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CONDITIONAL DISCRIMINATION AND EQUIVALENCE RELATIONS: CONTROL BY NEGATIVE STIMULI

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Three adult subjects were taught the following two-sample, two-comparison conditional discriminations (each sample is shown with its positive and negative comparison, in that order): A1-B1B2, A2-B2B1; B1-C1C2, B2-C2C1; and C1-D1D2, C2-D2D1. A teaching procedure was designed to encourage control by negative comparisons. Subjects were then tested for emergent performances that would indicate whether the baseline conditional discriminations were reflexive, symmetric, and transitive. The tests documented the emergence of two classes of equivalent stimuli: A1, B2, C1, D2 and A2, B1, C2, D1. These were the classes to be expected if the negative comparisons were the controlling comparisons in the baseline conditional discriminations. The negative comparisons, however, were not the comparisons that subjects were recorded as having chosen in the baseline conditional discriminations. Differential test results confirmed predictions arising from a stimulus-control analysis: In reflexivity tests (AA, BB, CC, DD), subjects chose comparisons that differed from the sample; one-node transitivity (AC, BD) and "equivalence" (CA, DB) tests also yielded results that were the opposite of those to be expected from control by positive comparisons; symmetry tests (BA, CB, DC), two-node transitivity (AD) tests, and two-node "equivalence" (DA) tests yielded results that were to be expected from control by either positive or negative comparisons.

Key words: equivalence relations, conditional discrimination, negative stimuli, stimulus control, computer touch screen input, adult humans

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It is impossible to tell from just the programmed contingency and the response record whether a subject's choices in a two-comparison conditional discrimination are controlled by positive or by negative comparisons. If the contingency has generated equivalence relations, however, the two types of control can be expected to yield predictably different outcomes in tests for the properties of equivalence relations (Carrigan & Sidman, 1992).

The Controlling Stimuli

Panel I in Figure 1 illustrates the programmed contingency in a two-sample (A1, A2), two-comparison (B1, B2) conditional discrimination. A reinforcer is delivered if the subject touches (points to, moves, etc.) B1 when the sample is A1, or B2 when the sample is A2. With Sample A1, Comparison B1 is said to be positive and B2 is negative; with Sample A2, the positive and negative designations are reversed. The contingency depicted in Panel I does not specify which comparison controls the subject's response.

Because of this ambiguity, descriptions of conditional discriminations often reflect unstated assumptions. For example, one may read that subjects were taught, "If the sample is A1 then respond to Comparison B1, and if A2 then B2." This description does not mention negative stimuli. "Select" and "reject" (below) specify the stimulus that is conditionally related to the sample, the positive ("select") or the negative ("reject") comparison. Panel II of Figure 1, illustrating select control, represents the assumption that the controlling stimuli on correct trials are the sample and the positive comparison. A second description of the contingency, however, might state, "If the sample is A1, respond away from Comparison B2, and if the sample is A2, respond away from B1." This description does not mention positive stimuli. Panel III of Figure 1, illustrating reject control, represents the assumption that the controlling stimuli on a correct trial are the sample and negative comparison. Even though the subject is recorded as having touched the positive comparison, the negative comparison,

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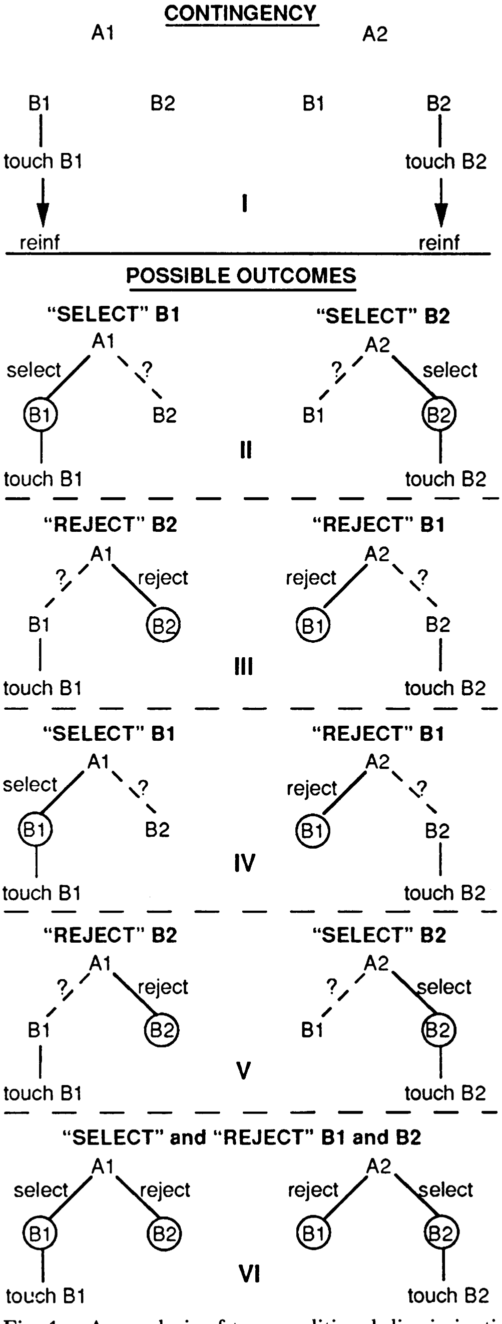

Fig. 1. An analysis of two conditional discrimination trials (the left and right sides of each panel), showing that a subject might touch the positive comparison either by selecting it or by rejecting the negative comparison. A1 and A2 designate sample stimuli; B1 and B2 designate comparisons. Panel I shows experimental contingencies; Panels II through VI illustrate control by the positive ("select") and/or the negative ("reject") comparisons. Controlling comparisons are circled and connected to samples by solid lines.

in being "rejected," controls the recorded choice.

Panels II and III of Figure 1 indicate that even though the record shows the same comparison being touched in conjunction with a given sample, only with select control do subjects touch the controlling comparison. One way of describing Panel II is to say that if the sample is A1, subjects look for and select Comparison B1; if the sample is A2, they look for and select Comparison B2. In describing Panel III, however, one might say that if the sample is A1, subjects look for and reject Comparison B2; if the sample is A2, they look for and reject B1.

A third way to describe the outcome of the contingency is to state, "Subjects are taught to respond to B1 if the sample is A1, and not to respond to B1 if the sample is A2." This description mentions only one comparison stimulus, which is sometimes positive and sometimes negative. In Panel IV, subjects might be said always to look for Comparison B1, sometimes selecting and sometimes rejecting it, depending on the sample. In Panel V, subjects might be said always to look for Comparison B2, either selecting or rejecting it.

A final possibility would have subjects "responding to B1 and not to B2 if the sample is A1, and responding to B2 and not to B1 if the sample is A2." Panel VI, which combines Panels IV and V, shows each comparison to be involved in both kinds of control. With Sample A1, subjects select B1 *and* reject B2; with A2, they select B2 *and* reject B1.

