SIX-MEMBER STIMULUS CLASSES GENERATED BY CONDITIONAL-DISCRIMINATION PROCEDURES

MURRAY SIDMAN, BARBARA KIRK, AND MARTHA WILLSON-MORRIS

NORTHEASTERN UNIVERSITY AND THE EUNICE KENNEDY SHRIVER CENTER

In conditional-discrimination procedures with three sets of stimuli, A, B, and C, three stimuli per set (A1A2A3, B1B2B3, and C1C2C3), subjects (children and adults) learned to select Set-B and Set-C comparisons conditionally upon Set-A samples (A1B1, A1C1, A2B2, A2C2, A3B3, A3C3). If the conditional-discrimination procedures also generated equivalence relations, three 3-member stimulus classes would be demonstrable, A1B1C1, A2B2C2, and A3B3C3. In addition to these three sets, the present experiments used three other sets of stimuli—D, E, and F. The subjects learned to select Set-E and Set-F comparisons conditionally upon Set-D samples (D1E1, D1F1, D2E2, D2F2, D3E3, D3F3). This established a second group of three 3-member stimulus classes, D1E1F1, D2E2F2, and D3E3F3. In all, two groups of three 3-member classes were established by teaching subjects 12 conditional discriminations. The two groups of 3-member classes were then combined (successfully for 5 of 8 subjects) into a single group of three 6-member classes by teaching the subjects three more conditional relations (E1C1, E2C2, and E3C3). With three other children, enlarging the classes one member at a time also produced 6-member classes. As a consequence of class formation, 60 untrained conditional relations emerged from 15 that had been explicitly taught. Six of the subjects also proved capable of naming the stimuli consistently in accord with their class membership, but two subjects demonstrated class formation even in the absence of consistent naming.

Key words: matching to sample, stimulus equivalence, stimulus classes, conditional discrimination, stimulus control, key press, normal and retarded children and adults

Procedures for teaching subjects conditional discriminations may also generate equivalence relations; sample stimuli may become equivalent to their corresponding comparison stimuli. If they do, the three defining properties of equivalence relations—reflexivity, symmetry, and transitivity—will be demonstrable. In brief, one can test directly for those properties as follows (see Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982; Sidman & Tailby, 1982, for a more detailed deriva-

tion). Reflexivity requires generalized identity matching. Symmetry requires the subject to be capable of reversing the sample and comparison functions of stimuli in the conditional discriminations; after having been taught AB (selecting Comparison B conditionally upon Sample A), the subject will be capable of a new conditional discrimination, BA (selecting Comparison A conditionally upon Sample B). If transitivity applies, a new conditional discrimination, AC, will emerge after the subject has been taught two other conditional discriminations, AB and BC, in which Stimulus B served as a comparison in one and as a sample in the other.

Figure 1 outlines a method for determining whether conditional relations, taught to subjects who can do generalized identity matching, also possess the other properties that define equivalence. In the upper "triangle," subjects are first taught to select Greek-letter comparison stimuli in Sets B

This research, carried out in the Behavior Laboratories of the E. K. Shriver Center for Research in Mental Retardation, was supported by Grants MH30063, HD05124, and NE-G-00-3-0011. We are grateful to F. Garth Fletcher for apparatus design and construction, to Charles Sidman for computer programming, and to Ben Wallace for apparatus maintenance and programming support. Reprints may be obtained from Murray Sidman, Department of Psychology, 282 Nightingale Hall, Northeastern University, 360 Huntington Avenue, Boston, Massachusetts 02115.

and C conditionally upon dictated letter-name samples from Set A; they learn to choose upper- and lower-case delta when "delta" is the sample, upper- and lower-case sigma when "sigma" is the sample, upper- and lower-case xi when "xi" is the sample. Then, in tests without reinforcement, the subjects match to each other those Set-B and Set-C letters that they had learned to match to the same dictated name: upper- and lower-case delta, upper- and lower-case sigma, upper- and lower-case xi.

Emergence of these new conditional discriminations signifies the formation of three 3-member classes of equivalent stimuli, each class containing a dictated letter name from Set A, a Set-B letter, and a Set-C letter. Such auditory-visual classes have been demonstrated with human subjects and several kinds of stimuli (Mackay & Sidman, 1984; Sidman, 1971, 1977; Sidman & Cresson, 1973; Sidman, Cresson, & Willson-Morris, 1974; Sidman & Tailby, 1982; Sidman, Willson-Morris, & Kirk, *in press*). The existence of classes of equivalent stimuli makes it possible for the subjects, who are explicitly taught six conditional relations (three AB and three AC), to match the three B samples to appropriate C comparisons, and vice versa (three BC and three CB relations); six new conditional relations emerge without having been explicitly taught.

The auditory stimuli in Set A cannot be presented simultaneously as comparisons, a methodological limitation that precludes BA and CA tests. In the lower triangle, however, all stimuli are visual. Subjects learn to select each Greek-letter comparison in Sets E and F conditionally upon a particular English script letter from Set D. Again, three 3-member classes emerge, subjects matching those Set-E and Set-F letters to each other that they had learned to match to the same Set-D sample. Such visual classes have also been demonstrated with human subjects and several kinds of stimuli (Lazar, 1977; Lazar, Davis-Lang, & Sanchez, 1984; Lazar & Kotlarchyk, 1980; Sidman *et al.*, 1982, *in press*; Spradlin, Cotter, & Baxley, 1973; Stromer & Osborne, 1982; Wetherby,

Fig. 1. Each box represents a set of three stimuli. Arrows representing conditional relations point from sample to comparison stimuli. The stimuli are arranged, for expository purposes, so that auditory "delta" is matched to the letter on the left in each box, "sigma" to the center letter, and "xi" to the letter on the right; in all other instances, letters are matched to each other according to their relative positions in the boxes. The 4 solid arrows represent 12 conditional relations taught by explicit reinforcement procedures; the 6 broken arrows represent 18 emergent relations.

Karlan, & Spradlin, 1983). Because the Set-D stimuli are visual, one can evaluate the DE and DF relations for symmetry by testing whether subjects will match samples from Sets E and F to Set-D comparisons (ED and FD relations). Although symmetry has not yet been unequivocally demonstrated with nonhuman subjects (Sidman *et al.*, 1982), humans do show symmetry in cond-

ditional relations (Lazar et al., 1984; Sidman & Tailby, 1982; Sidman et al., in press; Stromer & Osborne, 1982; Wetherby et al., 1983).

In the lower triangle, then, the existence of classes of equivalent stimuli makes it possible for subjects who have been explicitly taught six relations (three DE and three DF) to match three Set-E samples to appropriate Set-F comparisons and vice versa (three EF and three FE relations), and to match each Set-E and Set-F sample to appropriate Set-D comparisons (three ED and three FD relations); 12 new conditional relations emerge without having been explicitly taught.

Each of the four solid arrows AB, AC, DE, and DF denotes three conditional relations that a subject has been explicitly taught. Each of the six broken arrows BC, CB, EF, FE, ED, and FD denotes three emergent relations. If the 12 explicitly taught relations are also equivalence relations, the subject will be capable of 18 new conditional discriminations. The ratio of emergent to explicitly taught conditional discriminations is 3:2. One may appreciate the potential scope of the process of equivalence formation by considering the expansion of this ratio if a subject who has learned AB, AC, DE, and DF were then to be taught just three more conditional discriminations, denoted in Figure 2 by the solid arrow EC.

The subject now learns to select each comparison letter in Set C conditionally upon a particular sample from Set E; a member of each DEF class is matched to a member of each ABC class. If the new EC conditional relations were also equivalence relations, this linkage should combine the two groups of three 3-member classes into one group of three 6-member classes, each class containing one element from each of the six stimulus sets. The subject should then be able to match *any* two members of a class to each other.

Figure 3 depicts the potential for expansion of the emergent performances. Learning the 3 EC relations should add 42 new conditional discriminations to the subject's repertoire. In sum, the explicit teaching of

Fig. 2. The relations represented are as in Figure 1, with the addition of the 3 EC relations taught by explicit reinforcement procedures.

15 relations (3 each in AB, AC, EC, DE, and DF) should generate 60 new relations (3 denoted by each broken arrow). Combining the two groups of 3-member classes into one group of 6-member classes should therefore increase the ratio of emergent to explicitly taught conditional discriminations from 3:2 to 4:1. The present experiments explored several teaching and testing sequences to determine whether conditional-discrimination procedures would generate 6-member classes of equivalent stimuli, and to ascertain the composition of the emergent relations.

eight, with a ninth in the center. Sidman and Tailby (1982) have described additional features and dimensions of a similar projection and response system. The present experiments used only the center key and the lowest three keys in the circle. Automatic dispensers, mounted in an enclosure adjacent to the keys, delivered pennies or tokens into an open plastic receptacle below and at the right of the keys. The sound of chimes, mounted 1 m above the keys, helped to bridge the time pennies or tokens took to fall from the dispenser into the tray. A Nova minicomputer programmed the procedures. Data were also recorded online by printing counters, a 20-pen Esterline-Angus operations recorder, and an experimenter who was seated behind the subject.

