinforcer
			F2	S1:0	S2:3	Reinforcer
			F1	O1:3	O2:0	Reinforcer
			F2	O1:0	O2:3	Reinforcer
			N1	F1:3	F2:0	Reinforcer
			N2	F1:0	F2:3	Reinforcer
			S1	F1:3	F2:0	Reinforcer
			S2	F1:0	F2:3	Reinforcer
			O1	F1:3	F2:0	Reinforcer
			O2	F1:0	F2:3	Reinforcer
Subject MC						
1–12	OO, SS, FF	159/1				
	NO, OS	276/2				
13–16	OO, SS, FF, NO, OS	156/0				
			S1	O1:3	O2:0	Symmetry
			S2	O1:0	O2:3	Symmetry
			N1	S1:3	S2:0	Transitivity
			N2	S1:0	S2:3	Transitivity
17–24	OO, SS, FF, NO, OS, SO, NS	306/0				
			F1	S1:3	S2:0	Reinforcer
			F2	S1:0	S2:3	Reinforcer
			F1	O1:3	O2:0	Reinforcer
			F2	O1:0	O2:3	Reinforcer
			O1	F1:3	F2:0	Reinforcer
			O2	F1:0	F2:3	Reinforcer
			S1	F1:3	F2:0	Reinforcer
			S2	F1:0	F2:3	Reinforcer
			N1	F1:3	F2:0	Reinforcer
			N2	F1:0	F2:3	Reinforcer

On the other half, the sample was either N2 or S2, and selections of S2 and O2, respectively, could be followed by F2. Subject MC received the analogous NO and OS trials.

Identity matching to sample. Both subjects had displayed generalized identity matching, prior to the study. DL received 182 identity-matching trials in the first 13 sessions and made no errors. MC made one error in 160 identity-matching trials conducted in the course of 12 sessions.

Arbitrary matching to sample. DL received 6 prompted NS trials and 10 prompted SO trials (not shown in Table 2) before consistently anticipating the delayed prompts. He made no errors on 172 unprompted NS trials throughout the training, and only five errors on 160 unprompted SO trials (data combined in Table 2). DL made no errors on the last 84 SO trials, conducted in Sessions 6 through 13.

MC received four prompted NO trials and

four prompted OS trials (not shown in Table 2). She made only one error in 159 unprompted NO trials, and only one error in 119 unprompted OS trials (data combined in Table 2).

Symmetry and Transitivity Probes

As shown in Table 2, on symmetry probes, DL always selected S1 and S2 conditionally upon O1 and O2, respectively; on transitivity probes, he always selected O1 and O2 conditionally upon N1 and N2, respectively. DL made no errors on 132 baseline trials in the probe and intervening baseline sessions. MC performed similarly. On symmetry probes, she always selected O1 and O2 conditionally upon S1 and S2, respectively; on transitivity probes, she always selected S1 and S2 conditionally upon N1 and N2, respectively. Her performance on 156 baseline trials was perfect.

Reinforcer Probes

Table 2 also shows the results of the reinforcer probes, in which the food items were presented as samples or comparison stimuli (Sessions 17–27 for Subject DL and Sessions 17–24 for Subject MC). When samples were F1 and F2, subjects always selected S1 or O1 and S2 or O2, respectively. Further, when samples were N1, S1, or O1 and N2, S2, or O2, subjects always selected F1 and F2, respectively. Performance on baseline trials in the probe sessions was always highly accurate.

DISCUSSION

The results of the symmetry and transitivity probes showed that four-term units that were developed through programmed contingencies also established the basis for the emergence of derived units that were not taught explicitly. Both subjects demonstrated the derived units from the outset of testing. Every response on these probes was consistent with symmetry and transitivity of the directly taught units. Other studies have also reported immediate demonstration of derived relations (e.g., Sidman & Tailby, 1982). On the other hand, some have observed that such relations emerge gradually in the course of testing, or as a function of additional prerequisite training (e.g., Lazar, 1977; Sidman, Kirk, & Willson-Morris, 1985; Sidman, Willson-Morris, & Kirk, 1986; Spradlin, Cotter, & Baxley, 1973). Several factors may have contributed to the immediate

emergence of the derived relations in the present experiment. First, the phenomenon of gradual emergence may be less likely when each potential class includes an auditory stimulus (cf. Sidman et al., 1986). Second, the subjects were experienced with the apparatus and with conditional-discrimination procedures. This history may have contributed to the rapid emergence of derived units, perhaps by facilitating acquisition of the baseline performances during training. Third, reinforcer-specific contingencies such as we used may ultimately prove to hasten acquisition of derived units, just as they seem to hasten acquisition of behavior that is taught directly (see Shepp, 1962; Litt & Schreibman, 1981).

