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Functional Equivalence in Children: Derived Stimulus–Response and Stimulus–Stimulus Relations

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The present study investigated the simultaneous occurrence of emergent stimulus–response relations (functional equivalence) and stimulus–stimulus relations (stimulus equivalence). After being pretrained and tested on two symbolic match-to-sample tasks (X1-Y1, X2-Y2), 20 4- and 5-year-old children were trained to emit specified responses to pairs of stimuli (A1-R1, B1-R1, A2-R2, B2-R2) in one setting (original training) and to emit other responses to one member of each pair (A1-R3, A2-R4) in another setting (reassignment training). Of the 18 children who responded correctly on all trained tasks, 15 emitted the novel responses also in the presence of the nonreassigned stimuli (B1-R3, B2-R4). Eleven of these children also matched same-class stimuli with one another (A1-B1, A2-B2, and vice versa). Additional tests with four of these children documented the formation of conditional response–stimulus relations (R3-B1, R4-B2) in all four children, and of conditional response–response relations (R1-R3, R2-R4, and vice versa) in two of them. Children who did not show stimulus control transfer also failed to match same-class stimuli with one another. Present findings, together with those obtained in animal research, suggest that functional equivalence can imply but does not require stimulus equivalence.

An important area of stimulus control transfer deals with the formation of stimulus classes. Three types of stimulus classes can be distinguished: Func-

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tional stimulus classes, functional equivalence classes, and stimulus equivalence classes (Dougher & Markham, 1994). Functional stimulus class is a descriptive term for a set of stimuli that control a same response. For example, if A1 and A2 control response R1, and B1 and B2 control response R2, two classes of discriminative stimuli are formed, one consisting of A stimuli and one of B stimuli.

Functional equivalence, also referred to as acquired equivalence (Bonardi, Rey, Richmond, & Hall, 1993; Honey & Hall, 1989; Reese, 1968), implies transfer across stimuli with *same* functions: across discriminative stimuli *or* across conditional stimuli. Functional equivalence has been defined in terms of emergent stimulus-response and stimulus–stimulus relations, can be produced by classical and operant conditioning procedures, and has been repeatedly documented in animals and humans (Greenway, Dougher, & Markham, 1995; Grice & Davis, 1960; Honey & Hall, 1989; Shipley, 1935; Spradlin, Cotter, & Baxley, 1973; Urcuioli, Zentall, Jackson-Smith, & Steirn, 1989; Urcuioli, Zentall & DeMarse, 1995; Vaughan, 1988; Wasserman & DeVolder, 1993; Wasserman, DeVolder, & Coppage, 1992). For example, in the study by Wasserman and DeVolder (1993), 20 4- and 5-year-old children were trained to place multiple exemplars of each of four different stimulus categories (flowers, chairs, people, and cars) at two different locations of a quadrant: Flowers and chairs at the top right corner, and cars and people at the bottom left corner (original training). Then they were trained to place flowers at the top left corner and cars at the bottom right corner of another quadrant (reassignment training). During subsequent probes, 13 children (65%) placed the nonreassigned stimuli (chairs and people) at the same locations as the reassigned same-class stimuli (chairs: top left, people: bottom right). Across all 20 children, the percentage of ‘‘correct’’ responses to the nonreassigned stimuli was 80%. These findings were similar to those previously obtained with pigeons (Wasserman et al., 1992).

Simulus equivalence, as defined by Sidman (Sidman & Tailby, 1982; Sidman, Wynne, Maguire, & Barnes, 1989), refers to derived conditional stimulus relations that show the properties of reflexivity, symmetry, and transitivity. For example, stimulus equivalence is documented when, after being trained to relate samples A1 and A2 to comparisons B1 and B2, respectively (A1-B1, A2-B2), and to C1 and C2 (A1-C1, A2-C2), subjects match all class-1 stimuli and all class-2 stimuli (A1-A1, A2-A2; B1-B1, B2-B2; C1-C1, C2-C2: reflexivity. B1-A1, B2-A2; C1-A1, C2-A2: symmetry. B1-C1, B2-C2; C1-B1, C2-B2: transitivity). Stimulus equivalence (i) implies bidirectional transfer between stimuli of *different* functions (from conditional to discriminative stimuli, and vice versa) and (ii) has been repeatedly reported with verbal humans (Barnes, Smeets, & Leader, 1996; Devany, Hayes, & Nelson, 1986; Dube, McIlvane, Maguire, Mackay, & Stoddard, 1989; Saunders, Saunders, Kirby, & Spradlin, 1988; Sidman & Tailby, 1982; Smeets, Schenk, & Barnes, 1995; Steele & Hayes, 1991) but *not* with animals (Dube, McIlvane, Callahan, & Stoddard, 1993; Hayes, 1989; Lipkins, Kop, & Matthijs, 1988; Richards, 1988; Rodewald, 1974; Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982; Yamamoto, & Asano, 1995; but see Schusterman & Kastak, 1993).