In all panels of Figure 1, the recorded behavior remains the same: If the sample is A1, subjects touch B1; if the sample is A2, they touch B2. How is one to tell, then, whether a conditional discrimination involves select or reject control? Carrigan and Sidman (1992) pointed out limitations inherent in the usual novel-stimulus test (e.g., Cumming & Berryman, 1965; Dixon & Dixon, 1978; Stromer & Osborne, 1982) and provided a theoretical basis for predicting that tests for reflexivity or transitivity could unequivocally identify controlling comparisons (see below for a summary).

A broader question is what test performances would indicate the formation of equivalence relations if a subject rejects incorrect comparisons in the baseline. Carrigan and Sidman's (1992) analysis requires that the programmed contingencies give rise to equivalence relations; predictions generated by the analysis are based on the defining properties of equivalence relations (see below). Given reject control in the baseline (see *The Biasing Procedure* in Method, below), tests that show the baseline conditional discriminations to possess the properties of equivalence relations would demonstrate that reject control is compatible with equivalence. If reject control prevails, however, certain tests for the properties of equivalence relations can be expected to yield results that are opposite to those based on select control.

The Controlling Stimuli and Tests for Equivalence: Predictions

The uppermost section of Figure 2 illustrates the baseline conditional discriminations, AB, BC, and CD, that were explicitly taught in the present experiment. In each conditional discrimination, arrows connect the sample to its related (circled) comparison and checkmarks indicate the positive comparison. In accord with the reinforcement contingencies, the positive comparisons are the same under select and reject control. The reinforcement contingencies, however, do not specify the controlling comparisons. With select control, the positive comparison in each conditional discrimination is also the controlling comparison (the one that is related to the sample). With reject control, however, the positive comparison is not related to the sample. For example, with A1 as the sample under select control, B1 is both the positive and the controlling comparison; under reject control, B1 is still positive but B2 is the controlling comparison. Because the comparison that is related to each sample differs under select and reject control, the two types of control can be expected to generate different equivalence classes. The arrows connecting each sample to its related (selected or rejected)

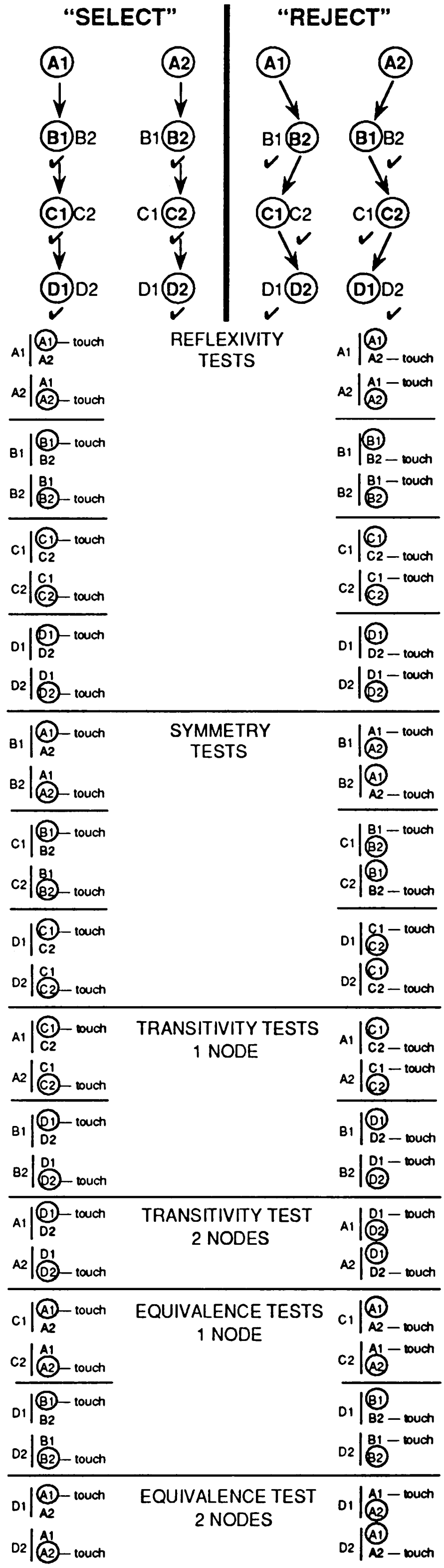

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Fig. 2. The controlling comparisons (circled) in an AB/BC/CD baseline under select (left) and reject (right) control. In the upper section, arrows point from samples to controlling comparisons; checkmarks indicate the comparison the subject touched—the observable outcome of the reinforcement contingencies. Diagrams in the lower sections, which show each sample at the left of its pair of comparisons, illustrate the tests. For each type of control, the sample, the controlling comparison (circled), and the comparison a subject can be expected to touch are shown side by side.

comparison show the two classes under select control to consist of A1B1C1D1 and A2B2C2D2 and under reject control to consist of A1B2C1D2 and A2B1C2D1.

The lower sections of Figure 2, which show each sample at the left of its pair of comparisons, illustrate the tests and their expected results, depending on whether the control is select or reject. Carrigan and Sidman's (1992) analysis leads to the following expectations when tests for the properties of equivalence relations are carried out.

Reflexivity tests. In a reflexive relation, the *same relation* will hold between each stimulus and itself. Opportunities for a subject to relate each stimulus to itself are provided by identity-matching tests in which a stimulus that is involved in the conditional relation being tested serves both as sample and comparison. If the relation being tested is reflexive, such a test will show a subject either selecting or rejecting the comparison that is the same as the sample, depending on whether select or reject control prevails in the baseline. One test, for example, would present a subject with A1 or A2 as a sample and both A1 and A2 as comparisons. If the baseline relation is reflexive and the control is select, subjects can be expected to select and touch Comparison A1 when A1 is the sample and Comparison A2 when A2 is the sample. With reflexivity and reject control, however, subjects can be expected to reject Comparison A1 and touch A2 when A1 is the sample and to reject A2 and touch A1 when A2 is the sample. The same holds true in tests involving stimuli from the other baseline conditional discriminations; compare the left and right columns of reflexivity tests in Figure 2. Test results indicating that the baseline relation is reflexive can therefore be expected to depend on whether the control is select or reject.

Symmetry tests. A symmetric baseline relation will hold when the samples become comparisons and the related comparisons become samples. One test, for example, presents B1 or B2 as a sample and both A1 and A2 as comparisons. With a symmetric baseline relation and select control, subjects can be expected to select and touch A1 when B1 is the sample and A2 when B2 is the sample. With reject control, however, they can be expected to reject A2 and touch A1 when B1 is the sample and to reject A1 and touch A2 when B2 is the sample. In symmetry tests, then, the type of control dictates the controlling comparison, but the comparison a subject touches remains the same whether the control is select or reject. The same recorded results can be expected for select and reject control in the three possible symmetry tests (Figure 2).