Conditional-Discrimination Procedures

Each trial began with a sample stimulus, visual samples being on the center key and auditory samples being dictated and repeated by a tape loop (Fletcher, Stoddard, & Sidman, 1971). Visual and auditory samples never occurred together. When the subject pushed the sample key after a sample was presented, comparison stimuli appeared on the other three keys. With dictated samples, pressing the blank center key could not produce comparisons until at least one complete sample word had sounded. Each sample remained, along with the comparisons, until the subject pressed a comparison key.

Unless a reduced reinforcement probability or a probe trial precluded reinforcement, correct choices were followed by the sound of chimes, the disappearance of all stimuli, the delivery of a penny or token, and a 1.5-s intertrial interval. No chimes, penny, or token followed incorrect choices. Subjects traded their tokens for money, often buying snacks or toys after the session. They kept all money they did not spend.

Positions of correct and incorrect stimuli varied among the three comparison keys from trial to trial. All sample-comparison combinations and all correct keys were equally probable on successive trials, with the following restrictions: Starting with the

first trial, within groups of three successive trials each key had to be scheduled as correct; trial sequences that included only two different samples (during training) had no more than three consecutive trials with the same sample; with more than two samples, all possible combinations of sample and comparison stimuli had to occur before any could repeat.

Pressing any key during an intertrial interval postponed the next sample for 1.5 s. Once a sample had come on, the subject could not produce comparison stimuli by pressing sample and comparison keys simultaneously, and had to break contact with all keys before a new sample press could be effective. Once comparisons had come on, pressing the sample no longer had programmed consequences. If the subject pressed an incorrect or blank key simultaneously with a correct comparison, the trial was scored as incorrect. A correct response was not defined until the subject had released the key for 0.2 s; pressure on another key during the preceding press, or within 0.2 s of a release, defined a simultaneous response. A computer programmed the procedures.

Oral-Naming Procedures

Oral-naming tests presented only samples, with no comparisons. Subjects pressed no keys, but were asked, "Tell me what you see" or "What is it?" After each reply the experimenter, seated behind the subject, pressed a switch to initiate the intertrial interval and the slide change. Subjects received no chimes, pennies, or tokens, even for "correct" names. Their responses were recorded by the experimenter, and on magnetic tape. As a reliability check, a second experimenter recorded the responses from the tape, in the absence of the visual stimuli to which the subject had been responding. There was never more than one disagreement between the two records in a 90-trial naming test.

Pretraining and Pretests

Subjects who were unfamiliar with the laboratory began with a program that taught

them a circle versus ellipse discrimination, with stimuli appearing only on the outer keys (Sidman & Stoddard, 1966; 1967). Then, matching to sample was introduced with hues as stimuli. First, pressing the center key when a hue was projected on it brought the same hue onto one of the outer comparison keys; pressing the single comparison produced a reinforcer. Next, non-matching comparison hues were also introduced, and subjects quickly learned to select the one that was the same as the sample. Hue names were then dictated as samples, with the visual comparisons, after which oral naming of the hues was tested. In the final pretests, which used the visual stimuli illustrated in Figure 1, the sample and correct comparison were the same, and the two incorrect comparisons were the other letters in the same set. All subjects performed accurately on all of these procedures, demonstrating their ability to do auditory-visual matching, oral naming, and generalized identity matching.

Baseline Teaching

Standard accuracy criterion. To advance from one teaching step to another, subjects had to achieve an overall score of at least 90% correct. In addition, they could make no more than one error on any trial type (combination of sample and comparisons).

The baseline. Subjects were taught the groups of baseline conditional discriminations represented by solid arrows in Figure 1. The sequence in which they learned the elements of this baseline varied among experiments. Figure 4 depicts the sample and comparison stimuli in the 15 trial types that all subjects were explicitly taught. These trial types would constitute a baseline into which probe trials would be inserted to evaluate the existence of equivalence relations.

At the beginning of each new teaching session, subjects had once again to meet the learning criterion on their most advanced performance. If they failed to do so, they were returned to an earlier teaching step before advancing through the teaching sequence again. The number of teaching trials

TASK	SAMPLE	COMPARISONS	
		CORRECT	INCORRECT
AB ₁	"DELTA"	Δ	Σ, Ξ
AC ₁	"DELTA"	δ	σ, 3
EC ₁	∧	δ	σ, 3
DE ₁	ℒ	∧	Ω, Γ
DF ₁	ℒ	λ	ω, 8
AB ₂	"SIGMA"	Σ	Δ, Ξ
AC ₂	"SIGMA"	σ	δ, 3
EC ₂	Ω	σ	δ, 3
DE ₂	θ	Ω	∧, Γ
DF ₂	θ	ω	λ, 8
AB ₃	"XI"	Ξ	Δ, Σ
AC ₃	"XI"	3	δ, σ
EC ₃	Γ	3	δ, σ
DE ₃	ℒ	Γ	∧, Ω
DF ₃	ℒ	8	λ, ω

Fig. 4. The sample and three comparison stimuli (one correct and two incorrect) in the 15 baseline conditional discriminations that all subjects were explicitly taught (see Figure 2). The numbers 1, 2, and 3 specify the expected class membership of the sample and correct comparison in each trial type. These trial types were presented to the subjects in mixed sequences. Quotation marks around the name of a letter indicate that the stimulus was auditory.

and the duration of teaching sessions varied considerably, but unsystematically, from subject to subject and, within subjects, from phase to phase. Subjects sometimes required only the minimum number of trials to learn a baseline element, and at other times needed review and reteaching before they could reach or maintain criterion performance. Most sessions lasted about 30 min, but they ranged from 15 to 60 min in duration.

Conditional-Discrimination Tests

Tests had 27 trials of a group of three untrained relations (each group denoted by a broken arrow in Figure 3) inserted as probes among 45 baseline trials (Figure 4). Subjects received no chimes, pennies, or tokens on probe trials. In preparation for unreinforced probes, the baseline reinforcement probability for two subjects (see Experiment 1) was gradually reduced to .20. The program for reducing the reinforcement probability

while ensuring the maintenance of high baseline accuracy has been described by Sidman et al. (in press). All other subjects, however, had 27-trial tests with no reinforcement on any trials, baseline or probe. To ensure that they could maintain high accuracy, they had first to achieve the standard criterion on baseline trials without reinforcement. After extinction training and after tests, they were given enough hue-hue or picture-picture matching trials to make up for missed baseline reinforcements.

Sessions in which a test was scheduled began with a review of the baseline, with reinforcement. To proceed to the test, subjects had to meet the standard criterion. Any subject who failed several times to achieve criterion returned to an earlier teaching step and advanced through the teaching sequence again.

Oral-naming tests. Each test had 90 unreinforced trials, 6 presentations each of the B-, C-, D-, E-, and F-stimuli.

EXPERIMENT 1

Conditional relations that are also equivalence relations will be reflexive, symmetric, and transitive. If the relations diagrammed in Figure 3 were equivalence relations, one could use transitivity to identify the sufficient prerequisites for the FB and BF relations: (1) For a subject to match Set-F samples to Set-B comparisons (FB) without being explicitly taught to do so, the FE, EC, and CB relations are prerequisites; (2) to match Set-B samples to Set-F comparisons (BF), the BC, CE, and EF relations are prerequisites; (3) BC and CB, themselves, require the explicitly taught AB and AC relations; EF and FE require DE and DF. Emergence of FB and BF therefore demands the involvement of all six sets of stimuli, and would provide the first indication that the baseline teaching had established 6-member classes.

In the event that 6-member classes did form, the subject should then be able to do more than match the Set-B and Set-F stimuli to each other. Even without having been

explicitly taught to do so, the subject should be able to match *any* two members of a class. All of the conditional discriminations denoted by the broken arrows in Figure 3 should emerge, providing final proof that the baseline teaching had established 6-member stimulus classes.

Because six sets of stimuli are necessary for the FB and BF relations to emerge, these may be called "6-stage" equivalence relations (a terminology adapted from the paired-associate literature—e.g., Jenkins, 1963). The concept of stages, different from class size, is useful because *n*-member classes can exist even though no component relation requires more than three sets of stimuli (stages) for its derivation (e.g., see Lazar et al., 1984). Figure 5 classifies all the potential relations in the present experiment according to stages, and illustrates the actual conditional discriminations for which subjects were tested. At the upper left (6-stage) are the three BF and the three FB trial types; the 5-stage section illustrates 9 trial types in the three groups of relations (BD, DB, and AF) that require five sets of stimuli for their derivation (FA could not be tested because the Set-A stimuli were auditory); the 4-stage section shows 15 trial types in the five groups of relations that require four sets of stimuli; the 3-stage section has 21 trial types in seven groups of relations that require only three sets of stimuli for their derivation; the symmetry section illustrates the trial types in the three sets of relations that require only the symmetric property in the relation from which each is derived (CE from EC, ED from DE, and FD from DF).

The 60 conditional discriminations illustrated in Figure 5 comprise the entire test battery. Complete consistency of a subject's performance on these derived relations is required if the explicitly taught relations are to be said to have established 6-member classes of equivalent stimuli.