Functional and stimulus equivalence frequently occur concurrently, at least in humans. After establishing stimulus equivalence classes (e.g., A1-B1-C1, A2-B2-C2), a function given to one member of a class (e.g., A1-R1, A2-R2) generally transfers to the other members of that class (B1-R1, C1-R1, B2-R2, C2-R2; Barnes, Browne, Smeets, & Roche, 1995; Barnes & Keenan, 1993; deRose, McIlvane, Dube, Galpin, & Stoddard, 1988; Dougher, Augustson, Markham, Greenway, & Wulfert, 1994; Dymond & Barnes, 1994; Hayes, Devany, Kohlenberg, Brownstein, & Shelby, 1987; Smeets, 1994; Wulfert & Hayes, 1988), but not always. These and other findings (Dube, McDonald, & McIlvane, 1990; Sidman et al., 1989) fuelled a still unresolved debate over the status of both types of equivalence as separable behavioral entities. Sidman's initial position was that functional and stimulus equivalence represent different kinds of behavioral phenomena that may or may not occur concurrently (Sidman et al., 1989). Later, he retracted his position and stated that functional equivalence is a demonstration of stimulus equivalence and class union in a three-term contingency context (Sidman, 1994). This assumption requires that the defined responses (R) participate in the equivalence relations, thereby rendering the distinction between stimuli and defined responses, and even the concept of transfer, irrelevant and unnecessary. Thus, training of A1-R1, B1-R1, A2-R2, B2-R2 three-term contingencies (functional stimulus classes) should lead to two A-B-R equivalence classes (*and* lead to A-B matching), just like B-A and C-A four-term contingencies should produce A-B-C classes (Sidman, 1994, p. 383). Subsequent A1-R3 and A2-R4 training then should produce class expansion, as evidenced by B1-R3 and B2-R4 performances. If that is correct, one would expect that subjects showing functional equivalence (B1-R3, B2-R4) should also relate same-class stimuli conditionally to one another in match-to-sample probes (A1-B1, A2-B2; abbreviated stimulus equivalence test).

The present study examined the degree in which functional stimulus classes lead to functional equivalence class formation and class-consistent stimulus matching (stimulus equivalence). A modified version of Wasserman's design (1993) was used. Preschool children served as subjects. At first, the subjects received pretraining on two symbolic match-to-sample tasks with X stimuli as samples and Y stimuli as comparisons (X1-Y1, X2-Y2; hereafter abbreviated as X-Y), followed by X-Y and Y-X probes. Then they received training on four stimulus-response relations: A1-R1, A2-R2, B1-R1, B2-R2 (original training). Subsequently, they were trained to emit a novel response in the presence of one member of each class: A1-R3, A2-R4 (reassignment training), followed by mixed training and testing (A1-R1, A2-R2, B1-R1, B2-R2; A1-R3, A2-R4). Finally, they received two tests, a functional equivalence test measuring B1-R3, B2-R4 relations, and an (abbreviated) equivalence test measuring A-B relations (A1-B1, A2-B2) and vice versa.

METHOD

Subjects

Twenty preschool children, 10 boys and 10 girls, served as subjects. Their ages ranged from 4 years and 1 month to 5 years and 11 months. The subjects were selected from three age levels: youngest, older, and oldest. The youngest subjects ($N = 7$) varied between 4;1 and 4;10 yrs ($M = 4;6$). The older subjects ($N = 7$) varied between 4;11 and 5;4 yrs ($M = 5;3$). The oldest subjects ($N = 6$) ranged from 5;5 to 5;11 yrs ($M = 5;8$). Table 3 shows the age and sex for each subject.

Sessions and Setting

Sessions were conducted in a quiet room of the school building, once a day, five times a week, and lasted from 4 to 22 min. An adult female served as the experimenter. The experimenter and subject were seated at the same table facing one another. Four other adults served as reliability observers, one at a time. The reliability observer was present in the same room but was situated such that she could clearly observe the subject's responses, but not the experimenter's data sheet.

Materials

The stimuli consisted of eight black forms (3.0 × 3.0 cm). Figure 1 shows the stimuli and their assigned alphanumerical codes (e.g., X1, B2; the subjects never saw these codes). The stimulus configurations differed across tasks, symbolic match-to-sample tasks and stimulus-placement tasks. When used in match-to-sample tasks, the stimuli were presented on white cards (15.0 × 21.0 cm). Each card showed three stimuli, two horizontally aligned choice stimuli 8 cm apart (e.g., Y1 and Y2) and a sample stimulus centered 3.0 cm below (e.g., X1). When used with stimulus-placement tasks, each stimulus was presented on a small separate card (5.0 × 5.0 cm). In addition, two white quadrants (32.5 × 32.5 cm) were used. Each quadrant showed three rectangles (5.0 × 5.0 cm), one at the center, one at the top right corner, and one at the bottom left corner (Quadrant 1); or one at the center, one top left and one bottom right (Quadrant 2). All materials were laminated in clear acrylic to prevent soiling.

Additional materials were a tray with beads and a standing glass tube showing a mark. Filling the tube to the mark required 50 beads.

Tasks, Responses, and Contingencies

A trial on a matching task consisted of the experimenter presenting a stimulus card while saying ‘‘Point’’ and waiting for the subject to respond. A trial on a stimulus-placement task involved the experimenter silently putting