Transitivity tests. For the baseline to exhibit transitivity, all of its conditional discriminations (AB, BC, and CD) must be based on the same relation (unlike Panels IV and V in Figure 1). One test trial might present a subject with A1 or A2 as a sample and both C1 and C2 as comparisons. With reference to the baseline diagrams in Figure 2, predicted results can be expressed as follows: (if Sample A1 select B1) and (if Sample B1 select C1), then, by transitivity, if Sample A1 select C1; or (if Sample A1 reject B2) and (if Sample B2 reject C1), then, by transitivity, if Sample A1 reject C1.

With a transitive baseline relation and select control, subjects can be expected to select and touch C1 when A1 is the sample, but with reject control, subjects will reject C1 and touch C2. As in reflexivity tests, then, the type of control in AC and BD transitivity tests (Figure 2) will determine which comparison the subject touches, even though the controlling comparison is the same for both select and reject control.

Baselines for AC and BD transitivity tests contain only one node, B stimuli in the AC test and C stimuli in the BD test. The whole baseline, however, contains two nodes, B and C stimuli (Fields & Verhave, 1987; Fields, Verhave, & Fath, 1984). The transivity test for the two-node baseline is the AD test, with predicted results as follows: (if Sample A1 select B1) and (if Sample B1 select C1) and (if Sample C1 select D1), then, by transitivity, if Sample A1 select D1; or (if Sample A1 reject B2) and (if Sample B2 reject C1) and (if Sample C1 reject D2), then, by transitivity, if Sample A1 reject D2.

With a transitive two-node baseline relation and select control, subjects can be expected to select and touch D1 when A1 is the sample, and with reject control, they will reject D2 and touch D1. For a given sample in the two-node transitivity test, the type of relation dictates the controlling comparison, but the comparison actually touched is the same in select and reject control. Unlike reflexivity and one-node transitivity tests, then, recorded two-node transitivity test results can be expected to show no difference between select and reject control.

Equivalence tests. CA, DB, and DA tests have been recommended as abbreviated tests for equivalence because results indicative of equivalence require the baseline to possess the defining symmetric and transitive properties of an equivalence relation (e.g., Sidman, 1986, 1990). Figure 2 shows these tests and their expected results, but the rationale for the predictions is essentially the same as for transitivity and need not be repeated.

METHOD

Subjects were first taught baseline conditional discriminations with a procedure that was designed to encourage control by negative comparisons. Then, tests were conducted to determine whether the baselines possessed the properties of equivalence relations. Test results were evaluated to ascertain whether they were in accord with predictions based on select or reject control, as outlined above.

Subjects

Subject JLM, a 27-year-old woman, a supervisor of educational services for autistic children and an MA candidate, participated in 19 30- to 60-min sessions. Subject DAW, a 27-year-old man with a BA in Psychology and a teacher of autistic children, participated in 22 30- to 60-min sessions. Subject JCG, a 15-year-old girl and a high school student, participated in eight sessions, each about 2 hr in duration. Sessions took place 2 or 3 days a week. The subjects were not acquainted with the topics of the investigation.

Apparatus

Apparatus and procedures have been presented elsewhere (Bush, Sidman, & de Rose, 1989), and only broad outlines and new details will be described here. A computer presented stimuli, managed trial sequences and contingencies, and recorded data. Five rectangular "keys" were continuously present on the monitor, with one of four outer keys adjacent to each side of a center key. After the preexperimental phase (see below), trial displays consisted of a sample stimulus in the center key, two comparison stimuli in outer keys, and two blank outer keys. Key positions of comparison stimuli and blanks varied from trial to trial. When a subject touched a key, the location of the touch was recorded via a transparent touch pad mounted over the face of the monitor. The bottom left corner of the monitor contained a white-highlighted counter that continuously displayed a subject's accumulated number of points.

Procedure

Instructions to subjects. In the first set of trials, the sample key was blank and only one of the outer comparison keys contained a stimulus. The subject was instructed, "Touch it." A touch on the key that contained the stimulus produced a high-pitched "beep" and the addition of a point to the counter. The subject was then asked how many points the counter showed and was told, "Sometimes a beep will sound and a point will be added to the counter. At the end of the session, each point will be exchanged for one cent." During the first few sessions, the experimenter intermittently asked, "How many points do you have?" After each set of trials, the subject moved away from the monitor while the experimenter entered the parameters for the next set of trials.

Before tests, subjects were told, "This time there will not be any beeps or points, but afterwards we will give you something you know how to do." Before such "make-up" sets of trials, Subjects JLM and DAW were told, "Points will be worth two cents each," and Subject JCG was told, "Two points will be added to the counter each time."

Standard accuracy criteria. Each combination of sample and comparison stimuli was defined as a trial type; a block of trials contained one presentation of each trial type. The intertrial interval was 0.68 s. Teaching trials continued until the subject scored at least 95% correct over six consecutive blocks of trials and made no more than one error on any trial type. Tests contained a predetermined number of trials, depending on the number of trial types involved.

Preexperimental phase. Preexperimental stimuli, different from those to be used later, were alphabet letters, geometric designs, and a white key area. First, without a sample being presented, subjects learned to produce a beep and point by touching the one outer key that contained a stimulus. Then, with a stimulus in the sample key, subjects learned to produce

Table 1

Examples of trial types that were intended to bias subjects toward rejecting incorrect comparisons in the AB, BC, and CD conditional discriminations. Roman numerals identify groups of trial types. S = sample; C = comparisons. Touching the left-hand member of each comparison pair produced a reinforcer.

I		II		III		IV		V		VI	
S	C	S	C	S	C	S	C	S	C	S	C
A1 →	B1B2	A2 →	B2B1	B1 →	C1C2	B2 →	C2C1	C1 →	D1D2	C2 →	D2D1
A1 →	X1B2	A2 →	X4B1	B1 →	Y1C2	B2 →	Y4C1	C1 →	Z1D2	C2 →	Z4D1
A1 →	X2B2	A2 →	X5B1	B1 →	Y2C2	B2 →	Y5C1	C1 →	Z2D2	C2 →	Z5D1
A1 →	X3B2	A2 →	X6B1	B1 →	Y3C2	B2 →	Y6C1	C1 →	Z3D2	C2 →	Z6D1

the single comparison by touching the sample. Finally, an incorrect comparison appeared along with the correct comparison; subjects had to learn a conditional discrimination. As before, touching the correct comparison was followed by a beep, an additional point on the counter, and the intertrial interval; touching the incorrect comparison was followed only by the intertrial interval. On no trial was the sample stimulus the same as any of the comparisons.