With respect to the other emergent performances, an important question is how to interpret the results of the reinforcer probes. Both subjects showed emergent four-term units in which the food items served as effective samples and comparisons in conditional-discrimination performances involving the non-food items. Emergent units are typically explained by one or more of the prerequisites for stimulus equivalence. Previous research on stimulus equivalence does not provide a basis for predicting emergence of the units on the reinforcer probes. Although the emergence of the derived units was consistent with the suggestion that the cumulative training had established two classes of equivalent stimuli (N1–O1–S1–F1 and N2–O2–S2–F2), neither subject had been directly taught any arbitrary-matching performances in which the foods served as samples or comparisons. The next experiment investigated this previously unknown phenomenon.

EXPERIMENT 2

Prior to the reinforcer probes in Experiment 1, F1 and F2 had never been displayed as samples or comparison stimuli on any arbitrary-matching trials with the names, objects, or symbols. Nonetheless, both subjects displayed emergent arbitrary matching of F1 and F2 with other stimuli that were terms of units previously established by direct teaching. Thus, it appeared that the basis for relating F1 with N1, O1, and S1, and F2 with N2, O2, and S2 was that all stimulus terms in directly trained units became members of stimulus classes (N1–O1–S1–F1 and N2–O2–

Fig. 3. Baseline trials and class-expansion probes in Experiment 2. N1 and N2 represent spoken names, O1 and O2 represent objects, S1 and S2 represent printed symbols, F1 and F2 represent food items, and X1 and X2 represent novel objects. Lines connect samples and pairs of comparison stimuli that were presented together on different trial types. Upper portion: intermittently reinforced mixed-baseline performances. Only selections of comparison stimuli in the columns labeled S+ for each sample were followed by food. S+ selections on the trials on the left were followed by F1; S+ selections on the trials on the right were followed by F2. Lower portion: class-expansion probe-trial types. Not every probe-trial type was presented for each subject (see text for details). No probe responses were ever followed by food.

S2–F2, respectively). If this analysis is correct, then it should be possible to add new members to the classes by incorporating them in new units that terminated with F1 or F2. In this experiment, novel objects, X1 and X2, were displayed on identity-matching trials. Selections of X1 comparisons conditionally upon X1 samples were followed by F1. Selections of X2 comparisons conditionally upon X2 samples were followed by F2. Thus, two new four-term units were established, X1 — X1 — R — F1 and X2 — X2 — R — F2.

If all stimulus terms of the directly trained units became class members, then X1 and F1 should comprise a class, as should X2 and F2. Because F1 and F2 were already members of stimulus classes, N1–O1–S1–F1 and N2–O2–S2–F2, respectively, X1 and X2, in becoming class members with F1 and F2, respectively, should also become members of the larger classes that contained F1 and F2. If so, emergent arbitrary matching of X1 with N1, O1, and S1, and X2 with N2, O2, and S2 should occur.

METHOD

The subjects, apparatus, and general session plan were the same as in Experiment 1.

Mixed Baseline

The mixed baseline established in Experiment 1 was maintained. This baseline included identity matching with objects, symbols, and food items (O1, O2, S1, S2, F1, and F2), and all possible arbitrary-matching relations among the names, objects, and symbols (N1, N2, O1, O2, S1, and S2), as diagrammed in the upper portion of Figure 3. As in Experiment 1, reinforced correct selections of O1, S1, and F1 were followed by presentation of F1, and those of O2, S2, and F2 were followed by presentation of F2. Reinforcers continued to be delivered on the VR 1.33 schedule.