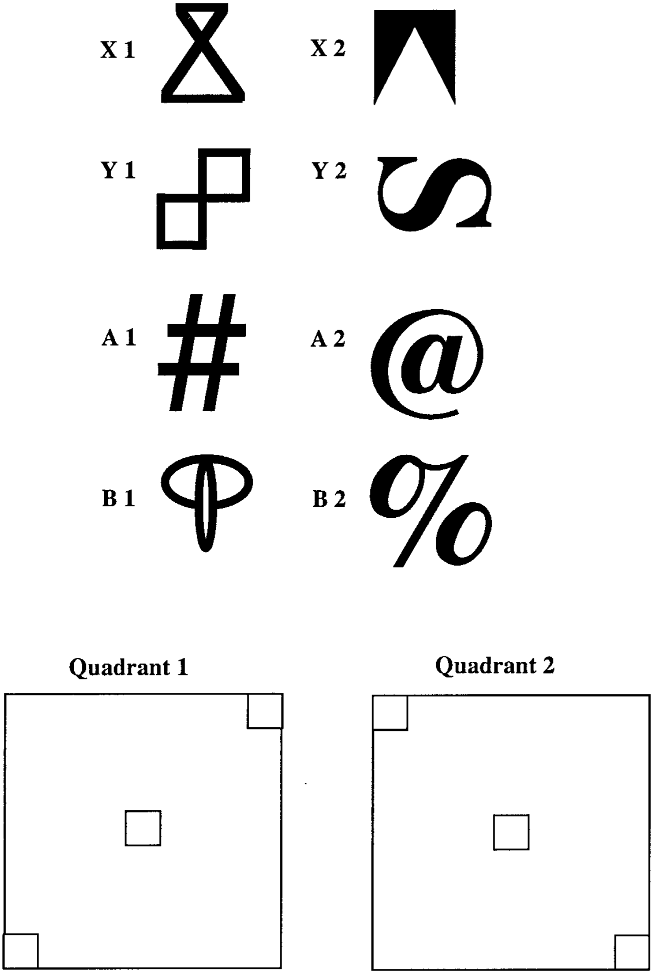

FIG. 1. Experimental stimuli and quadrants.

a stimulus (e.g., A1) at the quadrant's center rectangle and waiting for the subject to place that stimulus card in one of the peripheral rectangles.

Responses were scored correct or incorrect. During *training,* correct responses were followed by verbal praise (e.g., ''Very good,'' ''Correct'') and the delivery of a token (bead) in the glass tube. If at any point in training, the accumulated beads in the tube reached the mark (50 beads), the experimenter interrupted the training, allowed the subject to exchange the tokens for a color picture (animal, cartoon character, race car), and resumed the training. Incorrect responses were followed by ''Wrong. No Bead.'' During *testing,* each response was followed by the presentation of another trial (no programmed conse-

TABLE 1
Training and Testing Sequence for Group 3

Steps	Train/test	Tasks	Steps	Train/test	Tasks
1	Pretrn	X1-Y1, X2-Y2	7	Fe-tst	A1-R3, A2-R4** **B1-R3, B2-R4*****
2	Pretst	X1-Y1, X2-Y2 Y1-X1, Y2-X2	8	Rev-tst	X1-Y1, X2-Y2
3	Orig-trn	**A1-R1, A2-R2*** **B1-R1, B2-R2***	9	SE-tst	**A1-B1, A2-B2** **B1-A1, B2-A2**
4	Reass-trn	**A1-R3, A2-R4****			
5–6	Trn/Tst	A1-R1, A2-R2* B1-R1, B2-R2* A1-R3, A2-R4**			

Note. FE and SE indicate functional equivalence and stimulus equivalence, respectively. The critical tasks are printed in bold.

* Originally trained tasks, **reassigned tasks, ***nonreassigned tasks.

quences). However, after each block of 12 test trials, subjects received 10 beads irrespective of their performance (delayed noncontingent reinforcement).

Training and Test Sequence

The training and test sequence consisted of nine steps (see Table 1). Each step consisted of two blocks of 12 training trials (Steps 1, 3, 4, 5, and 6) or of 12 test trials (Steps 2, 6, 7, 8, 9). Criterion was set at 11/12 correct responses (92%) for the trained performances (Steps 1–6 and 8) and at 10/12 correct responses (83%) for the derived performances (Steps 7 and 9).

Step 1: Pretraining X-Y. The subjects were trained on two symbolic match-to-sample tasks with X1 and X2 as samples and Y1 and Y2 as comparisons. The revised blocked-trial procedure was used (Smeets & Striefel, 1994). Three substeps were used, 1a, 1b, and 1c. Immediately before Step 1a, the experimenter showed a match-to-sample card, pointed at all three stimuli, and explained that the subject was to point to only *one* of the two ‘‘upper pictures’’ (Y1 and Y2). After having verified that the subject understood the response requirements, the experimenter presented the first of 12 training trials while saying, ‘‘Point.’’ During this substep, the positions of the comparisons, Y1 and Y2, were at fixed positions, Y1 left and Y2 right. The samples, X1 and X2, varied quasirandomly over trials. Responding to Y1 was reinforced when given X1 and responding to Y2 when given X2 (X1-Y1, X2-Y2). Step 1b was the same except that the locations of the comparisons were reversed, Y2 left and Y1 right. In Step 1c, the locations of the Y stimuli varied unsystematically over trials.

Step 2: Testing X-Y and Y-X. Two substeps were used, 2a and 2b. Immediately before the introduction of Step 2a, the experimenter informed the subject

TABLE 2
Stimulus and Response Assignments during Training

	Original				Reassignment			
Groups	A1	A2	B1	B2	A1	A2	B1	B2
1	R1	R1	R2	R2	R3		R4	
2	R1	R1	R2	R2	R4		R3	
3	R1	R2	R1	R2	R3	R4		
4	R1	R2	R1	R2	R4	R3		

Note. R1, top right; R2, bottom left; R3, top left; R4, bottom right.

that she would no longer state whether the responses were ‘‘right’’ or ‘‘wrong’’ and instead of giving a bead after each (correct) response, she now would give 10 beads later, all at once (after the completion of the 12th trial). The X-Y relations (X1-Y1, X2-Y2) were tested in Step 2a, the Y-X relations (Y1-X1, Y2-X2) in Step 2b.

Step 3: Establishing A1-R1, A2-R2, B1-R1, B2-R2 (original training). Three substeps were used, 3a, 3b, and 3c. Immediately before the introduction of Step 3a, the experimenter presented Quadrant 1, placed a card at the center rectangle, and requested the subject to place that card at the top right (R1) or bottom left (R2) rectangle. In Step 3a, subjects were trained to emit R1 in the presence of A1 and R2 in the presence of A2 (A1-R1, A2-R2). Step 3b was the same but with stimuli B1 and B2 (B1-R1, B2-R2). Step 3c involved training with all four stimuli.