Delayed-cue procedure. A variation of Touchette's (1971) delayed-cue procedure was used to teach each new conditional discrimination. Because the objective was to teach subjects which stimulus *not* to touch, the cue was a display not of the positive but of the negative comparison. When a subject touched the sample, both comparisons came on together at first. Touching the positive comparison produced a beep and point; touching the negative comparison ended the trial without reinforcement. If a predetermined interval elapsed without any response, the key containing the correct comparison became white, thereby hiding the correct stimulus and leaving the incorrect comparison in view. The subject could then produce a reinforcer by touching the white key (perhaps learning to reject the negative stimulus). Subjects could therefore produce the beep and point by waiting for the cue and then touching the white key or by anticipating the cue and touching the correct comparison. The cue delay, initially set at 0.1 s, increased whenever a subject completed a block of trials without error. Delays were set to increase in 0.2-s steps from 0.1 to 0.8 s, in 1-s steps from 1 to 3 s, in 2-s steps up to 8 s, and in 5-s steps up to 20 s. It was not clear whether this delayed-cue procedure by itself succeeded in generating control by negative comparisons, but once subjects had become familiar with the procedure, they learned new conditional discriminations nearly errorlessly. The delayed-cue procedure was used only when new baseline conditional discriminations were introduced.

The biasing procedure. Underlying the procedure for encouraging control by samples and negative comparisons was the assumption that subjects would learn tasks in ways that required the fewest discriminations. Thus, all trial types involving a given sample contained the same negative but varying positive comparisons. For example, in teaching the AB conditional discrimination (Table 1, Columns I and II), all trials with A1 as the sample had the same negative comparison (B2) but varying positive comparisons (B1, X1, X2, or X3); with A2 as the sample, the invariant negative stimulus was B1 and the positive stimulus varied among B2, X4, X5, and X6.

Critical trial types are listed at the top of each column in Table 1. To produce reinforcement regularly on those trials, subjects had to attend to the samples because each comparison had a history of being both positive and negative (e.g., B1 and B2 in Columns I and II). On noncritical trials, however, subjects might have disregarded the samples, selecting any X stimulus or always rejecting B1 and B2. Given both critical and noncritical trials, subjects could regularly produce reinforcers by learning (a) eight relations between samples and positive comparisons, (b) two relations between samples and positive comparisons and six simple discriminations in which an X stimulus was always chosen, (c) two relations between samples and negative comparisons and two simple discriminations in which B1 and B2 were always rejected, (d) various combinations of the first three, or (e) control by two relations between samples and negative comparisons. The last possibility, which required the fewest discriminations, was relied on to generate consistent control by the sample and negative stimulus. Columns III through VI in Table 1 illustrate the same biasing procedure applied to conditional discriminations BC and CD.

Tests in extinction. All tests were carried out in extinction (no beeps or points). To determine whether subjects would maintain criterion performances in extinction, the baseline that had been explicitly taught was tested without reinforcement. All subjects met the criteria in their first extinction tests. Subsequent sessions in which tests were to be given started with a review of the relevant baseline trial types, with reinforcement, and the standard accuracy criteria had to be met before proceeding with tests.

In tests, probe trials for emergent conditional discriminations were interspersed among critical and noncritical baseline trials. After each test, the subject was given the same number of baseline trials with the doubled points or point values, as specified in the instructions. Figure 2 summarizes the baseline conditional discriminations and the probe trials in each test. Figure 3 depicts the actual stimuli that were used, and shows how they correspond to the alphanumeric designations.

Teaching and testing sequences. Each teaching phase continued until the subject met the standard accuracy criteria described above. Subjects JLM and DAW were taught the AB conditional discriminations in Teaching Phase I and BC in Phase II. In Phase III, they were given sets of mixed AB and BC trials. Then, with test trials interspersed among the combined AB/BC baseline trials, the subjects received tests for the emergent conditional discriminations that would show whether the baseline possessed the properties of an equivalence relation: symmetry (BA, CB), transitivity (AC), and equivalence (CA). Every test contained six presentations of each baseline and probe trial type. Because the conditional discriminations had two trial types (combinations of sample and comparison stimuli), tests contained 12 probe trials. Each test was given four times (Subject DAW received six CA tests). The testing sequence differed among subjects, as will be noted in the Results section.

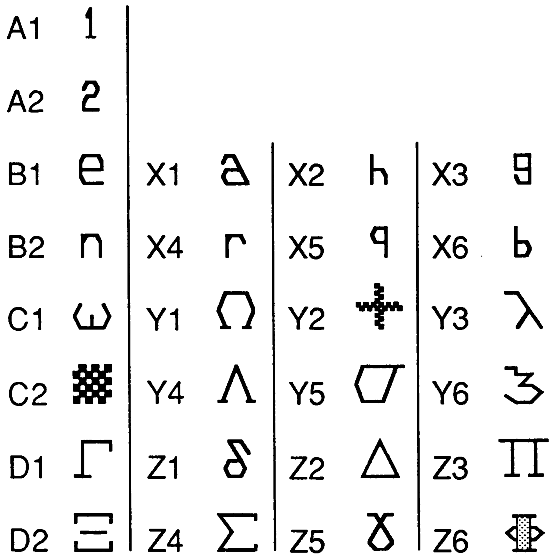

Fig. 3. The actual stimuli (reduced approximately 75%) shown beside the corresponding alphanumeric stimulus designations.

After the AB/BC baseline had been tested, Subjects DAW and JLM were taught the CD conditional discrimination (Teaching Phase IV), and a new baseline of mixed AB, BC, and CD trials was then established (Phase V). The subjects then received tests that would show whether the new baseline possessed the properties of an equivalence relation: symmetry (DC), transitivity (AC, BD, AD), equivalence (CA, DB, DA), and, for Subject DAW, reflexivity (AA, BB, CC, and DD). Each test was given three times. With the new baseline, tests contained five presentations of each trial type and therefore included 10 probe trials.

Subject JCG was taught the complete AB/BC/CD baseline before being tested. She received at least four repetitions of each test: symmetry (BA, CB, DC), transitivity (AC, BD, AD), equivalence (CA, DB, DA), and reflexivity (AA, BB, CC, DD). (The test sequence will be described in the Results section.) Tests contained three presentations of each trial type and therefore included six probe trials.

Verbal reports. After all tests were completed, Subjects DAW and JCG were presented with one instance of each trial type. When they had produced the comparisons, they were asked "What are you going to do?" or "What are you going to do and why?" Subject

DAW, however, was not asked about reflexivity trials, and Subject JCG's reports after the first few were invalidated by a procedural error.

RESULTS

Baselines

All subjects learned the baseline conditional discriminations quickly. When baselines were subsequently reviewed, tested in extinction, or given in conjunction with probes, subjects rarely made errors. Therefore, only probe trial results will be reported.

Tests in the Context of the One-Node AB/BC Baseline

Subjects JLM and DAW received their first tests after learning the one-node AB/BC baseline. Bars in Figure 4 show how many of the subjects' responses in the 12 probe trials of each test were consistent with select control (as outlined in Figure 2).