Identity Matching with X1 and X2

Identity-matching trials with the two novel objects, X1 and X2, were added to the mixed baseline, as shown in the upper portion of Figure 3. For Subject DL, X1 was a red electrical connector and X2 was a cylinder of tan cardboard; for MC, X1 was a red and silver toggle switch and X2 was a piece of molded green plastic. For four 48-trial sessions, approximately half the trials in each session were identity-matching trials on which X1 and X2 appeared as the comparison stimuli to be selected conditionally upon X1 or X2, respectively, as samples. Correct selections of X1 and X2 were always followed by F1 and F2, respectively. Thus, responses on trials displaying X1 and X2 were reinforced continuously, rather than intermittently as in the mixed baseline. No arbitrary-matching performances involving X1 or X2 were taught.

Table 3

Training and probe data for the 2 subjects in Experiment 2. Stimuli for trial types are abbreviated as follows: N = Names, O and X = Objects, S = Symbols, and F = Foods; the first letter refers to the sample, and the second letter to the comparison. Training results are presented as the number of trials correct/number of errors (C/E). Probe results are given as the number of selections of each probe comparison in the presence of each probe sample; the number of selections of each probe comparison follows the colon.

Sessions	Training	C/E	Class-expansion probes		
			Sample	Comparisons	
Subject DL					
28–35	OO, SS, FF, NS, SO, OS, NO XX (X1 — F1; X2 — F2)	233/3 126/0			
			X1	S1:3	S2:0
			X2	S1:0	S2:3
			X1	O1:3	O2:0
			X2	O1:0	O2:3
			N1	X1:3	X2:0
			N2	X1:0	X2:3
Subject MC					
25–31	OO, SS, FF, NO, OS, SO, NS XX (X1 — F1; X2 — F2)	161/1 150/0			
			S1	X1:3	X2:0
			S2	X1:0	X2:3
			O1	X1:3	X2:0
			O2	X1:0	X2:3
			N1	X1:3	X2:0
			N2	X1:0	X2:3

Class-Expansion Probes

Unreinforced probe trials tested for emergent arbitrary matching of X1 with N1, O1, and S1, and X2 with N2, O2, and S2. Potentially emergent performances are shown in the lower portion of Figure 3.

Not all of the potentially emergent performances were tested in each subject. For DL, probes in Sessions 32 and 33 displayed X1 and X2 as samples; comparison stimuli were S1 and S2 in the former session, and O1 and O2 in the latter. After one intervening baseline session, probes in Session 35 presented N1 and N2 as samples and X1 and X2 as comparisons. For MC, all probes displayed X1 and X2 as comparisons. Samples were S1 and S2 in Session 29, O1 and O2 in Session 30, and N1 and N2 in Session 31.

For both subjects, six probe trials (three per potential relation) were presented in each probe session, interspersed among mixed-baseline trials. For DL, each probe session contained two identity-matching trials with X1 and X2, presented early in the session, prior to the probes. For Subject MC, whom we considered less capable, three-eighths of the trials

in each probe session were identity-matching trials with X1 and X2, providing a more extensive review of these performances.

RESULTS

Data from Experiment 2 are shown in Table 3. Reliability was taken in one probe session for DL and in all probe sessions for MC. Reliability scores were always 100%.

Training

Data on the mixed-baseline performances are combined in Table 3, because both subjects performed almost errorlessly throughout the experiment. In the first four sessions (28-31 for DL and 25-28 for MC), both subjects performed errorlessly on 96 identity-matching trials with X1 and X2, and those correct selections were followed by F1 and F2, respectively. Errorless performance on these trials was maintained in subsequent sessions.

Class-Expansion Probes

As shown in Table 3, DL reliably selected both S1 and O1 conditionally upon X1, and S2 and O2 conditionally upon X2. He also

reliably selected X1 and X2 conditionally upon N1 and N2, respectively. MC never failed to select X1 conditionally upon S1, O1, and N1, and X2 upon S2, O2, and N2.

DISCUSSION

Neither X1 nor X2 had ever been displayed on arbitrary-matching trials involving the names, objects, or symbols. Nonetheless, both subjects consistently related the former stimuli with the latter, suggesting that X1 was a member of a stimulus class that also contained N1, O1, S1, and F1, and that X2 was a member of a class that also contained N2, O2, S2, and F2. The analysis presented in the introduction to this experiment was supported. X1 and X2, which were involved only in four-term behavioral units with F1 and F2 in training, apparently became class members with the reinforcing stimuli, and thereby became members of the larger classes. The next experiment conducted an even more stringent test of the analysis.