Step 4: Establishing A1-R3, B1-R4 (reassignment training). The subjects were trained to emit a novel response to one member of each class, A1 and A2. The procedures were the same as in Step 3a except the subjects had to place the cards at the top left or bottom right rectangles of Quadrant 2 (A1-R3, A2-R4).

To control for horizontal vs vertical differences from the original locations, four groups of five subjects each were formed. Each group included subjects of three different age levels. Groups 1 and 3 received horizontal reassignment training, Groups 2 and 4 received vertical reassignment training (see Table 2). For example, during the original training, subjects of Group 3 were trained to place A1 and B1 at the top right rectangle, and A2 and B2 at the bottom left rectangle of Quadrant 1, while during the reassignment training, they were trained to place A1 at the top left regtangle and A2 at bottom right regtangle of Quadrant 2 (horizontal shift).

Step 5: Mixed original and reassignment training. This step assessed whether the originally trained stimulus–response relations were still in tact after the completion of the reassignment training. The two performances were trained in separate blocks of trials, the original performance in the first block (3 A1-

R1, 3 A2-R2, 3 B1-R1, and 3 B2-R2 trials), and the reassignment performance in the second block (e.g., 6 A1-R3 and 6 A2-R4 trials). Eleven correct responses on each block were required. Subjects who made less than 11 but 9 or more correct responses in each block received Step 5 again. Subjects who made less than 9 correct responses on the originally trained tasks returned to Step 3c (original training). Subjects who made less than 9 correct responses on the reassigned tasks returned to Step 4 (reassignment training).

Step 6: Testing original and reassigned tasks. This step assessed the continued accurate performance on the original and reassigned tasks under testing conditions. The procedures were the same as in Step 5 but without immediate consequences (verbal praise or beads). Instead, the subjects received 10 beads after each block of 12 trials irrespective of their performance (same as in Step 2). Subjects who demonstrated criterion performance on the original and reassigned tasks immediately proceeded to Step 7. Subjects who failed to demonstrate criterion performance on the original tasks received one more run on all steps from Step 3c on; those who failed to demonstrate criterion performance on the reassigned tasks received a second run on all steps from Step 4 on. During the second run of Step 6, criterion performance on the reassigned tasks (but not on the original tasks) was sufficient to go to Step 7 (testing B1-R3, B2-R4). This criterion permitted subjects to receive the functional equivalence test (Step 7) even though the original stimulus class no longer existed (i.e., a subject showed A1-R3, B1-R4, but no longer showed A1-R1, A2-R2, B1-R1, B2-R2). This procedure allowed us to assess whether transfer (B1-R3, B2-R4) resulted from linking multiple stimuli with a common response or from other, spurious variables.

Step 7: Testing B1-R3, B2-R4 (functional equivalence). Only Quadrant 2 was used. This test consisted of 24 trials, 12 on nonreassigned tasks (6 B1-R3 and 6 B2-R4 trials) mixed with 12 trials on the reassigned tasks (6 A1-R3 and 6 A2-R4 trials), see also Table 1. Criterion performance was met if a subject responded correctly on 10/12 trials on the nonreassigned tasks *and* on 11/12 trials on the reassigned tasks. Subjects who demonstrated criterion performance on both types of tasks immediately proceeded to the match-to-sample tests (Steps 8 and 9). Subjects who did not demonstrate both criterion performances received one more run on Steps 5, 6, and 7. At that point the subjects proceeded to the next steps irrespective of their performance in Steps 6 and 7. This procedure allowed us to relate the performance on the match-to-sample probes in Step 8 (A1-B1, A2-B2) to the demonstrated class-consistent stimulus-response relations (or the absence thereof) in Steps 6 and/or Step 7 (no functional stimulus classes, functional stimulus classes only, functional equivalence classes).

Step 8: Testing X-Y (review). This step assessed whether, following the training and testing of the stimulus-placement tasks (Steps 3-7), the trained matching tasks (X1-Y1, X2-Y2) were still intact. The procedures were the same as in Step 2a.

Step 9: Testing A-B and B-A (Stimulus equivalence). This step assessed the conditional relations between the indirectly linked A and B stimuli. Two blocks of 12 symbolic match-to-sample trials were used. One block consisted of 12 trials with B1 and B2 as comparisons. On six of these trials, A1 served as sample (measuring A1-B1). On the other six trials A2 served as sample (measuring A2-B2). The other block was the same except that the B stimuli served as samples and the A stimuli as comparisons (measuring B1-A1, B2-A2). The procedures were the same as in in Step 2a. The test was conducted twice with an interval of 24 h in between the first and second run.

Reliability

The reliability observers recorded a total of 1164 responses on training trials (29%) and 660 responses on test trials (22%). The experimenter and observers disagreed on two trials, one training trial and one test trial.

RESULTS

Establishing and Testing Trained Stimulus–Response Relations

Most subjects learned the pretrained X-Y tasks with great ease (Step 1) and responded accurately on the X-Y and Y-X tasks during testing (Step 2). The same applied to the original and reassigned stimulus-response relations in Step 3 (A1-R1, A2-R2, B1-R1, B2-R2) and in Step 4 (A1-R3, A2-R4). Several subjects, however, had difficulties demonstrating criterion performance on *both* types of tasks during training (Step 5) and/or testing (Step 6) and required extra runs on previous training steps, *always* due to deterioration of the originally trained performance. These procedures were sufficient for all but two subjects to demonstrate criterion performance on the originally and reassigned training tasks under testing conditions (Step 6). During testing, Subjects 4 (CA 4; 6) and 13 (CA 5; 4) responded accurately on the reassigned but not on the originally trained tasks. Table 3 shows the test results on the original and reassigned stimulus-placement tasks in Step 6, the reassigned and nonreassigned (derived) stimulus-placement tasks in Step 7, and on the A-B and B-A matching tasks in Step 9.