METHOD

Subjects

Subjects were five normal children, whose sex (M or F), and age (years/months) at the

COMPARISONS			
TASK	SAMPLE	CORRECT	INCORRECT
6-STAGE: BF1	Δ	(λ)	(ω, δ)
	BF2	(ω)	(λ, δ)
	BF3	(δ)	(λ, ω)
	FB1	(Δ)	(Σ, Ξ)
	FB2	(Σ)	(Δ, Ξ)
	FB3	(Ξ)	(Δ, Σ)
5-STAGE: BD1	Δ	($\mathcal{L}$)	($\theta, \mathcal{Y}$)
	BD2	(θ)	($\mathcal{L}, \mathcal{Y}$)
	BD3	($\mathcal{Y}$)	($\mathcal{L}, \theta$)
	DB1	(Δ)	(Σ, Ξ)
	DB2	(Σ)	(Δ, Ξ)
	DB3	(Ξ)	(Δ, Σ)
	AF1	"DELTA" (λ)	(ω, δ)
	AF2	"SIGMA" (ω)	(λ, δ)
	AF3	"XI" (δ)	(λ, ω)
COMPARISONS			
TASK	SAMPLE	CORRECT	INCORRECT
4-STAGE: BE1	Δ	($\wedge$)	(Ω, Γ)
	BE2	(Ω)	($\wedge, \Gamma$)
	BE3	(Γ)	($\wedge, \Omega$)
	EB1	(Δ)	(Σ, Ξ)
	EB2	(Σ)	(Δ, Ξ)
	EB3	(Ξ)	(Δ, Σ)
	CF1	(δ)	(ω, λ)
	CF2	(ω)	(λ, δ)
	CF3	(λ)	(ω, δ)
	FC1	(δ)	($\sigma, \mathfrak{z}$)
	FC2	(σ)	($\delta, \mathfrak{z}$)
	FC3	($\mathfrak{z}$)	(δ, σ)
	AD1	"DELTA" ($\mathcal{L}$)	($\theta, \mathcal{Y}$)
	AD2	"SIGMA" (θ)	($\mathcal{L}, \mathcal{Y}$)
	AD3	"XI" ($\mathcal{Y}$)	($\mathcal{L}, \theta$)
COMPARISONS			
TASK	SAMPLE	CORRECT	INCORRECT
3-STAGE: BC1	Δ	(δ)	($\sigma, \mathfrak{z}$)
	BC2	(σ)	($\delta, \mathfrak{z}$)
	BC3	($\mathfrak{z}$)	(δ, σ)
	CB1	(Δ)	(Σ, Ξ)
	CB2	(Σ)	(Δ, Ξ)
	CB3	(Ξ)	(Δ, Σ)
	EF1	(λ)	(ω, δ)
	EF2	(ω)	(λ, δ)
	EF3	(δ)	(λ, ω)
	FE1	($\wedge$)	(Ω, Γ)
	FE2	(Ω)	($\wedge, \Gamma$)
	FE3	(Γ)	($\wedge, \Omega$)
	CD1	($\mathcal{L}$)	($\theta, \mathcal{Y}$)
	CD2	(θ)	($\mathcal{L}, \mathcal{Y}$)
	CD3	($\mathcal{Y}$)	($\mathcal{L}, \theta$)
	DC1	(δ)	($\sigma, \mathfrak{z}$)
	DC2	(σ)	($\delta, \mathfrak{z}$)
	DC3	($\mathfrak{z}$)	(δ, σ)
	AE1	"DELTA" ($\wedge$)	(Ω, Γ)
	AE2	"SIGMA" (Ω)	($\wedge, \Gamma$)
	AE3	"XI" (Γ)	($\wedge, \Omega$)
COMPARISONS			
TASK	SAMPLE	CORRECT	INCORRECT
SYMMETRY: CE1	δ	($\wedge$)	(Ω, Γ)
	CE2	(Ω)	($\wedge, \Gamma$)
	CE3	(Γ)	($\wedge, \Omega$)
	ED1	($\mathcal{L}$)	($\theta, \mathcal{Y}$)
	ED2	(θ)	($\mathcal{L}, \mathcal{Y}$)
	ED3	($\mathcal{Y}$)	($\mathcal{L}, \theta$)
	FD1	($\mathcal{L}$)	($\theta, \mathcal{Y}$)
	FD2	(θ)	($\mathcal{L}, \mathcal{Y}$)
	FD3	($\mathcal{Y}$)	($\mathcal{L}, \theta$)

Fig. 5. The sample, "correct," and "incorrect" stimuli in each probed conditional discrimination. Because there was no reinforcement on probe trials, "correct" and "incorrect" comparisons are enclosed within parentheses. The numbers 1, 2, and 3 specify the expected class membership of the sample and correct comparison in each trial type. The conditional discriminations are grouped according to their *n*-stage equivalence classification, the number of stimulus sets required for their derivation, except for those that require only symmetric baseline relations for their derivation. Quotation marks around the name of a letter indicate that the stimulus was auditory.

start of the experiment were: N.O., F, 5/4; E.H., F, 5/6; R.W., M, 5/7; J.S., F, 6/2; F.M., F, 9/2; and one retarded adult with a medical diagnosis of Down's syndrome: P.M., M, 21/1 (mental age of 4-1 on the Peabody Picture Vocabulary Test).

Table 1

Sequences in which subjects were taught each set of conditional discriminations. The identifiers, AB, AC, EC, DE, and DF refer to the relations diagrammed in Figure 2.

Conditional Relations	Subjects					
	<i>E.H.</i>	<i>F.M.</i>	<i>N.O.</i>	<i>R.W.</i>	<i>J.S.</i>	<i>P.M.</i>
AB	1	1	4	5	4	4
AC	2	2	1	4	5	5
AB,AC	3	3	-	6	6	6
DE	4	4	5	2	1	1
DF	5	5	2	1	2	2
DE,DF	6	6	-	3	3	3
AB,DE	-	-	6	-	-	-
AC,DF	-	-	3	-	-	-
AB,AC,DE,DF	7	7	7	7	7	7
EC	8	8	8	8	8	8
AB,AC,EC, DE,DF	9	9	9	9	9	9

Procedure

Table 1 gives the sequence in which subjects were taught the baseline conditional discriminations represented by solid arrows in Figure 2. Subject E.H., for example, first learned AB and then AC, and then had trial sequences with both groups of trial types mixed; next, she learned DE, then DF, and then both of those together; next, AB, AC, DE, and DF trials were mixed; all subjects were taught the EC relations last, and the final phase mixed all five groups of trial types. The three conditional discriminations within a group were taught in a carefully programmed sequence, and groups were combined into a longer series of trials only after subjects met the standard accuracy criterion at each step (Sidman et al., in press).

After learning the 15 baseline conditional relations, subjects were tested for the existence of 6-member classes. The first test had the three FB trial types inserted as probes into the baseline, and the second had the three BF trials as probes. The subsequent testing sequence varied among subjects and will be described below. The baseline reinforcement probability during tests was .20 for Subjects P.M. and E.H., but was changed to zero for the latter after a few tests (see below); all other subjects were tested in extinction. Subjects E.H., F.M.,

and N.O. were tested for oral naming of the stimuli after they completed conditional-discrimination testing.

RESULTS

Conditional Discriminations

Subject E.H. Figure 6 summarizes Subject E.H.'s probe-trial performances in 27 consecutive tests. Matrices representing her first 8 tests show how often she selected each comparison stimulus, given each sample. Beneath the column totals of each matrix, and underlined, are the test number, the relation that was tested, and the total number of "hits" per opportunity. For Tests 9 to 27 these data, not underlined, are tabulated without their corresponding matrices.

The matrix rows and columns have been arranged as follows: If the conditional relations the subject had been taught were also equivalence relations, thereby creating three 6-member stimulus classes, the uppermost sample and the leftmost comparison in any matrix would be members of Class 1; the center sample and comparison would be members of Class 2; the bottom sample and the rightmost comparison would be members of Class 3. Any comparison selection that was consistent with these class memberships was tabulated as a "hit"; all others were "false alarms." Every test contained 9 trials with each sample. Therefore, if the subject always selected a comparison according to these class specifications, the three diagonal cells of the matrix, extending from upper left to lower right, would each contain 9 hits (as in Test 7).

Since random selection of the three comparisons would have produced only 9 hits in the 27 opportunities, one might conclude that Subject E.H.'s 18 hits in her first FB test provided evidence for the existence of 6-member stimulus classes. That evidence, however, is questionable. First, the matrix suggests a strong bias toward one comparison (9 hits and 8 false alarms), especially in trials with two of the samples; 9 hits therefore could reflect the comparison bias rather than the relation between sample and

		COMPARISON STIMULI											
SAMPLE STIMULI	$\Delta \Sigma \Xi$			$\lambda \omega \gamma$			$\Delta \Sigma \Xi$			$\lambda \omega \gamma$			
	λ	9	0	0	Δ	9	0	0	$\mathcal{L}$	7	1	1	"DELTA" 3 3 3
	ω	7	2	0	Σ	1	5	3	θ	3	4	1	"SIGMA" 1 8 0
	γ	1	1	7	Ξ	2	2	5	$\mathcal{H}$	0	2	7	"X1" 2 1 6
		17	3	7		12	7	8		10	7	9	6 12 9
	<u>1. FB: 18/27</u>			<u>2. BF: 19/27</u>			<u>3. DB: 18/26</u>			<u>4. AF: 17/27</u>			
	$\mathcal{L} \theta \mathcal{H}$			$\Delta \Sigma \Xi$			$\Delta \Sigma \Xi$			$\Delta \Sigma \Xi$			
	Δ	8	1	0	$\wedge$	7	2	0	$\mathcal{L}$	9	0	0	λ 9 0 0
	Σ	3	5	1	Ω	2	7	0	θ	0	9	0	ω 2 7 0
	Ξ	1	0	8	Γ	0	0	9	$\mathcal{H}$	0	0	9	γ 0 0 9
		12	6	9		9	9	9		9	9	9	11 7 9
	<u>5. BD: 21/27</u>			<u>6. EB: 23/27</u>			<u>7. DB: 27/27</u>			<u>8. FB: 25/27</u>			
	9. BF: 27/27			10. BD: 26/27			11. AF: 27/27			12. EB: 26/27			
	13. BE: 26/27			14. FC: 27/27			15. CF: 26/27			16. AD: 27/27			
	17. CB: 27/27			18. BC: 27/27			19. FE: 27/27			20. EF: 26/27			
	21. DC: 27/27			22. CD: 25/27			23. AE: 26/27			24. CE: 27/27			
	25. FD: 26/27			26. ED: 27/27			27. BF: 26/27			E.H.			