EXPERIMENT 3

The results of Experiment 2 suggested that X1 and X2 had become members of existing stimulus classes because selections of these stimuli had been followed by F1 and F2, respectively—stimuli already members of those classes. However, Stromer (1986) has recently reported that mentally retarded subjects who have extensive matching-to-sample histories may display immediate and reliable conditional behavior on novel arbitrary-matching-to-sample trials. For example, on trials that display two novel comparisons in the presence of either of two novel samples, Stromer reported that some subjects consistently selected a given comparison in the presence of a given sample, although such performances were never taught explicitly and never followed by reinforcers. Similarly, in the present study, our subjects may have adventitiously related X1 to N1, O1, S1, and F1, and X2 to N2, O2, S2, and F2. If so, the subjects' probe behavior in Experiment 2 need not have resulted from establishment of the units X1 — X1 — R — F1 and X2 — X2 — R — F2; instead, the probe results might have been an artifact.

To control for this possibility, Experiment 3 repeated the procedures of Experiment 2, but reversed the reinforcing stimuli for correct

X1 and X2 selections on identity-matching trials. The newly trained units were X1 — X1 — R — F2 and X2 — X2 — R — F1. The previously established units (X1 — X1 — R — F1 and X2 — X2 — R — F2) were no longer maintained. Would class membership of X1 and X2 remain as shown in Experiment 2, or, in accordance with the new contingencies, would X1 now become a class member with N2, O2, S2, and F2 and would X2 now become a class member with N1, O1, S1, and F1? If the latter outcomes occurred, the results would provide strong evidence that class membership of X1 and X2 depended on the reinforcers that their selections produced, and not on some artifactual source of stimulus control.

METHOD

The subjects, apparatus, and general session plan were the same as in the preceding experiments. The intermittently reinforced mixed baseline, established in Experiment 1 and continued in Experiment 2, was maintained. The food items, F1 and F2, continued to be samples and comparison stimuli only on identity-matching trials.

Identity Matching with Reversed Contingencies

As in Experiment 2, sessions included identity-matching trials with X1 and X2, but the programmed contingencies were changed on these trials. Correct X1 selections were now followed by F2, and correct X2 selections were now followed by F1. For each subject, the first three sessions in Experiment 3 (Sessions 36–38 for DL and Sessions 32–34 for MC) included a total of 72 X1 and X2 identity-matching trials, with these reversed contingencies. Again, no arbitrary-matching performances involving X1 or X2 were taught explicitly.

Class-Reversal Probes

After the three training sessions, probe sessions evaluated whether the class membership of X1 and X2 reversed as a result of the reversed contingencies. Probe procedures were identical to those in Experiment 2, except as noted below.

RESULTS

The results of Experiment 3 are shown in Table 4. Reliability, assessed in two probe sessions for each subject, was always 100%.

Table 4

Training and probe data from Experiment 3. Stimuli for trial types are abbreviated as follows: N = Names, O and X = Objects, S = Symbols, and F = Food items; the first letter refers to the sample, and the second letter to the comparison. Training results are presented as the number of trials correct/number of errors (C/E). Probe results are given as the number of selections of each probe comparison in the presence of each probe sample; the number of selections of each probe comparison follows the colon.

Sessions	Training	C/E	Class-reversal probes		
			Sample	Comparisons	
Subject DL					
36–39	OO, SS, FF, NS, SO, OS, NO XX (X1 — F2; X2 — F1)	110/2 74/0	X1	S1:1	S2:2
			X2	S1:3	S2:0
40–41	OO, SS, FF, NS, SO, OS, NO XX (X1 — F2; X2 — F1)	73/1 26/0	X1	S1:0	S2:3
			X2	S1:2	S2:1
42–43	OO, SS, FF, NS, SO, OS, NO XX (X1 — F2; X2 — F1)	73/1 26/0	X1	S1:0	S2:3
			X2	S1:3	S2:0
44–46	OO, SS, FF, NS, SO, OS, NO XX (X1 — F2; X2 — F1)	103/1 28/0	X1	O1:0	O2:3
			X2	O1:3	O2:0
			N1	X1:0	X2:3
			N2	X1:3	X2:0
Subject MC					
32–35	OO, SS, FF, NO, OS, SO, NS XX (X1 — F2; X2 — F1)	96/0 90/0	S1	X1:0	X2:3
			S2	X1:3	X2:0
36	OO, SS, FF, NO, OS, SO, NS XX (X1 — F2; X2 — F1)	24/0 18/0	O1	X1:1	X2:2
			O2	X1:3	X2:0
37–38	OO, SS, FF, NO, OS, SO, NS XX (X1 — F2; X2 — F1)	48/0 36/0	O1	X1:0	X2:3
			O2	X1:3	X2:0
			N1	X1:0	X2:3
			N2	X1:3	X2:0