Transitivity (AC). With Sample A1, both subjects nearly always touched Comparison C2, and with Sample A2, they always touched C1. Replicating Carrigan's (1986) findings, the subjects' choices in the one-node transitivity test were in accord with expectations based on reject rather than select control.

Symmetry (BA and CB). In all BA symmetry tests, both subjects always touched Comparison A1 when B1 was the sample and A2 when B2 was the sample. In CB tests, they always touched B1 when C1 was the sample and B2 when C2 was the sample. These symmetry test results were to be expected whether the type of control was select or reject (Figure 2).

Equivalence (CA). In Subject JLM's first equivalence test, which was also her first test of any type, she showed consistent select control, always touching A1 when C1 was the sample and A2 when C2 was the sample. She did not maintain this performance, however, in three subsequent repetitions of the CA test (8, 10, and 13) that followed transitivity and symmetry tests. All probe trials in the last three equivalence tests showed reject rather than select control: When C1 was the sample, she touched A2; with C2 as the sample, she touched A1.

Subject DAW's first test was also the CA equivalence test. His performance, like that of Subject JLM, was consistent with select control. To determine whether a shift in control would take place if the equivalence test were repeated without other kinds of tests intervening, Subject DAW was given four consecutive CA tests. In Tests 2 and 3, his performance lacked consistency, but Test 4 once again indicated select control. A complete performance shift took place, however, when he received two more CA tests immediately after four consecutive AC transitivity tests. In Tests 9 and 10, all probe trials showed reject control; he always touched A2 when C1 was the sample and A1 with C2 as the sample.

Tests in the Context of the Two-Node AB/BC/CD Baseline

After their AB/BC baseline had been tested, Subjects JLM and DAW were taught CD conditional discriminations. Although DC, AC, CA, BD, and DB tests required only one-node baselines (AB/BC or BC/CD), all tests were now carried out in the context of the two-node baseline (AB/BC/CD). With CD added to the baseline, Subjects JLM and DAW were given the newly possible symmetry test (DC) once, the one-node transitivity (AC) and equivalence (CA) tests three times, and the newly possible two-node transitivity (AD) and equivalence (DA) tests three times. Both subjects had the same test sequence. Subject JCG learned the complete two-node AB/BC/CD baseline and was then given at least two tests of each type.

Symmetry (DC). The DC symmetry test given to Subjects JLM (Figure 5) and DAW (Figure 6) confirmed the results of their earlier symmetry tests: With Sample D1, they touched Comparison C1, and with D2, they touched C2. Again, these findings could have arisen from either select or reject control. The three types of symmetry tests given to Subject JCG, all in the context of the two-node baseline, were also consistent with either type of control (Figure 7); only two of her 36 choices failed to match the expectations outlined in Figure 2.

One-node transitivity (AC and BD). Subjects JLM and DAW again demonstrated reject control in AC tests: With Sample A1, they always touched Comparison C2; with Sample A2, they always touched C1. Similarly, their choices were in accord with reject control in the new one-node BD transitivity tests: They reliably touched Comparison D2 in the pres-

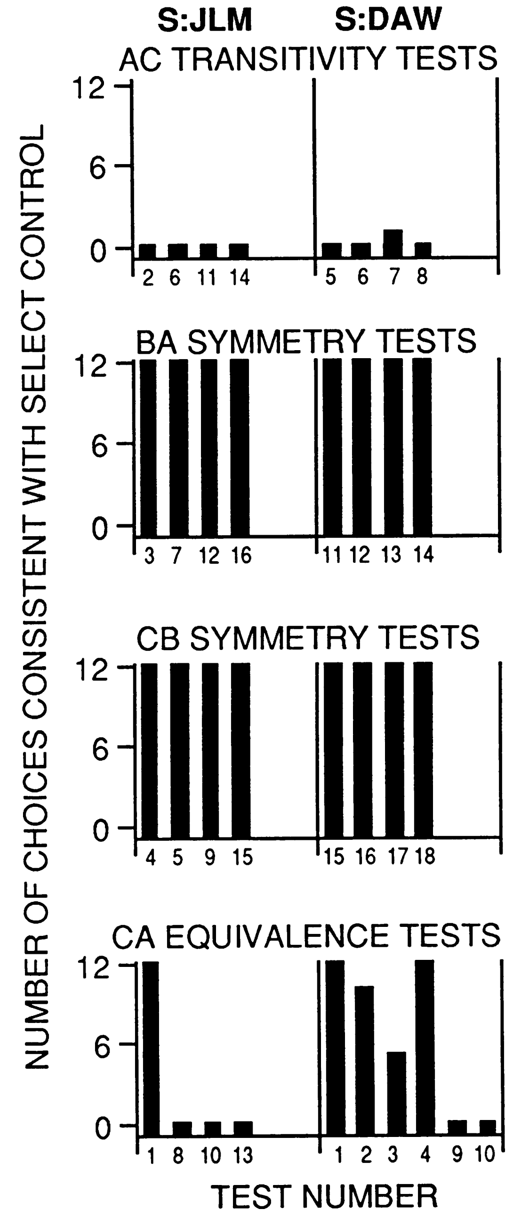

Fig. 4. Results of tests in the context of the AB/BC baseline for Subjects JLM and DAW. Each row of bars represents one type of test. Within rows, tests are shown sequentially, with test numbers below the bars. Each bar represents the number of choices that were consistent with select control (Figure 2).

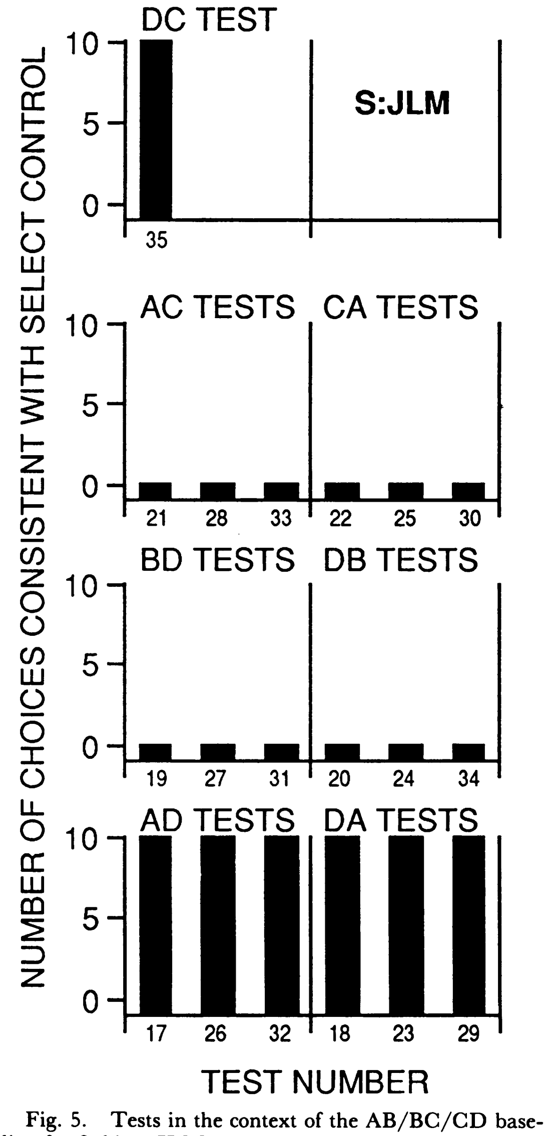

Fig. 5. Tests in the context of the AB/BC/CD baseline for Subject JLM.

ence of Sample B1 and D1 in the presence of B2. In Subject JCG's one-node AC and BD transitivity tests, her 24 choices were in accord with expectations based on reject control.