Fig. 6. Subject E.H. Scores on the 27 probe trials in each of 27 consecutive tests. Matrices representing the first 8 tests show how often the subject selected each illustrated comparison stimulus (columns), given each illustrated sample (rows). Quotation marks around the name of a letter indicate that the stimulus was auditory. Every test contained 9 trials with each sample (in Test 3, the subject selected a blank key once, rather than one of the three comparison keys). Beneath the column totals of each matrix, and underlined, are the test number (1 for the first test, 2 for the second, etc.), the relation being tested (FB, BF, etc., corresponding to the broken arrows in Figure 3 and to the "tasks" in Figure 5), and the total number of hits per opportunity (18/27 in the first test, 19/27 in the second test, etc.). For Tests 9 to 27, these data (not underlined) are listed without the corresponding matrix.

comparison. Then, in trials with the third sample, she almost always chose a particular one of the two remaining comparisons; given a 50% chance of choosing the one that was in the same class as the sample, this could have added another 7 hits "by chance" to the total. The score of 18/27, therefore, may have reflected forms of stimulus control that were unrelated to the baseline conditional discriminations, and cannot be accepted as evidence of stimulus-class formation.

The total number of hits remained relatively constant in the 6-stage BF probes

(Test 2) and the 5-stage DB and AF probes (Tests 3 and 4), but the pattern of hits and false alarms varied. Early suggestions that one and perhaps two classes had formed were not sustained. The first four tests therefore provided no solid evidence for the existence of 6- or 5-member classes.

In Test 4, however, before starting to respond inconsistently, Subject E.H. scored hits on the first few probe trials. This observation raised the possibility that she had discriminated the zero reinforcement frequency on probe trials, in contrast to the

COMPARISON STIMULI				
$\Delta \Sigma \Xi$ $\lambda \begin{array}{ccc} 6 & 0 & 3 \\ 2 & 7 & 0 \\ \hline 4 & 2 & 3 \\ 12 & 9 & 6 \end{array}$ <u>1. FB: 16/27</u>	$\Delta \Sigma \Xi$ $\lambda \begin{array}{ccc} 0 & 2 & 7 \\ 0 & 9 & 0 \\ \hline 9 & 0 & 0 \\ 9 & 11 & 7 \end{array}$ <u>2. FB: 9/27</u>	$\Delta \Sigma \Xi$ $\mathcal{L} \begin{array}{ccc} 2 & 7 & 0 \\ 8 & 1 & 0 \\ \hline 0 & 0 & 9 \\ 10 & 8 & 9 \end{array}$ <u>3. DB: 12/27</u>	$\Delta \Sigma \Xi$ $\Lambda \begin{array}{ccc} 9 & 0 & 0 \\ 9 & 0 & 0 \\ \hline 1 & 0 & 8 \\ 19 & 0 & 8 \end{array}$ <u>4. EB: 17/27</u>	$\Lambda \Omega \Gamma$ $\delta \begin{array}{ccc} 9 & 0 & 0 \\ 0 & 9 & 0 \\ \hline 0 & 0 & 9 \\ 9 & 9 & 9 \end{array}$ <u>5. CE: 27/27</u>
$\Delta \Sigma \Xi$ $\Lambda \begin{array}{ccc} 9 & 0 & 0 \\ 9 & 0 & 0 \\ \hline 0 & 0 & 9 \\ 18 & 0 & 9 \end{array}$ <u>6. EB: 18/27</u>	$\Lambda \Omega \Gamma$ $\delta \begin{array}{ccc} 9 & 0 & 0 \\ 0 & 9 & 0 \\ \hline 0 & 0 & 9 \\ 9 & 9 & 9 \end{array}$ <u>7. CE: 27/27</u>	$\Delta \Sigma \Xi$ $\delta \begin{array}{ccc} 8 & 0 & 1 \\ 9 & 0 & 0 \\ \hline 0 & 1 & 8 \\ 17 & 1 & 9 \end{array}$ <u>8. CB: 16/27</u>	$\delta \sigma \mathfrak{Z}$ $\Delta \begin{array}{ccc} 3 & 6 & 0 \\ 0 & 8 & 1 \\ \hline 0 & 0 & 9 \\ 3 & 14 & 10 \end{array}$ <u>9. BC: 20/27</u>	$\delta \sigma \mathfrak{Z}$ $\Delta \begin{array}{ccc} 0 & 9 & 0 \\ 0 & 8 & 1 \\ \hline 0 & 0 & 9 \\ 0 & 17 & 10 \end{array}$ <u>10. BC: 17/27</u>
$\Delta \Sigma \Xi$ $\delta \begin{array}{ccc} 9 & 0 & 0 \\ 9 & 0 & 0 \\ \hline 0 & 0 & 9 \\ 18 & 0 & 9 \end{array}$ <u>11. CB: 18/27</u>	$\Delta \Sigma \Xi$ $\delta \begin{array}{ccc} 6 & 0 & 0 \\ 3 & 3 & 0 \\ \hline 0 & 0 & 6 \\ 9 & 3 & 6 \end{array}$ <u>12. CB: 15/18</u>	$\Delta \Sigma \Xi$ $\delta \begin{array}{ccc} 6 & 0 & 0 \\ 0 & 6 & 0 \\ \hline 0 & 0 & 6 \\ 6 & 6 & 6 \end{array}$ <u>13. CB: 18/18</u>	$\Delta \Sigma \Xi$ $\delta \begin{array}{ccc} 9 & 0 & 0 \\ 0 & 9 & 0 \\ \hline 0 & 0 & 9 \\ 9 & 9 & 9 \end{array}$ <u>14. CB: 27/27</u>	$\Delta \Sigma \Xi$ $\Lambda \begin{array}{ccc} 9 & 0 & 0 \\ 1 & 8 & 0 \\ \hline 0 & 0 & 9 \\ 10 & 8 & 9 \end{array}$ <u>15. EB: 26/27</u>
$\Delta \Sigma \Xi$ $\mathcal{L} \begin{array}{ccc} 9 & 0 & 0 \\ 1 & 8 & 0 \\ \hline 0 & 0 & 9 \\ 10 & 8 & 9 \end{array}$ <u>16. DB: 26/27</u>	$\Delta \Sigma \Xi$ $\delta \begin{array}{ccc} 9 & 0 & 0 \\ 0 & 9 & 0 \\ \hline 0 & 0 & 9 \\ 9 & 9 & 9 \end{array}$ <u>17. FB: 27/27</u>	<u>18. BF: 27/27</u> <u>21. BE: 27/27</u> <u>24. AD: 27/27</u> <u>27. CD: 27/27</u> F.M.	<u>19. BD: 27/27</u> <u>22. FC: 27/27</u> <u>25. BC: 25/27</u> <u>28. AE: 27/27</u>	<u>20. AF: 27/27</u> <u>23. CF: 27/27</u> <u>26. DC: 27/27</u> <u>29. BF: 25/27</u>

Fig. 7. Subject F.M. Probe-trial scores in each of 29 consecutive tests. Data from the first 17 tests are in matrix form. Below each matrix are the test number, the tested relation, and the hits per opportunity; for Tests 18 to 29, these data are listed without the corresponding matrix. The baseline in Tests 12 and 13 (matrices "boxed in") did not contain the EC relations and had only 6 trials with each sample.

occasionally reinforced baseline trials. Her comments also supported this possibility. Therefore, in order to prevent selective extinction on probe trials, she was given no reinforcements during subsequent tests, even on baseline trials.

The fifth test, 5-stage BD probes, yielded more hits than before but the false-alarm rate was still high, so 4-stage EB probes were given next. Matrix 6 provided encouraging evidence for the formation of 4-member classes, so the 5-stage DB test was repeated; Matrix 7 represented a perfect performance. Then, Test 8, a repetition of the FB probes,

gave clear evidence for the existence of 6-member classes.

Subject E.H. then completed the remaining tests, ending with a repetition of the BF probes (Test 27). Her consistent performances on the 60 emergent conditional discriminations (rarely as many as 2 false alarms) provided overwhelming evidence that three 6-member stimulus classes had been established.

Subject F.M. Figure 7 summarizes Subject F.M.'s tests. Her first FB test gave little indication of 6-member classes, and when the test was repeated she scored only 9 hits. Tests 3 and 4 (5-stage DB and 4-stage EB)

gave no convincing evidence of 5- or 4-member classes; in Test 4, she showed a comparison bias with two samples, and with the third sample she nearly always chose the same one of the other two comparisons—a pattern, like Subject E.H.'s first test, of doubtful validity as an indicator of class formation.