Testing Emergent Stimulus–Response Relations

Both subjects (4 and 13) who responded correctly on the reassigned tasks but not on the originally trained tasks in Step 6 responded at chance level on the nonreassigned tasks in Step 7. Of the other 18 subjects, who responded accurately on the original *and* reassigned tasks in Step 6, 15 (83%) demonstrated transfer from A to B (functional equivalence) in step 7: 4/6 of the youngest subjects (67%), 5/6 of the older subjects (83%), and 6/6 of the oldest subjects (100%). One of these subjects (6) reversed the stimulus-response relations during the reassigned *and* nonreassigned tasks. Across all

TABLE 3

Age (CA) and Sex of Each Subject, and Percentages of Correct Responses on the Original (O) and Reassigned (R) Training Tasks during Testing (Tst), the Reassigned (R) and Nonreassigned (NR) Tasks during the Functional Equivalence Test (FE-Tst), and on the Matching Tasks during the Stimulus Equivalence Test (SE-Tst)

			Tst		FE-Tst		SE-Tst					Tst		FE-Tst		SE-Tst					Tst		FE-Tst		SE-Tst	
Ss	CA	Sex	O	R	R	NR	A-B	B-A	Ss	CA	Sex	O	R	R	NR	A-B	B-A	Ss	CA	Sex	O	R	R	NR	A-B	B-A
Youngest subjects									Older subjects									Oldest subjects								
1	49	M	+	+	92	100	100	100	8	62	M	+	+	100	100	58	67	15	66	F	+	+	100	100	100	100
2	53	M	+	+	75	100	33	33	9	62	M	+	+	83	92	50	83	16	66	F	+	+	100	100	100	100
3	54	M	+	+	83	50	75	42	10	62	F	+	+	50	0	50	58	17	67	M	+	+	100	100	42	42
4	54	F	−	+	83	67	8	8	11	63	F	+	+	100	100	100	100	18	67	M	+	+	100	100	100	100
5	55	F	+	+	100	92	92	83	12	63	F	+	+	100	100	100	100	19	68	M	+	+	92	92	100	100
6	56	M	+	+	0	0	100	100	13	64	F	−	+	100	50	100	100	20	71	F	+	+	100	100	100	100
7	58	M	+	+	100	100	100	100	14	64	M	+	+	92	83	25	33									
M	54				76	73	73	67	*M*	63				89	75	69	77	*M*	68				99	99	90	90

Note. *M* = mean. Age is expressed in months. Plus (+) indicates criterion performance; minus (−) indicates no criterion performance.

20 subjects, the percentages of correct choices on the reassigned and nonreassigned tasks were 88 and 81%, respectively.

Subsequent analyses revealed that transfer was related to age and the ease with which the X-Y matching tasks (Step 1) and the originally and reassigned stimulus-placement tasks (Steps 3-5) were learned. The three subjects who did not show transfer (2, 3, 10) were younger (*M* = 56 months) than those (*N* = 15) who showed transfer (*M* = 63 months), and required more trials for demonstrating criterion performance in Step 1 (*M* = 72) and in Steps 3-5 (*M* = 140) than their more successful counterparts (Step 1: *M* = 50; Steps 3-5: *M* = 117).

Testing Emergent Stimulus–Stimulus Relations

After demonstrating near perfect accurate performance on the trained X-Y matching task (Step 8), all 20 subjects were given the opportunity to match the experimental stimuli. Eleven of the 15 subjects (73%) who demonstrated stimulus control transfer also related same-class stimuli conditionally to one another (e.g., A1-B1, A2-B2, and vice versa). The other four subjects (8, 9, 14, 17) consistently responded to the same stimulus (simple discrimination responding) or demonstrated position responding. So did Subjects 2, 3, and 10 who responded correctly on all trained tasks but showed no transfer (functional stimulus classes but no functional equivalence). Interestingly, Subjects 4 and 13, who gave no evidence for the existence of any type of classes (functional equivalence or functional stimulus classes) also demonstrated conditional discrimination performances. Subject 13 matched same-class stimuli and Subject 4 opposite-class stimuli. Because these performances may simply reflect chance-determined generalized matching (Saunders et al., 1988), they will not be given further consideration.

The four subjects who demonstrated emergent stimulus-response relations but no emergent stimulus-stimulus relations were about the same age (*M* = 63 months) as the 11 subjects who did (*M* = 62 months). However, they required more trials for learning the pretrained X-Y matching tasks in Step 1 (*M* = 60) and the stimulus-placement tasks in Steps 3-5 (*M* = 144) than their more successful counterparts (Step 1: *M* = 46; Steps 3-5: *M* = 107).

Following the completion of the experiment, 4 of the 11 subjects who responded accurately on the A-B and B-A matching tasks (5, 11, 12, 18) were given two more tests to assess stimulus equivalence. Each test consisted of four trials. As before, no feedback and/or beads were given until both tests were completed. During the first test, hereafter referred to as the Response-Stimulus test, the experimenter presented Quadrant 2, placed both nonreassigned stimuli (e.g., B1 and B2) in front of the subject, and told him/her, ‘‘Another child placed one of these pictures (the experimenter pointed to B1 and B2) here (and pointed to the top left rectangle [R3], or to the bottom right rectangle [R4]) and got a bead. Which picture did he put there? Think carefully.’’ During the second test, hereafter referred to as the Response-

Response test, the experimenter placed both quadrants on the table next to one another and two paper clips, one at the center rectangle of Quadrant 1 and one at the center rectangle of Quadrant 2. Then she said, ‘‘If I put my clip here (and placed it at the top right or bottom left rectangle of Quadrant 1, i.e., demonstrated R1 or R2), where do you put the clip on your board?’’. During the first two trials, the experimenter used Quadrant 1 and the subject Quadrant 2 (measuring R1-R3, R2-R4). During the following two trials, the experimenter used Quadrant 2 and the subject Quadrant 1 (measuring R3-R1, R4-R2). All subjects responded accurately during the first test (R3-B1, R4-B2). Two subjects (11, 18) also responded accurately during the second test (R1-R3, R2-R4, and vice versa). Subject 5 responded accurately when the experimenter demonstrated her responses on Quadrant 1 (measuring R1-R3, R2-R4) but became confused when using Quadrant 2 (measuring R3-R1, R4-R2). During several of these trials, she indicated she did not know how to respond, shrugged her shoulders, and wanted to stop. Subject 12 responded seemingly randomly on all trials.