Two-node transitivity (AD). Unlike AC and BD, which tested one-node subsets of the baseline for transitivity, AD tested the complete two-node baseline. In the AD tests, all 3 subjects always touched Comparison D1 in the presence of Sample A1 and D2 in the presence of A2. Although the one-node transitivity tests had unequivocally shown reject control, the two-node AD tests yielded results that were to be expected as an outcome of either select or reject control (Figure 2).

One-node equivalence (CA and DB). Subjects JLM and DAW replicated the reject control shown by the final results of their earlier

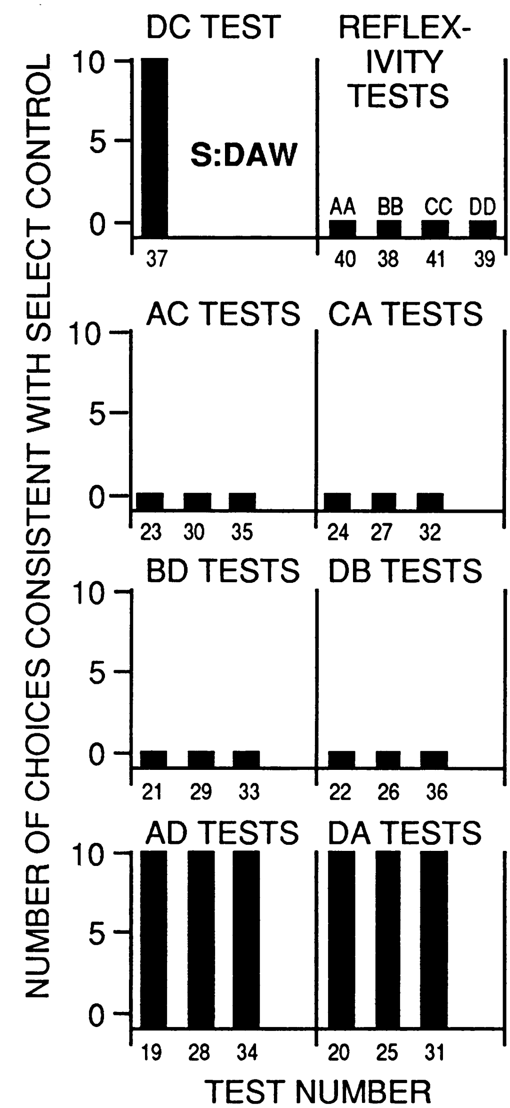

Fig. 6. Tests in the context of the AB/BC/CD baseline for Subject DAW.

CA tests: In the context of the two-node baseline, they always touched Comparison A2 in the presence of Sample C1 and A1 in the presence of C2. Subject JCG replicated these data in her four CA tests (four, rather than the usual two, because of the changes that had taken place in the other subjects' CA tests).

Subjects JLM and DAW also demonstrated reject control in their newly possible DB tests, always touching B2 in the presence of Sample D1, and B1 in the presence of D2 (Figures 5 and 6). Subject JCG's first DB test yielded equivocal results, with two of her six recorded

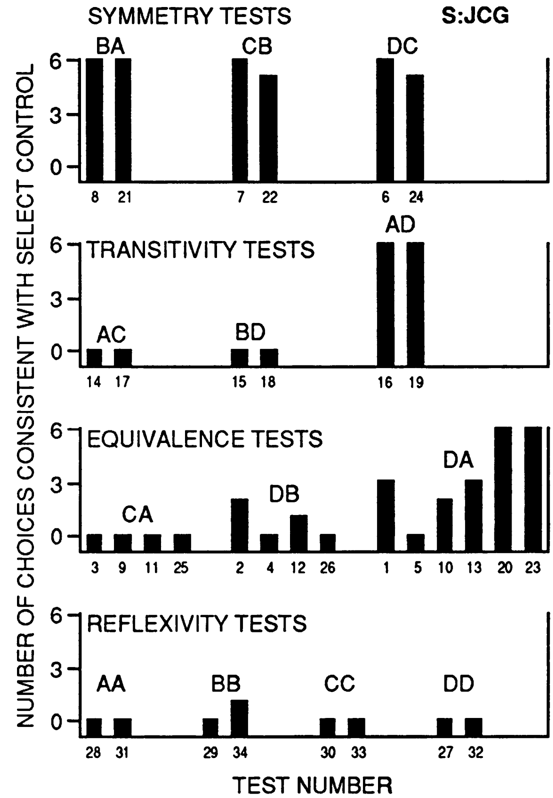

Fig. 7. All tests, each in the context of the AB/BC/CD baseline, for Subject JCG.

choices being consistent with select control (Figure 7, Test 2). In her second DB test, given after a CA test, all probe trials showed reject control, a result confirmed in 11 of 12 trials in two more DB tests.

Two-node equivalence (DA). Unlike CA and DB, which tested one-node subsets of the two-node baseline for equivalence, DA tested the complete baseline. Subjects JLM and DAW always touched Comparison A1 in the presence of Sample D1 and A2 in the presence of D2 (Figures 5 and 6), results to be expected as an outcome of either select or reject control.

Subject JCG's DA test, her first of any kind, yielded equivocal results, with three of her six recorded choices being consistent with select control (Figure 7). After DB and CA tests that demonstrated reject control, her second DA test (Test 5) shifted also to reject control. The next two DA tests (10 and 13), given after three symmetry tests (6, 7, and 8) and additional one-node equivalence tests (9, 11, and 12), were again variable. Only in the next two

DA tests (20 and 23), after one- and two-node transitivity tests (14 through 19), did her choices come to correspond reliably with expectations that could be derived either from select or reject control (Figure 2).

One-node equivalence tests, therefore, even in the context of the two-node baseline, were consistent with reject control. All subjects' final results on two-node equivalence tests, however, were in accord with either select or reject control in the baseline.

Reflexivity (AA, BB, CC, DD). Subject DAW's performance on reflexivity tests, each given once after all the other tests (Figure 6), was perfectly in accord with expectations based on reject control in the baseline conditional discriminations. He always touched the comparison that was not identical to the sample: A2 in the presence of A1 and A1 in the presence of A2, B2 in the presence of B1 and B1 in the presence of B2, and so forth.