The CE relations were tested next to determine whether an absence of symmetry in the explicitly taught EC relations might have prevented the ABC and DEF classes from combining. Test 5, however, demonstrated complete emergence of the CE relations. The next two tests were precautionary, Test 6 to determine whether the symmetry test, even though no reinforcement was given, might by itself have brought about the emergence of the EB relations, and Test 7 to ensure that the pattern of hits and false alarms on the EB retest had not adversely affected EC symmetry. Neither possibility was substantiated.

Then, in Test 8, the 3-stage CB relations failed to emerge, the subject's hits and false alarms closely resembling her pattern in the EB probes. That pattern was not maintained, however, when the other 3-stage relations, BC, were probed (Test 9). Because the number of hits increased, the BC probes were repeated (Test 10), but a new comparison bias only became more pronounced. A return to the CB probes (Test 11) reinstated the earlier pattern of choices.

Previous studies in this laboratory in which subjects had been taught the conditional discriminations AB, AC, DE, and DF, but *not* EC (as shown in Figure 1) had rarely failed to document the emergence of BC and CB. The EC relations were therefore removed from the baseline, and 18 CB probes were inserted into the abbreviated baseline. This test (Matrix 12) suggested a shift away from the earlier comparison bias toward control by individual samples, and a repetition of the CB probes in Test 13 found the subject scoring a hit on every trial. Then, upon a return to the original baseline, with the EC trials restored, she maintained her perfect CB performance.

Once 3-member classes had been estab-

lished (although final proof did not come until the BC relations were probed in Test 25), the subject scored hits on nearly all trials in Tests 15-18, which went sequentially through 4-stage EB, 5-stage DB, and 6-stage FB and BF probes. Then, moving back down through the 5-, 4-, and 3-stage relations that had not been tested before, she documented the emergence of most of the relations needed to prove the existence of 6-member classes. (She had to end her participation in the experiment before being tested for the EF, FE, ED, and FD relations.)

Subject N.O. Figure 8 summarizes Subject N.O.'s tests. Her first FB test showed a marked bias toward one comparison. In the next two tests, 5- and 4-stage (DB and EB), the hit and false-alarm pattern suggested forms of control that were unrelated to classes that the teaching procedures might have established. Test 4 then gave imperfect but encouraging evidence of 3-stage CB relations, and Tests 5, 6, and 7 substantiated the existence of 3-member ABC classes. Because testing the 3-stage relations might have strengthened those prerequisites for the 6-stage relations, the FB probes were given again in Tests 8 and 9, but still yielded no evidence of 6-member classes.

After the unsuccessful 6-stage FB probes, the next four tests (10-13) repeated the 3-stage BC and CB probes until the subject achieved a 100% hit rate. Then, in five consecutive 5-stage DB tests (14-18), her hit rate increased from 21/27 to 26/27. Finally, after the 5-stage DB relations had emerged, FB and BF tests (19 and 20) provided solid evidence for the existence of 6-member stimulus classes.

Untested relations were then probed, ending with a repeat of the FB probes (Test 37). Although the AF relations were weak at first, these improved on retesting (Tests 22 and 23), and the series of probes gave final proof of the formation of 6-member classes.

Subject P.M. failed at first to demonstrate the emergence of equivalence relations in 6-, 5-, 4-, or 3-stage tests (Table 2, Tests 1-9); his only positive tests (4 and 6) were those for CE/EC symmetry. Then, even with EC

COMPARISON STIMULI				
$\Delta \Sigma \Xi$	$\Delta \Sigma \Xi$	$\Delta \Sigma \Xi$	$\Delta \Sigma \Xi$	$\Delta \Sigma \Xi$
λ 8 0 1	$\mathcal{L}$ 9 0 0	$\wedge$ 9 0 0	δ 9 0 0	δ 9 0 0
ω 8 1 0	σ 9 0 0	Ω 9 0 0	σ 3 6 0	σ 0 9 0
γ 5 2 2	$\mathcal{J}$ 1 3 5	Γ 1 0 8	$\mathfrak{Z}$ 0 0 9	$\mathfrak{Z}$ 0 0 9
21 3 3	19 3 5	19 0 8	12 6 9	9 9 9
1. FB:11/27	2. DB:14/27	3. EB:17/27	4. CB:24/27	5. CB:27/27
$\delta \sigma \mathfrak{Z}$	$\Delta \Sigma \Xi$	$\Delta \Sigma \Xi$	$\Delta \Sigma \Xi$	$\Delta \Sigma \Xi$
Δ 9 0 0	δ 9 0 0	λ 8 0 1	λ 7 2 0	δ 8 1 0
Σ 0 9 0	σ 1 8 0	ω 4 4 1	ω 5 3 1	σ 0 8 1
Ξ 0 2 7	$\mathfrak{Z}$ 0 0 9	γ 2 3 4	γ 4 2 3	$\mathfrak{Z}$ 0 1 8
9 11 7	10 8 9	14 7 6	16 7 4	8 10 9
6. BC:25/27	7. CB:26/27	8. FB:16/27	9. FB:13/27	10. CB:24/27
$\delta \sigma \mathfrak{Z}$	$\Delta \Sigma \Xi$	$\delta \sigma \mathfrak{Z}$	$\Delta \Sigma \Xi$	$\Delta \Sigma \Xi$
Δ 9 0 0	δ 9 0 0	Δ 9 0 0	$\mathcal{L}$ 9 0 0	$\mathcal{L}$ 9 0 0
Σ 0 9 0	σ 0 9 0	Σ 0 9 0	σ 4 5 0	σ 1 7 1
Ξ 1 2 6	$\mathfrak{Z}$ 0 0 9	Ξ 0 0 9	$\mathcal{J}$ 1 1 7	$\mathcal{J}$ 0 1 8
10 11 6	9 9 9	9 9 9	14 6 7	10 8 9
11. BC:24/27	12. CB:27/27	13. BC:27/27	14. DB:21/27	15. DB:24/27
$\Delta \Sigma \Xi$	$\Delta \Sigma \Xi$	$\Delta \Sigma \Xi$	$\Delta \Sigma \Xi$	$\lambda \omega \gamma$
$\mathcal{L}$ 9 0 0	$\mathcal{L}$ 9 0 0	$\mathcal{L}$ 9 0 0	λ 9 0 0	Δ 9 0 0
σ 2 7 0	σ 1 8 0	σ 1 8 0	ω 0 8 1	Σ 0 9 0
$\mathcal{J}$ 0 0 9	$\mathcal{J}$ 0 1 8	$\mathcal{J}$ 0 0 9	γ 0 0 9	Ξ 0 0 9
11 7 9	10 9 8	10 8 9	9 8 10	9 9 9
16. DB:25/27	17. DB:25/27	18. DB:26/27	19. FB:26/27	20. BF:27/27
21. BD:27/27	22. AF:23/27	23. AF:25/27	24. EB:25/27	25. BE:27/27
26. CF:27/27	27. FC:26/27	28. AD:25/27	29. CD:27/27	30. DC:27/27
31. CE:27/27	32. EF:25/27	33. FE:26/27	34. ED:26/27	35. FD:27/27
36. AE:26/27	37. FB:26/27			N.O.

Fig. 8. Subject N.O. Probe-trial scores in each of 37 consecutive tests. Data from the first 20 tests are in matrix form. Below each matrix are the test number, the tested relation, and the hits per opportunity; for Tests 21 to 37, these data are listed without the corresponding matrix.

removed from the baseline, 3-stage relations in both the upper and lower triangles (CB and FE) proved deficient (Tests 10-11).

When only AB and AC were kept in the baseline, repeated testing (12-16) did bring about the emergence of BC and CB; then, with only EC removed from the baseline (17-18), the FE relations remained deficient even though CB was perfect. CB deteriorated again, however, when the EC relations were reinserted into the baseline (Tests 19-21).

EC was removed once more, and repeated tests (22-29) succeeded in reinstating the CB but not the FE relations. Finally, with the full baseline and with repeated verification of the 3-stage BC and CB relations, the 6-stage FB, 5-stage DB, and 4-stage EB relations failed again to emerge (30-41). Subject P.M. was unable to return for more testing.

Subjects R.W. and J.S. also failed to demonstrate the emergent FB, DB, or EB relations that would have documented the formation

Table 2

Subject P.M. Hits per opportunity on successive tests. Under "Full Baseline," the indicated probes were inserted into the complete baseline, AB, AC, EC, DE, and DF (shown by the solid arrows in Figure 2); under "EC removed," the EC relations were removed from the full baseline; under "AB and AC," the baseline contained only AB and AC trial types.