DISCUSSION

The present findings showed a high degree of correspondence between functional stimulus classes and functional equivalence classes, and between functional equivalence and stimulus equivalence. After being trained to emit differential stimulus-placement responses to pairs of stimuli (A1-R1, B1-R1; A2-R2, B2-R2) in one setting and to emit novel stimulus-placement responses to one member of each pair (A1-R3, A2-R4) in another setting (reassignment training), most (15/18) children emitted the novel responses also in the presence of same-class nonreassigned stimuli (B1-R3, B2-R4; functional stimulus class → functional equivalence class). Most (11/15) of these children also related same-class stimuli conditionally to one another (A1-B1, A2-B2, and vice versa; functional equivalence → stimulus equivalence). Additional tests with four children showing stimulus–stimulus relations documented the formation of conditional response–stimulus relations (R3-B1, R4-B2) in all four and of conditional response–response relations (R1-R3, R2-R4, and vice versa) in two of these children. Both children who failed to maintain the originally trained performances after reassignment training also failed to show transfer-consistent performance (no functional stimulus class → no functional equivalence class). Likewise, all three children who did not evidence transfer also failed to match same-class stimuli to one another (no functional equivalence → no stimulus equivalence).

The present findings on emergent stimulus–response relations corroborate those reported by Wasserman and DeVolder (1993) on children of the same age range. Some of our children, notably the younger ones, had temporary or permanent problems with maintaining criterion performance on the original and reassigned training tasks. These difficulties, however, were only mild compared to those reported in other studies (Astly & Wasserman, 1996) that came to our attention after the data collection of the present study had been completed. This discrepancy may be related to the fact that, in the present study, the children had already completed a conditional discrimination training (X-Y) before the stimulus-placement training was introduced. The training errors may have led to the formation of inappropriate stimulus–response relations that interfered with the class-consistent stimulus–response and stimulus–stimulus relations under testing conditions (Dube & McIlvane, 1996).

Further research should investigate if the emergent stimulus-reponse relations are a function of the order in which the prerequisite tasks are trained. Previous work by Dixon and Spradlin (1976), Spradlin and Saunders (1986), Urcuioli (1996), and Urcuioli et al. (1995) suggests that animals and humans find it easier to derive stimulus relations (B1-C1, B2-C2) from training protocols in which multiple samples are linked with same comparisons (B1-A1, B2-A2; C1-A1, C2-A2; many-to-one protocol) than from training protocols in which same samples are linked to multiple comparisons (A1-B1, A2-B2; A1-C1, A2-C2; one-to-many protocol). The present study and those by Wasserman started with the training of a *stimulus class* that can be defined as a many-to-one protocol (A1-R1, B1-R1, A2-B2, B2-R2) followed by a second training (A1-R3, A2-R4). Would the results be the same if (i) a *response class* is trained first (one-to-many protocol): A1-R1, A2-R2, A1-R3, A2-R4 training followed by B1-R1 and B2-R2 training, or (ii) if *no class* is trained first: A1-R3, A2-R4, B1-R1, B2-R2 training followed by A1-R1 and A2-R2 training?

Most of the subjects who demonstrated stimulus-control transfer also matched same-class stimuli with one another. This finding plus the obtained response–stimulus and response–response relations suggest that functional equivalence can imply stimulus equivalence and thereby supports Sidman’s position that (i) responses can participate in equivalence relations, and (ii) from an equivalence position, the distinction between stimuli and defined responses is basically irrelevant in terms of their causal status.

But, was functional equivalence necessarily a demonstration of stimulus equivalence as Sidman (1994) suggested? The answer to this question must be negative in view of the fact that four subjects (8, 9, 14, and 17) showed functional equivalence but no stimulus equivalence. How could functional equivalence for these subjects be based on stimulus equivalence (e.g., B1-R3 emanate from B1-R1, R1-A1, A1-R3) given their inadequate performances in the subsequent match-to-sample probes (no class-consistent A-B matching)? Proponents of Sidman’s position might argue that these subjects showed stimulus equivalence within the *context* of the quadrants but not within the *context* of match-to-sample tasks. Such an argument, however, would make Sidman’s position impossible to refute, at least conceptually, because transfer tests, including those on functional and stimulus equivalence, are always conducted in contexts different from those during training.