Identity Matching with Reversed Contingencies

Table 4 shows that both subjects performed errorlessly on all X1 and X2 identity-matching trials throughout the experiment. Also, performance on mixed-baseline trials was highly accurate as well.

Class-Reversal Probes

Subject DL. As shown in Table 4, DL's probe performance was slightly inconsistent in Session 39. When the sample was X2, he selected S1 on each of three probe trials. He also selected S1, however, when the sample

was X1 on one of three probe trials; on the remaining two, he selected S2. After Session 40 reviewed identity matching of X1 and X2, with the reversed contingencies, he again responded inconsistently on probes in Session 41. This time, the single inconsistent response was selecting S2 when the sample was X2. After another review session, DL's probe selections became perfectly consistent in Session 43. He selected S1 conditionally upon X2 and S2 upon X1. After another review session, DL selected O2 conditionally upon X1, and O1 upon X2. In his final probe session, he se-

lected X2 conditionally upon N1, and X1 upon N2.

Subject MC. In her first probe session (Session 35), MC selected X2 conditionally upon S1, and X1 upon S2. In the next session, she displayed slight inconsistency. When the sample was O1, she selected X1 on one probe trial and X2 on the other two. When the sample was O2, she always selected X1 in this session. When these probes were repeated in the next session, however, her probe behavior became perfectly consistent. She selected X2 conditionally upon O1, and X1 upon O2. In her final probe session, MC's probe behavior was also perfectly consistent; she selected X2 conditionally upon N1, and X1 upon N2.

DISCUSSION

Overall, the results strongly suggest that the reversed reinforcement contingencies led to changed class membership of X1 and X2: X1, N2, O2, S2, and F2 came to comprise one class, and X2, N1, O1, S1, and F1 the other. In all, 28 of 30 probe responses indicated this outcome for DL, and 23 of 24 did so for MC. These outcomes seem all the more noteworthy in that both X1 and X2 had been established previously as members of different classes. Perhaps this history led to the slight inconsistencies in the probe behavior. Nonetheless, the reversed reinforcement contingencies were sufficiently powerful to overcome the history and to change the class memberships of X1 and X2.

GENERAL DISCUSSION

The present study suggests that when programmed contingencies establish four-term behavioral units that terminate with different reinforcing stimuli, all three stimulus terms of each unit may become members of the same stimulus class. This study did not comprehensively show that these classes were defined by stimulus equivalence, because not all of the potentially emergent units were tested in each experiment. All results, however, were consistent with acquisition of equivalence relations among the names, objects, symbols, and food items. Systematic replications will determine whether procedures such as those described here do lead to stimulus equivalence and will assess generality across populations of subjects.

Further research must analyze which aspects of the present procedures are necessary to establish reinforcers as members of stimulus classes. In this first study, the training procedures were designed to provide a number of possible prerequisites for this outcome. Specifically, both subjects were first given training that might lead to derived units based on symmetry and transitivity; such units did emerge, perhaps increasing the likelihood that further derived units would be demonstrated. Also, units that had originally emerged through symmetry and transitivity were added to the mixed baseline and reinforced, thereby giving the subjects additional experience with specific reinforcement procedures in different contexts. Finally, the food items themselves served as samples and as comparison stimuli on reinforced identity-matching trials. Such trials had two purposes. First, they verified visual discrimination of the two foods. Second, they provided an experimental history of those foods serving as samples and comparisons, perhaps increasing the likelihood that the food items would serve as effective samples and comparisons on the probes. In sum, both subjects had received extensive preparation prior to the critical probes. It remains to assess whether results similar to those reported here would be obtained if the preparation were less extensive.