<i>Full Baseline</i>	<i>AB and AC</i>	<i>EC removed</i>	<i>Full Baseline</i>
1. FB:10/27	12. CB:19/24	22. CB:14/18	30. CB:27/27
2. DB:10/27	13. CB:15/24	23. FE: 9/18	31. BC:27/27
3. EB: 9/27	14. BC:18/24	24. CB:18/18	32. CB:27/27
4. CE:27/27	15. CB:24/24	25. FE:12/18	33. BC:27/27
5. EB:10/27	16. BC:21/24	26. CB:18/18	34. FB: 9/27
6. CE:27/27	<i>EC removed</i>	27. FE:12/18	35. CB:26/27
7. CB:18/27	17. CB:18/18	28. CB:18/18	36. BC:27/27
8. BC:13/27	18. FE:12/18	29. FE:12/18	37. DB: 9/27
9. CB:14/27	<i>Full Baseline</i>		38. CB:27/27
<i>EC removed</i>	19. CB:23/27		39. BC:26/27
10. CB:12/18	20. CB:23/27		40. EB:13/27
11. FE:12/18	21. CB:20/27		41. EB:10/27

of 6-, 5-, or 4-member stimulus classes. They, too, had to leave the study before all questions raised by their data could be investigated, but they had enough tests to verify two observations that were noted in other subjects' data: (1) The presence of EC in the baseline had a deleterious effect on the 3-stage conditional relations; (2) BC and CB did emerge with continued testing in the context of a reduced baseline, and remained intact in the context of the full baseline.

Oral Naming

Subject E.H.'s oral naming, tested after the series of equivalence probes, was also consistent. Given 6 trials with each of the 15 visual stimuli, she applied the names from Set A, calling the Class-1 stimuli "delta," the Class-2 stimuli "sigma," and the Class-3 stimuli "xi."

Subject F.M. was old enough to have learned the names of upper-case script letters, and in the naming test she called the Set-D letters "L," "O," and "G." She applied the Set-A names, "delta," "sigma," and "xi," however, to all Greek letters, even those in Sets E and F that she had learned to match to the script letters. She did not, therefore, give the same name to all members of any class. She was then given a second test in which she was asked, immediately after giving a Greek or English letter the same name

as before, "Can you call it anything else?" She proved able to supply the names "L," "O," and "G" to the Greek letters in Classes 1, 2, and 3, respectively, and to apply the Greek names appropriately to the Set-D letters L, O, and G.

Subject N.O. called the letters in Classes 1, 2, and 3, "delta," "sigma," and "xi," respectively. Then, when asked for a second name, she always replied, "I don't know." Finally, when given 15 trials with each of the script letters in Set D, and asked successively, "Is it an L?", "Is it an O?", and "Is it a G?", she answered "yes" and "no" indiscriminately.

EXPERIMENT 2

In Experiment 1, subjects learned each group of conditional discriminations separately, the three relations within a group being taught in a prescribed sequence, and groups being combined only after subjects met the standard accuracy criterion at each step (Table 1). In Experiment 2, however, subjects were given the first 12 conditional discriminations all mixed together, with no restrictions on the order in which they were to be learned. The subjects were then tested for the 3-member ABC and DEF classes (Figure 1) before those classes were linked together by teaching the EC relations (Figure 2).

Table 3

Experiment 2. Hits per opportunity on successive tests. Baseline 1 did not include the EC relations.

<i>Subject P.H. Baseline 1</i>	<i>Subject K.H. Baseline 1</i>	<i>Full Baseline</i>	<i>Full Baseline</i>
1. BC:18/18	1. CB:18/18	9. AF:25/27	18. BC:27/27
2. EF:17/18	2. FE:17/18	10. EB:27/27	19. EF:27/27
3. CB:18/18	3. BC:18/18	11. BE:26/27	20. FE:25/27
4. FE:17/18	4. EF:18/18	12. CF:27/27	21. AE:27/27
<i>Full Baseline</i>	<i>Full Baseline</i>	13. FC:27/27	22. ED:27/27
5. FB: 8/27	5. FB:27/27	14. AC:27/27	23. FD:26/27
6. FB:11/27	6. BF:26/27	15. CD:27/27	24. CE:26/27
7. FB:21/27	7. DB:25/27	16. DC:27/27	25. BF:26/27
8. FB:15/27	8. BD:26/27	17. CB:27/27	
9. FB:26/27			
10. FB:27/27			
11. BF:26/27			

METHOD

Subjects

Two normal human subjects served—one adult, P.H., M, 22/9, and one child, K.H., F, 10/2.

Procedure

The subjects continued through a lengthy sequence of the 12 AB, AC, DE, and DF trial types (Figure 1) mixed together until they attained the standard learning criterion. BC, CB, EF, and FE trials (Figure 5, 3-stage) were then mixed into the baseline as tests for 3-member ABC and DEF classes. Then, the 3 EC relations were mixed among the original 12 (Figure 2) until the subjects achieved criterion on the full baseline (Figure 4). Finally, they were tested for the existence of 6-member classes, as in Experiment 1.

RESULTS

Conditional Discriminations

Subject P.H. The first column of Table 3 shows Subject P.H.'s scores on 11 consecutive tests. His hit rates on the 3-stage probes, before he was taught the EC relations, were uniformly high (Tests 1-4). After learning the full baseline, he scored only 8 hits on his first 6-stage FB probe (FB, Test 5). In successive FB tests, however, his scores increased. He eventually reached 100% in Test 10, and in Test 11 he was nearly perfect on BF also.

He was unable to complete the conditional-discrimination test series, but his final performances were consistent with the formation of 6-member stimulus classes.

Subject K.H. The scores for Subject K.H. on 25 consecutive probes are in the three righthand columns of Table 3. She never gave more than 2 false alarms in any test. She scored nearly 100% on the 3-stage probes (Tests 1-4) and then, with the full baseline, showed an immediate emergence of the 6-stage FB and BF conditional discriminations (Tests 5-6). Her nearly perfect scores in all of the remaining tests demonstrated all of the equivalence relations required to prove the formation of 6-member classes.

Oral Naming

Oral naming was tested after Subject P.H.'s BF probes. He applied the Set-A names, "delta," "sigma," and "xi" appropriately to all of the Class-1, -2, and -3 letters in the upper triangle (Sets B and C). In the lower triangle, he sometimes called the Class-1 stimuli in Sets D, E, and F "delta" and sometimes "L," and the Class-3 stimuli sometimes "xi" and sometimes "G," but he always called the Class-2 stimuli "sigma."

Subject K.H. gave the appropriate Greek names from Set A to all stimuli, including the Set-D English letters. When asked if she could call the letters anything else, she ap-

Table 4

Experiment 3. Teaching and testing sequences. Relations that were taught correspond to the solid arrows in Figure 3; tested relations correspond to the broken arrows.

Phase	Teach	Baseline	Test
1.	AB,AC	AB,AC	BC,CB (3-member classes)
2.	EC	AB,AC,EC	BE,EB (4-member classes)
3.	DE	AB,AC,EC,DE	BD,DB (5-member classes)
4.	DF	AB,AC,EC,DE,DF	BF,FB (6-member classes)
5.	—	AB,AC,EC,DE,DF	All remaining relations

plied English letter names only to Set-D, saying that she could not call the other letters anything else (than the Set-A Greek names) or naming them by their shapes ("triangle" for upper-case delta, etc.).

EXPERIMENT 3

Subjects in Experiment 1 were first tested for 6-stage equivalence after learning the full baseline, without having had lower-stage tests. Six-stage relations did not emerge, however, until prerequisites were tested and shown to be intact. Subjects in Experiment 2 were tested for 3-stage relations in the context of a reduced baseline (Figure 1) before learning the full baseline. Six-stage relations emerged without additional testing of the prerequisites. In Experiment 3, the baseline was enlarged progressively; starting with AB and AC, subjects were taught conditional relations that were prerequisites for classes of gradually increasing size. After each consecutive teaching step, they were tested for the appropriate stimulus class before learning the next set of relations. Thus, they were successively taught the baseline relations AB, AC, EC, DE, and DF (Figure 2), with tests for 3-, 4-, 5-, and 6-member classes, respectively, after successive teaching phases.

METHOD

Subjects

Three normal children served: E.B., M, 5/3; C.J., F, 5/8; M.D., M, 5/10.

Procedure

After learning the baseline conditional discriminations AB and AC, the subjects

were immediately tested for the 3-stage relations BC and CB. The baseline was then progressively enlarged, one set of relations at a time, and conditional discriminations that would demonstrate 4-, 5-, and 6-stage equivalence were probed successively. Table 4 shows the sequence in which baseline conditional discriminations were taught and mixed with previously learned relations to form new baselines. The tests were given (with no reinforcement) immediately after subjects had learned each baseline. Probe trials were presented in a context of the smallest baseline that would be required to derive the probed relations. After the 6-stage tests, the existence of 6-member classes was verified by probing all remaining relations in the context of the full baseline. Finally, oral naming was tested.

RESULTS

Conditional Discriminations

Subject M.D. The first column of Table 5 shows high hit rates in tests for 3-, 4-, and 5-member classes. (Although the 3-stage CB and the 4-stage BE probes [Tests 2 and 4] did not quite meet the accuracy criterion, experimental error kept them from being repeated.) The 6-stage FB and BF probes in the context of the full baseline (second column of Table 5) required two and three tests, respectively (7-11), to reach criterion levels. Columns 3 and 4 of Table 5 show the subject proceeding with nearly 100% hit rates through all remaining tests (12-30), ending with a perfect score on the BF probes.

Subject E.B. The first column of Table 6 shows Subject E.B. proceeding through the 3-, 4-, and 5-stage probes with few false alarms, requiring one repetition (Test 6) of

Table 5

Experiment 3. Subject M.D. Hits per opportunity on successive tests, with progressively increasing baselines. Probes are listed beneath the baseline relations in which they are embedded.