An alternative explanation would be that functional equivalence can be based on secondary or response mediated generalization (Miller & Dollard, 1941; Urcuioli, 1996; Urcuioli et al., 1995; Wasserman & Devolder, 1993) and hence, unrelated to stimulus equivalence. This account states that when new responses are conditioned to a subset of originally trained stimuli, a mediating link is formed via covert demonstration of the originally trained response (Hefferline & Perera, 1963). For example, after training A-R1 and B-R1, both stimuli continue to produce R1 covertly (‘‘R1’’). Thus, when during the second phase A-R3 is trained, subjects covertly emit, ‘‘feel’’ or ‘‘see’’, the originally trained response (‘‘R1’’) before emitting R3: A→‘‘R1’’→ R3. When during the third phase (test) B is presented subjects continue to emit ‘‘R1’’ which, given the reinforced ‘‘R1’’-R3 link established during the second phase, leads to the emission of R3: B→‘‘R1’’→R3. Note that this process implies a linear and unidirectional stimulus–response relation similar to the stimulus-stimulus relation referred to as transitivity (A-B, B-C → A-C) and does not require bidirectionality (e.g., R1-B); nor does it not require subjects to respond in accordance with relation between A and B (stimulus equivalence) because R3 is directly controlled by ‘‘R1’’ rather than by A or B (Saunders, Williams, & Spradlin, 1996). In short, functional equivalence may represent a behavioral process that is largely independent of stimulus equivalence. Hence, it should not come as a surprise that (i) some children showing functional equivalence did not also show stimulus equivalence and (ii) animals show functional equivalence and transitivity (Manabe, Kawashima, & Staddon, 1995; Urcuioli et al., 1995; Wasserman et al., 1992; Yamamoto & Asano, 1995; Zentall & Urcuioli, 1993) but not stimulus equivalence (Dube et al., 1993; Hayes, 1989).

Although the data were generally in support of Sidman’s recent formulations, some of the present findings and those reported by others suggest that functional equivalence can imply but does not require stimulus equivalence. Thus, Sidman’s recent position (Sidman, 1994) does not necessarily invalidate his previous one (Sidman et al., 1989). Perhaps phylogenetically and ontogenetically young organisms do form functional equivalence through mediated or secondary generalization. This may continue to be the major source for transfer in animals (functional equivalence, transitivity), whereas in verbal humans, this process may be incorporated or transformed into diverse relational framing behaviors, including that of sameness, so that transfer, functional equivalence, and stimulus equivalence become inextricably bound to one another (Barnes, 1994).

REFERENCES

Astley, S. L., & Wasserman, E. A. (1996). Mediating associations, essentialism, and nonsimilarity-based categorization. In T. R. Zentall & P. M. Smeets (Eds.), *Stimulus class formation in humans and animals* (pp. 111–133). Amsterdam: Elsevier.

Barnes, D. (1994). Stimulus equivalence and relational frame theory. *The Psychological Record,* **44,** 91–124.

Barnes, D., Browne, M., Smeets, P. M., & Roche, B. (1995). A transfer of functions and a conditional transfer of functions through equivalence relations in three- to six-year-old children. *The Psychological Record,* **45,** 405–430.

Barnes, D., & Keenan, M. (1993). A transfer of functions through derived arbitrary and nonarbitrary stimulus relations. *Journal of the Experimental Analysis of Behavior,* **59,** 61–81.

Barnes, D., Smeets, P. M., & Leader, G. (1996). New procedures for establishing emergent matching performances in children and adults: Implications for stimulus equivalence. In T. R. Zentall & P. M. Smeets (Eds.), *Stimulus class formation in humans and animals* (pp. 153–171). Amsterdam: Elsevier.

Bonardi, C., Rey, V., Richmond, M., & Hall, G. (1993). Acquired equivalence of cues in pigeon autoshaping: Effects of training with common consequences and with common antecedents. *Animal Learning and Behavior,* **21,** 369–376.

de Rose, J. C., McIlvane, W. J., Dube, W. V., Galpin, V. C., & Stoddard, L. T. (1988). Emergent simple discrimination established by indirect relation to differential consequences. *Journal of the Experimental Analysis of Behavior,* **50,** 1–20.

Devany, J. M., Hayes, S. C., & Nelson, R. O. (1986). Equivalence class formation in language-able and language-disabled children. *Journal of the Experimental Analysis of Behavior,* **46,** 243–257.

Dixon, M. H., & Spradlin, J. E. (1976). Establishing stimulus equivalence among retarded adolescents. *Journal of Experimental Child Psychology,* **21,** 144–164.

Dougher, M. J., & Markham, M. R. (1994). Stimulus equivalence, functional equivalence and the transfer of functions. In S. C. Hayes, L. J. Hayes, M. Sato, & K. Ono (Eds.), *Behavior analysis of language and cognition* (pp. 71–90). Reno (NV): Context Press.

Dougher, M. J., Augustson, E., Markham, M. R., Greenway, D. E., & Wulfert, E. (1994). The transfer of respondent eliciting and extinction functions through stimulus equivalence classes. *Journal of the Experimental Analysis of Behavior,* **62,** 331–351.

Dube, W. V., McDonald, S. J., & McIlvane, W. J. (1990). A note on the relationship between equivalence classes and functional stimulus classes. *Experimental Analysis of Human Behavior Bulletin,* **9,** 7–11.

Dube, W. V., & McIlvane, W. J. (1996). Some implications of stimulus control topography analysis for emergent behavior and stimulus classes. In T. R. Zentall & P. M. Smeets (Eds.), *Stimulus class formation in humans and animals* (pp. 197–218). Amsterdam: Elsevier.

Dube, W. V., McIlvane, W. J., Callahan, T. D., & Stoddard, L. T. (1993). The search for stimulus equivalence in nonverbal organisms. *The Psychological Record,* **43,** 761–778.

Dube, W. V., McIlvane, W. J., Maguire, R., Mackay, H. A., & Stoddard, L. T. (1989). Stimulus class formation and stimulus-reinforcer relations. *Journal of the Experimental Analysis of Behavior,* **51,** 65–76.

Dymond, S., & Barnes, D. (1994). A transfer of self-discrimination response functions through equivalence relations. *Journal of the Experimental Analysis of Behavior,* **62,** 251–267.

Greenway, D., Dougher, M., & Markham, M. (1995). S+/S− reversal procedures may not result in functional equivalence. *Experimental Analysis if Human Behavior Bulletin,* **13,** 16–17.

Grice, G. R., & Davis, J. D. (1960). Effect of concurrent responses on the evocation and generalization of the conditioned eye blink. *Journal of Experimental Psychology,* **59,** 391–395.