Subject JCG's reflexivity tests yielded the same results. Except for just one trial, she never touched the comparison that was identical to the sample. As was outlined in Figure 2, these results were to be expected if reject control predominated in the baseline.

Verbal Reports

All subjects named the probe stimuli when explaining what they were going to do. For expository convenience, however, the following summary of their reports will use the alphanumeric stimulus designations (Figure 3) instead of the names the subjects gave.

BA symmetry, Sample B2. Subject JLM said, "I'm going to touch A2 because B2 goes with A1." Subject DAW said, "A1 and B2 have been paired together and . . . they're in the same group, so I'm choosing A2 because it's not in that group." Subject JCG said, "I am going to touch A2 because A1 always goes with B2 and you have to press the other one."

AC transitivity, Sample A1. Subject JLM said she would "touch C2 because A1 goes with B2 which goes with C1." Subject DAW said he would "choose C2 because C1 was paired with B2 which was paired with A1, and I'm choosing the different group."

AD transitivity, Sample A2. Subject JLM said she would "touch D2 because A2 goes with B1 which goes with C2 which goes with D1." Subject DAW said, "I'm choosing D2 because D1 was paired with C2 which was paired with B1 which was paired with A2, and they're in the same group. I don't want that group. I want the other group which is D2." Subject JCG had A1 as the sample, and stated that she would pick D1 because D2 "always comes with A1, and you have to press the other one."

DB equivalence, Sample D1. Subject JLM said she was going to "touch B2 because B1 goes with C2 and C2 goes with D1." Subject DAW said, "The choice I'm going to select is B2 because B1 was paired with C2 which was paired with D1, and I'm choosing from a different group."

DA equivalence, Sample D2. Subject JLM said she would "touch A2 because A1 goes with B2, B2 goes with C1, and C1 goes with D2." Subject DAW said, "I'm going to choose A2 because D2 was paired with C1 which was paired with B2 which was paired with A1. They're in the same group and I'm choosing the different group." Subject JCG, who had D1 as the sample, said, "I am going to touch A1 because A2 goes with D1 and you have to touch the other one."

DD and AA reflexivity. Subject JCG said, "I am going to touch the one that is not alike."

DISCUSSION

The substantial agreement between predicted and obtained results indicates that (a) the biasing procedure did generate control by the sample and negative comparison (reject control) in each baseline conditional discrimination; (b) even with reject control, the baseline relation was an equivalence relation; and (c) select and reject control can be expected to yield different results when conditional relations are tested for the properties of equivalence relations.

In the context of a four-term reinforcement contingency (uppermost panel of Figure 1), the difference between select and reject control became visible in subjects' responses in reflexivity, one-node transitivity, and one-node equivalence tests. The differing results, depending on the type of control, support Carrigan and Sidman's (1992) proposal that these, rather than novel-stimulus tests, are definitive for evaluating select versus reject control in two-comparison conditional discriminations that give rise to equivalence relations. As they pointed out, substitution of a novel stimulus for the positive comparison can identify reject control but can produce misleading results if the tested conditional discrimination is under select control. Similarly, substitution for the negative comparison can identify select control but may be misleading in the case of reject control. Evaluations of reflexivity, one-node transitivity, or one-node equivalence, however, can identify both types of control in a single test. Carrigan and Sidman suggested that the sensitivity of transitivity and equivalence tests can be extended to baselines that possess any odd number of nodes, but this generalization has not been tested. Reflexivity tests, on the other hand, can differentiate select from reject control independently of the number of nodes in the baseline.

Perhaps the most startling outcome of the Carrigan and Sidman (1992) analysis that the present investigation tested and confirmed was the subjects' selection of nonmatching comparisons in reflexivity tests. Earlier formulations, which stipulated the identity-matching procedure as the test for the reflexive property of equivalence relations, assumed that positive tests would show a subject's choice on any trial to be the comparison that was identical to the sample (e.g., Sidman, 1986, 1990; Sidman et al., 1982; Sidman & Tailby, 1982). This assumption did not take into account the possibility of reject control. With reject control, subjects can be expected to choose the comparison that is not the same as the sample.

Saunders and Green (1992) suggested that the seemingly unexpected possibility of subjects choosing the nonmatching comparison in reflexivity tests requires consideration of something more than a mathematically derived definition of equivalence relations. On the other hand, Carrigan and Sidman's (1992) analysis leads to the recognition that regardless of whether the control is select or reject, the controlling comparison in a positive (for equivalence) reflexivity test trial is always identical to the sample. Only with select control, however, is the controlling comparison also a subject's recorded choice; with reject control, subjects "respond away from" the controlling comparison.

Although Saunders and Green (1992) were undoubtedly correct in calling for the examination of other variables in addition to those suggested by the mathematics of the equivalence relation, the effect of reject control on the outcome of reflexivity tests does not provide an appropriate rationale for that position. A more rigorous adherence to the mathematical definition will resolve the interpretive problem raised by reject control in reflexivity tests. What is called for is the abandonment neither of reflexivity as a defining characteristic of equivalence relations nor of the identity-matching test for reflexivity. Rather, the original formulation must be corrected by abandoning the assumption that a positive reflexivity test has to show a subject's choice to be identical to the sample. Even while retaining the characteristics of its formal definition, the reflexivity test is valid and useful if (a) the comparison that is identical to the sample is the controlling comparison and (b) the relation between sample and controlling comparison in a test trial is the same as the relation between samples and controlling comparisons in the baseline.

Why *is* the comparison that is identical to the sample the controlling comparison in reflexivity testing? Why did subjects not come under control by the nonidentical comparison and reject it? We are indebted to an anonymous reviewer for these questions, the answer to which emphasizes the analytic power of the mathematically derived definition of equivalence relations. The definition specifies that pairs of identical stimuli will be included in the relation (Carrigan, 1986) but specifies nothing about stimuli that are paired on the basis of differences. The formation of an equivalence relation in the baseline, therefore, sets up *by definition* related pairs of identical stimuli. Reflexivity test trials contain only one established relation that is consistent from trial to trial; that is the relation between the sample and itself. No relation has been established between the sample and the "odd" stimulus. The stimulus that is the same as the sample therefore becomes the controlling comparison. Reflexivity can thus be said to bring the notion of sameness into the definition of equivalence even though reject control causes the subject to choose the comparison that differs from the sample.

A second outcome of the present investigation that the Carrigan and Sidman (1992) analysis predicted was the "toggling" or "flip-flop" effect in transitivity and equivalence tests when the nodality of the baseline changed. In tests that required a one-node baseline (AC, BD, DB, CA), subjects' choices were the opposite of those to be expected if select control prevailed. In tests that required a two-node baseline (AD, DA), the choices were in accord with either select or reject control. One-node tests distinguished select from reject control, but two-node tests failed to make such a distinction.