<i>AB,AC</i>	<i>AB,AC,EC,DE,DF</i>	<i>AB,AC,EC,DE,DF</i>	<i>AB,AC,EC,DE,DF</i>
1. BC:23/24	7. FB:23/27	12. DB:25/27	22. EF:27/27
2. CB:21/24	8. FB:26/27	13. BD:27/27	23. FE:26/27
<i>AB,AC,EC</i>	9. BF:22/27	14. AF:26/27	24. DC:27/27
3. EB:25/27	10. BF:22/27	15. EB:27/27	25. CD:27/27
4. BE:24/27	11. BF:26/27	16. BE:27/27	26. AE:27/27
<i>AB,AC,EC,DE</i>		17. FC:27/27	27. ED:27/27
5. DB:26/27		18. CF:26/27	28. FD:26/27
6. BD:26/27		19. AD:27/27	29. BF:26/27
		20. CB:27/27	30. BF:27/27
		21. BC:27/27	

the 5-stage DB probes. His FB probes (Column 2), although never far from the criterion level, were "shaky," so even though he attained a satisfactory hit rate in Tests 15 and 17, he was kept at this level until he met the criterion on two consecutive tests (19-20). Then (Test 21) he also gave a perfect score on the BF probes. He then proceeded with criterion performances through all remaining tests (22-41), ending with a satisfactory score on the BF probes.

Subject C.J. The 3-stage BC and CB relations emerged immediately in Tests 1-2, and the 4-stage EB and BE relations in Tests 3-5 (Table 7, Column 1). Subject C.J. then needed many repetitions of the 5-stage DB and BD tests (Column 2, Tests 6-18). She met criterion on DB after three tests (6-8),

but then BD remained just below criterion for five tests (9-13). At that point, her DB performance was also found to have regressed, but regained criterion in three more tests (14-16). After that, two tests (17-18) carried BD also to a perfect score. Then (Column 3), three consecutive tests (19-21) saw her attain a perfect score on the 6-stage FB relations, followed by immediate emergence of BF (Test 22).

Although Subject C.J. had to leave the experiment before completing all tests, several 3-, 4-, and 5-stage relations did emerge with the full baseline (Column 4). Unlike other subjects, however, she did require retesting on the 3-stage CB and EF relations (Tests 25-26, 27-29) before meeting criterion.

Table 6

Experiment 3. Subject E.B. Hits per opportunity on successive tests, with progressively increasing baselines. Probes are listed beneath the baseline relations in which they are embedded.

<i>AB,AC</i>	<i>AB,AC,EC,DE,DF</i>	<i>AB,AC,EC,DE,DF</i>	<i>AB,AC,EC,DE,DF</i>
1. BC:22/24	8. FB:23/27	22. CB:27/27	32. FD:26/27
2. CB:23/24	9. FB:23/27	23. BC:25/27	33. CE:26/27
<i>AB,AC,EC</i>	10. FB:24/27	24. BC:26/27	34. EB:25/27
3. EB:26/27	11. FB:24/27	25. EF:26/27	35. BE:26/27
4. BE:26/27	12. FB:23/27	26. FE:27/27	36. CF:26/27
<i>AB,AC,EC,DE</i>	13. FB:22/27	27. DC:26/27	37. FC:25/27
5. DB:24/27	14. FB:22/27	28. CD:27/27	38. AD:26/27
6. DB:25/27	15. FB:25/27	29. AE:25/27	39. DB:25/27
7. BD:27/27	16. FB:24/27	30. ED:26/27	40. BD:27/27
	17. FB:26/27	31. AE:25/27	41. AF:26/27
	18. FB:22/27		42. BF:25/27
	19. FB:27/27		
	20. FB:27/27		
	21. BF:27/27		

Table 7

Experiment 3. Subject C.J. Hits per opportunity on successive tests, with progressively increasing baselines. Probes are listed beneath the baseline relations in which they are embedded.

<i>AB,AC</i>	<i>AB,AC,EC,DE</i>	<i>AB,AC,EC,DE,DF</i>	<i>AB,AC,EC,DE,DF</i>
1. BC:24/24	6. DB:24/27	19. FB:19/27	23. DB:26/27
2. CB:24/24	7. DB:18/27	20. FB:23/27	24. BC:26/27
<i>AB,AC,EC</i>	8. DB:26/27	21. FB:27/27	25. CB:21/27
3. EB:21/27	9. BD:18/27	22. BF:27/27	26. CB:26/27
4. EB:27/27	10. BD:20/27		27. EF:18/27
5. BE:26/27	11. BD:22/27		28. EF:24/27
	12. BD:23/27		29. EF:27/27
	13. BD:22/27		30. FE:27/27
	14. DB:19/27		31. AF:26/27
	15. DB:24/27		32. AD:26/27
	16. DB:26/27		
	17. BD:24/27		
	18. BD:27/27		

Naming

The three subjects applied names from Set A to all letters, calling the Class-1 stimuli "delta," the Class-2 stimuli "sigma," and the Class-3 stimuli "xi." In a second test, after giving each of those names, they were asked, "What else is it?" They answered consistently, "I don't know."

GENERAL DISCUSSION

Stimulus-class formation as an outcome of conditional-discrimination training has now been carried well beyond the original demonstration of 3-member classes. Eight of the eleven subjects showed that the conditional relations they had learned were also equivalence relations. The first indication was the emergence of the FB and BF conditional discriminations, for which the prerequisites involved all six sets of stimuli (6-stage equivalence). Then, in test after test with no reinforcement being provided, the lower-stage relations emerged; with remarkable consistency, subjects matched stimuli according to class memberships that the original teaching had established. Teaching 15 conditional discriminations (5 groups of 3) had created three 6-member stimulus classes, making the subjects capable of 60 new conditional discriminations that they had not been explicitly taught. The consistency of the 60 new relations, with respect

to the baseline conditional discriminations, was more than sufficient to rule out irrelevant test-specific sources of control as explanations for the new behavior.

All but one of the successful subjects (Subject K.H., Table 3) needed repeated testing before proving capable of 6-stage, and sometimes even of lower-stage, conditional discriminations. Although many subjects in previous studies have shown equivalence on their very first test, its emergence only after continued testing, even without reinforcement in the tests, has now been reported several times (Lazar *et al.*, 1984; Sidman *et al.*, in press; Spradlin *et al.*, 1973).

A related observation, confirming earlier findings with 4-stage relations (Sidman & Tailby, 1982), was that whenever 6-stage conditional discriminations failed to emerge, prerequisite relations, when tested, were also deficient. The missing or weak prerequisites often included even the 3-stage relations needed to document 3-member ABC or DEF classes. Once continued testing had caused missing prerequisites to emerge, however, it often proved possible to verify the formation of progressively larger classes. Sidman and his colleagues (in press) also reported that symmetry testing may have expedited the emergence of 3-stage relations for which baseline symmetry was a prerequisite. They noted, for example, with reference to the lower triangle in Figure 1, that

giving subjects the ED and FD tests for symmetry of the baseline relations seemed to facilitate the emergence of the FE and EF relations.

It is possible that extended overlearning of the baseline conditional discriminations must take place before progressively larger stimulus classes can emerge. Also, no experiments have yet evaluated the relative efficacy of continued n -stage testing versus the testing of lower-stage prerequisites in the eventual formation of n -member classes. Nevertheless, it was clear in the present experiments that mere testing could facilitate the emergence of new conditional discriminations. Were it not for the absence of reinforcement during the tests, one might have supposed that final performances were being deliberately programmed by first teaching their prerequisites.

The actual observation, however, was that if any relations had somehow failed to develop, then their subsequent establishment, even through nonreinforced testing, also permitted higher-stage relations derived from them to emerge. The puzzling aspect of this observation was not the instructional programming—the production of new conditional discriminations by first establishing their prerequisites; the creation of classes of equivalent stimuli could account for the new relations (Sidman & Tailby, 1982). The puzzle was the emergence of any conditional discriminations, 6-stage or lower-stage, as a consequence of testing them repeatedly without providing reinforcement.

A solution may lie in the answer to the question, "When do the classes of equivalent stimuli come into existence?" One possibility is that they form when the subjects learn the baseline conditional discriminations. Another, which seems more consistent with the present data, is that the classes do not exist until they are tested. Teaching the baseline relations may only create the potential for class formation, a potential that remains unrealized until the test itself. Although such a suggestion might seem unverifiable—how can one separate proof of class formation from the test?—observations in the present

study do supply indirect evidence.

That the tests themselves provided the final conditions necessary for class formation was indicated first by the very fact that the emergence of equivalence relations sometimes required repeated testing. It seems incontrovertible that in such instances the classes formed subsequent to the initial test, not earlier when the subjects had been taught only the baseline relations.

A second relevant observation was that n -stage relations sometimes failed to emerge until lower-stage relations had been tested. Furthermore, once testing had established classes of $n-1$ members, previously nonexistent n -member classes often were manifested *immediately*. In this way, tests that demonstrated n -member classes were separated at least from lower-stage tests that were required to bring the n -member classes into existence, thereby providing almost a direct proof that the tests had generated the classes.