Another topic for future consideration is that of interpreting the observation that particular reinforcing stimuli may become members of stimulus classes. With four-term contingencies, do reinforcers become class members because they participate in stimulus-reinforcer relations that emphasize temporal contiguity among stimulus terms in the contingencies? This account recalls the extensive analyses of respondent conditioning in operant-conditioning procedures (see Pear & Eldridge, 1984). On the other hand, the results can be viewed in a different way: Perhaps all stimulus terms in a four-term behavioral unit can become members of the same stimulus class simply through formation of that unit. Of course, separating these accounts would be difficult because four-term units typically include close temporal contiguity between earlier stimulus terms and reinforcers. Perhaps modifications of the matching-to-sample procedure will permit clarification of whether temporally contiguous arrangements of samples, comparisons,

and reinforcers are necessary to produce results such as those obtained here.

It is not yet clear whether the results of the present study shed any light on why reinforcer-specific procedures sometimes produce more rapid acquisition of conditional discriminations in both humans (Litt & Schreibman, 1981; Shepp, 1962) and infrahumans (Carlson & Wielkiewicz, 1972, 1976; DeLong & Wasserman, 1981; Honig et al., 1984; Trapold, 1970). Neither is it clear whether they have any relevance to another reported outcome of reinforcer-specific procedures, enhanced performance on delayed matching-to-sample problems (Brodigan & Peterson, 1976; Honig et al., 1984; Peterson & Trapold, 1980; Peterson, Wheeler, & Armstrong, 1978; Peterson, Wheeler, & Trapold, 1980). The conclusion of the present study—that reinforcers may become class members with samples and comparisons in four-term contingencies—may have some bearing on these observations, however. Consider the units established by typical conditional-discrimination procedures: A1 — B1 — R — F1 and A2 — B2 — R — F1. Both units terminate with F1. If A1, B1, and F1 form a class and if A2, B2, and F1 also form a class, then, using the logic of Experiments 2 and 3, all of the stimuli (A1, A2, B1, B2, and F1) should become members of the same class. Such an outcome might be expected to interfere with subsequent discrimination among these stimuli; if A1 and B2 were members of the same stimulus class, for example, one might expect a subject sometimes to select B2 conditionally upon A1. Of course, this does not happen ordinarily. As many studies of conditional discrimination document, programmed four-term contingencies effectively establish units that maintain their integrity despite sharing a common reinforcing stimulus with other units. Subjects cannot effectively meet the contingencies if they relate stimuli that are followed by the same reinforcer (i.e., in the example given above, relation of A1 and B2 would result in errors and hence extinction). In addition, contingencies may establish specific four-term units that are simply conditional “if . . . then . . .” performances, without stimulus class formation (see Carter & Werner, 1978; Sidman et al., 1982; Sidman & Tailby, 1982).

We may ask, however, whether the common relation to the same reinforcer in the

above example does establish some basis for relating all training stimuli with each other. If so, perhaps this common relation slows acquisition, an effect that is revealed only by comparison with specific reinforcement procedures, which remove the commonality. Also, perhaps a common relation to the same reinforcer makes performances more easily disrupted, for example, by interposing delays between the sample and comparison. Future research may be able to address the question directly, by arranging training and testing conditions that will create and distinguish the different types of classes: (a) one consisting only of the stimuli in an individual four-term unit, as done in the present study, and (b) a larger one that includes the stimuli from more than one unit, each of which terminates with a common reinforcer.

A final point: Two features of the methods and results appear relevant to the analysis of human verbal behavior and its acquisition. Like the four-term units studied here, mands are acquired and maintained under specific-reinforcer control whereas other functional verbal categories are not (Skinner, 1957). More generally, several investigators have proposed that emergent classes of equivalent stimuli may be integral to, or even prerequisite for, language (Devany, Hayes, & Nelson, 1986; Mackay & Sidman, 1984). Our data extend the implications of that proposal and suggest additional research. For example, might conditional discriminations (and perhaps equivalence relations) established and maintained by specific reinforcers differ from comparable behavior supported by nonspecific reinforcers? If so, would the variables responsible for the difference be among those that distinguish mands from other verbal categories (cf. Lamarre & Holland, 1985)? Further, relevant to language development and instruction, what variables might be critical in shifting control of discriminative performance from specific to nonspecific reinforcement conditions (cf. Savage-Rumbaugh, 1984)?

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