Hayes, S. C. (1989). Nonhumans have not yet shown stimulus equivalence. *Journal of the Experimental Analysis of Behavior,* **51,** 385–392.

Hayes, S. C., Devany, J. M., Kohlenberg, B. S., Brownstein, A. J., & Shelby, J. (1987). Stimulus equivalence and the symbolic control of behavior. *Revista Mexicana de Analysis de la Conducta,* **13,** 361–374.

Hefferline, R. F., & Perera, T. B. (1963). Proprioceptive discrimination of a covert operant without its observation by a subject. *Science,* **139,** 834–835.

Honey, R. C., & Hall, G. (1989). The acquired equivalence and distinctiveness of cues. *Journal of Experimental Psychology: Animal Behavior Processes,* **15,** 338–346.

Lipkins, R., Kop, P. F. M., & Matthijs, W. (1988). A test of symmetry and transitivity in the conditional discrimination performances of pigeons. *Journal of the Experimental Analysis of Behavior,* **49,** 395–409.

Manabe, K., Kawashima, T., & Staddon, J. E. R. (1995). Differential vocalization in budgarigars: Toward an experimental analysis of naming. *Journal of the Experimental Analysis of Behavior,* **63,** 111–126.

Miller, N. E., & Dollard, J. (1941). *Social learning and imitation.* New Haven (CT): Yale University Press.

Reese, H. W. (1968). *The perception of stimulus relations: Discrimination learning and transposition.* New York: Academic Press.

Richards, R. W. (1988). A question of bidirectional associations in pigeons' learning of conditional discrimination tasks. *Bulletin of the Psychonomic Society,* **26,** 577–579.

Rodewald, H. K. (1974). Symbolic matching-to-sample by pigeons. *Psychological Reports,* **34,** 987–990.

Saunders, R. R., Saunders, K. J., Kirby, K. C., & Spradlin, J. E. (1988). The merger and development of equivalence classes by unreinforced conditional selection of comparison stimuli. *Journal of the Experimental Analysis of Behavior,* **50,** 145–162.

Saunders, K., Williams, D. C., & Spradlin, J. E. (1996). Derived stimulus control: Are there differences among procedures and processes? In T. R. Zentall & P. M. Smeets (Eds.), *Stimulus class formation in humans and animals* (pp. 93–109). Amsterdam: Elsevier.

Schusterman, R. J., & Kastak, D. (1993). A California sea lion (Zalophus Californianus) is capable of forming equivalence relations. *The Psychological Record,* **43,** 823–839.

Shipley, W. C. (1935). Indirect conditioning. *Journal of General Psychology,* **12,** 337–357.

Sidman, M. (1994). *Equivalence relations and behavior: A research story*. Boston, MA: Authors Cooperative.

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., & 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., Wynne, C. K., Maguire, R. W., & Barnes, T. (1989). Functional classes and equivalence relations. *Journal of the Experimental Analysis of Behavior,* **52,** 261–274.

Smeets, P. M. (1994). Stability of emergent simple discriminations in young children. *Journal of Experimental Child Psychology,* **57,** 397–417.

Smeets, P. M., Schenk, J. J., & Barnes, D. (1995). Establishing arbitrary stimulus classes via identity-matching training and non-reinforced matching with complex stimuli. *The Quarterly Journal of Experimental Psychology,* **45B,** 311–328.

Smeets, P. M., & Striefel, S. (1994). A revised blocked-trial procedure for establishing arbitrary matching in children. *The Quarterly Journal of Experimental Psychology,* **47B,** 241–261.

Spradlin, J. E., & Saunders, R. R. (1976). Development of stimulus class: Sample classification vs comparison classification. *Analysis and Intervention in Developmental Disabilities,* **6,** 41–58.

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.

Steele, D., & Hayes, S. C. (1991). Stimulus equivalence and arbitrarily applicable relational responding. *Journal of the Experimental Analysis of Behavior,* **56,** 519–555.

Urcuioli, P. J. (1996). Acquired equivalences and mediated generalization in pigeon's matching-to-sample. In T. R. Zentall & P. M. Smeets (Eds.), *Stimulus class formation in humans and animals* (pp. 55–70). Amsterdam: Elsevier.

Urcuioli, P. J., Zentall, T. R., & DeMarse, T. (1995). Transfer to derived sample-comparison relations by pigeons following many-to-one versus one-to-many matching with identical training relations. *The Quarterly Journal of Experimental Psychology,* **48B,** 158–178.

Urcuioli, P. J., Zentall, T. R., Jackson-Smith, P., & Steirn, J. N. (1989). Evidence for common coding in many-to-one matching: Retention, intertrial interference, and transfer. *Journal of Experimental Psychology: Animal Behavior Processes,* **15,** 264–273.

Vaughan, W. J. (1988). Formation of equivalence sets in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes,* **14,** 36–42.

Wasserman, E. A., & DeVolder, C. L. (1993). Similarity- and nonsimilarity-based conceptualization in children and pigeons. *The Psychological Record,* **43,** 779–793.

Wasserman, E. A., DeVolder, C. L., & Coppage, D. J. (1992). Nonsimilarity based conceptualization in pigeons via secondary order or mediated generalization. *Psychological Science,* **3,** 374–379.

Wulfert, E., & Hayes, S. C. (1988). Transfer of a conditional ordering response through conditional equivalence classes. *Journal of the Experimental Analysis of Behavior,* **50,** 125–141.

Yamamoto, J., & Asano, T. (1995). Stimulus equivalence in a chimpansee (pan troglodytes). *The Psychological Record,* **45,** 3–21.

Zentall, T. R., & Urcuioli, P. J. (1993). Emergent relations in the formation of stimulus classes in pigeons. *The Psychological Record,* **43,** 795–810.

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