Strong rational support also exists for supposing that classes of equivalent stimuli form during the test rather than during the original teaching. Stimuli in the present experiment could have combined in various ways to form many classes besides those that arose from the equivalence relations. Other classes might have been based on stimulus characteristics like angles, lines, curves, or features determined by a subject's own stimulus-control history. Still other classes might have been determined, like those based on equivalence relations, by features of the experimental procedures.

One possibility arises because stimuli in Sets A and D were used only as samples during the original teaching, never as comparisons; Sets B, C, and F were always comparisons, never samples. Testing for "sample" or "comparison" classes with appropriate stimulus groupings might have demonstrated their existence also. For example, any AD trial (Figure 3) presented stimuli that had been used only as samples during training, but which had come to differ with respect to class membership. With "delta" as the sample, then, subjects selected script-*L* on the basis of the Class-1 member-

ship it shared with "delta," rejecting Class-2 and -3 letters *O* and *G*. Suppose, however, the subjects were given a different kind of test, again with "delta" as the sample but with the comparisons being script-*O* (from Set D), lower-case omega (from Set F), and upper-case omega (from Set E)—all Class-2 members. Now, they might well have selected script-*O* on the basis of the "sample class" membership it shared with "delta," rejecting "comparison class" members. Thus, the teaching procedures might have generated classes of equivalent stimuli, classes of samples, and classes of comparisons, but none of those classes need actually have existed in a subject's repertoire until an appropriate test actually called for it.

Class membership, therefore, need not be based solely on a relation between sample and "correct" comparison. Also relevant are contextual stimuli, of which the "incorrect" comparisons constitute an important category. If a stimulus can be a member of several classes, such contextual stimuli will determine the particular class to which it belongs at any moment. A subject may reject a comparison in one context and select it in another, even with the same sample. Uncontrolled physical or functional stimulus similarities, arising from the current experimental environment or from the subject's history, may transform a first-order conditional discrimination into a second- or higher-order relation.

The learning that apparently took place during the tests may well have represented a kind of sorting-out process, in which the stimuli chosen on some trials were determined by class memberships that proved to be invalid on other trials. This is speculation, clearly, but it is potentially verifiable, first by demonstrating that higher-order control is possible (Fucini, 1982), and second by experimentally manipulating various sources of control during the tests themselves. The latter has not yet been done.

All subjects in Experiment 1 failed to demonstrate 6-member classes in their first tests, and three never demonstrated those classes. Several observations indicated that

teaching them the EC relations caused 3-stage equivalences either to fail to emerge or to break down if they had previously emerged in the context of a reduced baseline. First, the failures of 3-stage BC, CB, EF, and FE relations to emerge were themselves most unusual in this laboratory. Then, when the EC relations were removed from the baseline, repeated testing brought about the eventual emergence of some 3-stage relations; these deteriorated again when the EC relations were reinstated. Eventually, after two or more testing cycles (return to a reduced baseline, recover 3-stage relations through retesting, and return to the complete baseline for continued testing), subjects were able to sustain their performance on two or more groups of 3-stage relations, although BC and CB were more likely than EF and FE to be maintained; indeed, the FE relations never did emerge for Subject P.M.

Teaching EC in Experiment 3 and in an earlier study (Sidman & Tailby, 1982) succeeded in establishing 4-member classes, with the integrity of the 3-stage relations being maintained. Why did the EC relations interfere with 3-stage equivalence in Experiment 1? A quantitative factor may have been at work. Teaching subjects the EC relations in Experiment 3 enlarged the already established 3-member classes by only one member. In Experiment 1, however, teaching the EC relations was an attempt to double the size of the 3-member classes by combining the ABC and DEF classes in one stroke. The number of members that can be added simultaneously to a class may be a parameter of class formation, and may itself interact with a subject's age, experience, intellectual status, and other developmental or historical factors.

There was some indication, therefore, that the teaching and testing sequence can facilitate or hinder the formation of classes of equivalent stimuli. Enlarging the classes one member at a time and testing for class formation at each step, as in Experiment 3, may be the most effective method. Adding three new members all at once, however, may not only prevent 6-member classes from forming, but

may prevent and even break down the original 3-member classes. This speculation, too, remains to be confirmed; quantitative parameters of the training and testing procedures have yet to be worked out.

In previous experiments that involved 3-member ABC classes, the names subjects applied to Set-B and Set-C stimuli were the dictated Set-A names to which they had become conditionally related. In the present experiment, six of the eight subjects who formed 6-member classes applied names from Set A even to the letters in Sets D, E, and F. In addition to 60 new conditional discriminations, therefore, the procedures also generated 15 new simple discriminations, each stimulus in Sets B, C, D, E, and F controlling a naming response that was consistent with its class membership.

Classes of equivalent stimuli can form, however, even when subjects do not apply the same name to all members of a class (Lazar et al., 1984; Sidman et al., in press). Such classes, therefore, need not be defined by reference to a response that all members control in common. The naming data of two subjects in the present experiments supported that conclusion. Subject P.H. (Experiment 2) applied the Set-A names appropriately to the Class-1, -2, and -3 stimuli in the upper triangle (Figure 2), and to the Class-2 stimuli in the lower triangle; sometimes, however, he gave the Set-A names and at other times he gave the English names of the Set-D letters to Class-1 and -3 stimuli in the lower triangle. For two of the classes, therefore, he did not give the same name to each member. In Experiment 1, Subject F.M. gave the English names to the Set-D letters, but applied the Set-A names to all others in both the upper and lower triangles. Although in subsequent tests she proved capable of giving either the Set-A or the English-letter names to all stimuli, her first naming test indicated that she had not originally given the same name to all members of any class.

REFERENCES

Fletcher, F. G., Stoddard, L. T., & Sidman, M. (1971). A system for unlimited repetitive presen-

- tation of auditory stimuli. *Journal of Experimental Child Psychology*, 11, 165-169.
- Fucini, A. (1982). *Stimulus control of class membership*. Unpublished doctoral dissertation, Northeastern University, Boston.
- Jenkins, J. J. (1963). Mediated associations: Paradigms and situations. In C. N. Cofer & B. S. Musgrave (Eds.), *Verbal behavior and learning: Problems and processes* (pp. 210-245). New York: McGraw-Hill.
- Lazar, R. (1977). Extending sequence-class membership with matching to sample. *Journal of the Experimental Analysis of Behavior*, 27, 381-392.
- Lazar, R. M., Davis-Lang, D., & Sanchez, L. (1984). The formation of visual stimulus equivalences in children. *Journal of the Experimental Analysis of Behavior*, 41, 251-266.
- Lazar, R. M., & Kotlarchyk, B. J. (1980, April). *The acquisition of sequence-class membership through stimulus equivalences*. Paper presented at the meeting of the Eastern Psychological Association, Hartford, CT.
- Mackay, H. A., & Sidman, M. (1984). Teaching new behavior via equivalence relations. In P. H. Brooks, R. Sperber, & C. McCauley (Eds.), *Learning and cognition in the mentally retarded* (pp. 493-513). Hillsdale, NJ: Erlbaum.
- Sidman, M. (1971). Reading and auditory-visual equivalences. *Journal of Speech and Hearing Research*, 14, 5-13.
- Sidman, M. (1977). Teaching some basic prerequisites for reading. In P. Mittler (Ed.), *Research to practice in mental retardation: Vol. 2. Education and training* (pp. 353-360). Baltimore, MD: University Park Press.
- Sidman, M., & Cresson, O., Jr. (1973). Reading and crossmodal transfer of stimulus equivalences in severe retardation. *American Journal of Mental Deficiency*, 77, 515-523.
- Sidman, M., Cresson, O., Jr., & Willson-Morris, M. (1974). Acquisition of matching to sample via mediated transfer. *Journal of the Experimental Analysis of Behavior*, 22, 261-273.
- Sidman, M., Rauzin, R., Lazar, R., Cunningham, S., Tailby, W., & Carrigan, P. (1982). A search for symmetry in the conditional discriminations of rhesus monkeys, baboons, and children. *Journal of the Experimental Analysis of Behavior*, 37, 23-44.
- Sidman, M., & Stoddard, L. T. (1966). Programming perception and learning for retarded children. In N. R. Ellis (Ed.), *International review of research in mental retardation* (Vol. 2, pp. 151-208). New York: Academic Press.
- Sidman, M., & Stoddard, L. T. (1967). The effectiveness of fading in programming a simultaneous form discrimination for retarded children. *Journal of the Experimental Analysis of Behavior*, 10, 3-15.
- Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching to sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior*, 37, 5-22.
- Sidman, M., Willson-Morris, M., & Kirk, B. (in press). Matching-to-sample procedures and the development of equivalence relations: The role of naming. *Analysis and Intervention in Developmental Disabilities*.

- Spradlin, J. E., Cotter, V. W., & Baxley, N. (1973). Establishing a conditional discrimination without direct training: A study of transfer with retarded adolescents. *American Journal of Mental Deficiency, 77*, 556-566.
- Stromer, R., & Osborne, J. G. (1982). Control of adolescents' arbitrary matching-to-sample by positive and negative stimulus relations. *Journal of the Experimental Analysis of Behavior, 37*, 329-348.
- Wetherby, B., Karlan, G. R., & Spradlin, J. E. (1983). The development of derived stimulus relations through training in arbitrary-matching sequences. *Journal of the Experimental Analysis of Behavior, 40*, 69-78.

Received March 29, 1984

Final acceptance November 21, 1984