Although tests requiring a two-node baseline failed, as predicted, to identify the type of control, the reflexivity and one-node test results justify an inference that reject control also prevailed in two-node tests. The same inference holds with respect to symmetry tests which, predictably, failed to make the prevailing type of control visible. To assume that reflexivity tests and one-node transitivity and equivalence tests demonstrated reject control in the baseline, but that symmetry and two-node transitivity and equivalence tests demonstrated select control, would introduce unnecessary interpretive complexities.

All subjects received equivalence tests first, having had no experience with reflexivity, symmetry, or transitivity probes. In their first CA tests, Subjects JLM and DAW showed uniform select rather than reject control, and Subject JCG's first DA test results were unreliable. In repetitions of the initial tests, however, the CA performances of Subjects JLM and DAW confirmed predictions based on reject control, and the DA performances of Subject JCG came into agreement with predictions based on either type of control. Although the reasons for the anomalous initial test results are unclear, the circumstances under which changes took place do justify some speculation.

Subject JLM's CA performance shifted to uniform reject control on her second test (Figure 4). Between her first two CA tests (1 and 8), however, she had transitivity (AC) and symmetry (BA and CB) Tests 2 through 7, all showing reject control. Her CA test might therefore have become consistent with reject control because of her experience with the other tests. On the other hand, repetition of the CA test might by itself have produced the change.

In an attempt to resolve this question, Subject DAW was given the CA test three more times before he received other tests (Figure 4, Tests 1 through 4). Repeated CA testing yielded no shift to reject control. But then, after four intervening AC transitivity tests (5 through 8), all showing reject control, two more CA tests (9 and 10) also demonstrated uniform reject control. It seems reasonable to conclude that the AC test was responsible for shifting the CA control from select to reject.

Subject JCG's first three tests were, respectively, the two-node DA and the one-node DB and CA tests (Figure 7). The results of her initial DA and DB tests were variable. After the first one-node CA test (Test 3), which showed reliable reject control, her one-node DB performance (Test 4) also became and remained consistent with reject control. The results of her first four DA tests, however, were predictable on the basis of neither select nor reject control, even when unvarying (Test 5), or after symmetry tests (6 through 8), or after DB and CA tests (9, 11, and 12). Only after she had received one- and two-node transitivity tests (14 through 19), all showing reject control, did her fifth and sixth DA tests also become uniform and in accord with expectations based on reject control. Once again, transitivity tests (AC, AD, or both) seemed to have been responsible for bringing an equivalence test into conformity with reject control, this time the DA rather than the CA test.

It seems unlikely that the baseline shifted to reject control after having been at first under select control (Subjects JLM and DAW) or under varying control (Subject JCG). If it had shifted, why would the first transitivity tests and, for Subject JCG, the first one-node equivalence tests have shown reject control even though those tests preceded the presumed baseline shift?

A second possibility is that the baselines were under joint select and reject control (e.g., Figure 1, Panel VI), with the CA tests of Subjects JLM and DAW simply reflecting one of the two possibilities and the DA tests of Subject JCG reflecting vacillation. Again, however, one is faced with the question of why transitivity tests would have produced a change, and why that change would have persisted.

In the case of Subject JCG, perhaps a more appropriate question is not why her initial DA tests failed to document reject control in the baseline, but why those tests failed to show that the baseline relation was an equivalence relation. Fields, Adams, Newman, and Verhave (1992) found that early testing of emergent relations that require fewer prerequisites increases the probability that more complex tests given later will be consistent with equivalence. Fields, Adams, Verhave, and Newman

(1990) and Kennedy (1991), testing several emergent relations concurrently, suggested that nodality influenced the likelihood that derived relations would emerge in early probes. Adams, Fields, and Verhave (in press) have found that testing all the "simpler" emergent relations first almost guarantees a positive result even in equivalence tests that require as many as three baseline nodes. It appears that the fewer the number of baseline and simpler emergent relations that a test requires in order to demonstrate equivalence, the more likely the first test result is to be consistent with equivalence. These indications that the testing sequence can be critical are in accord with suggestions that variables arising from the tests themselves must be considered when evaluating the properties of equivalence relations (Devany, Hayes, & Nelson, 1986; Sidman, 1992; Sidman, Kirk, & Willson-Morris, 1985; Sidman, Willson-Morris, & Kirk, 1986).

Is it possible, therefore, that the initial CA tests of Subjects JLM and DAW also reflected not the type of control in the baseline, but rather a failure to demonstrate an equivalence relation in the baseline? Perhaps the subjects arbitrarily selected and then stayed with one of the two possible choices (Saunders, Saunders, Kirby, & Spradlin, 1988). If so, giving simpler tests first might have prevented the anomalous results. This inference has not yet been verified in the context of a baseline in which reject control is known to prevail.

In spite of these few anomalies, the final test results indicate that the subjects learned two classes of equivalent stimuli, as shown in the upper right section of Figure 2. One class contained A1, B2, C1, and D2; the other contained A2, B1, C2, and D1. These were the classes to be expected if reject control prevailed in the baseline conditional discriminations. Unlike the sample–comparison pairs that were to be expected from a select-control baseline, the comparison that was related to a particular sample was not the comparison that the subjects were recorded as having chosen in the presence of that sample.

Verbal reports reflected the same class structures. Subject JLM invariably said that she was going to touch one of the comparisons because the sample "goes with" the other comparison. Subject DAW described a sample and related comparison as being "paired together" and "in the same group," and then chose the other comparison because it was "in the other group." Subject JCG specified the controlling comparison as the one that "always comes with" the sample, and stated, "You have to press the other one." In reflexivity trials, she pointed out that you have to touch "the one that is not alike." Both their recorded choices and their verbal reports indicated that the subjects were "rejecting" or "responding away from" the controlling comparison—the comparison that "went with," "was in the same group as," or "was like" the sample.

One might assume that the mere chaining of the subjects' stated rules and recorded performances was responsible for the emergence of equivalence relations. Even if the verbalizations could be shown to have been occurring subvocally during the tests, however, such an assumption might be unnecessary and perhaps even incorrect. One would have to explain why or how *any* verbalizations give rise to equivalence relations. The present data are in accord with the more parsimonious suggestion (Sidman et al., 1986) that both the recorded responses and the verbal reports are consequences of the same history, rather than one being a necessary precursor of the other.

That equivalence relations must arise from more fundamental behavioral processes is, of course, a respectable notion, although as yet unproved. Dugdale and Lowe (1990, p. 135), Hayes (1991, pp. 25–26), and Hayes and Hayes (1989, pp. 167–168) have outlined how equivalence might plausibly arise from experiences with symmetric relations. Still unidentified, however, are behavioral processes that might explain how a generalized concept of equivalence, the latter defined by properties of reflexivity, symmetry, and transitivity, might arise from repetitions of those types of experiences.

In any case, the kinds of experiences that have been hypothesized to be responsible for equivalence relations based on select control do not clarify the present results. Rather than choosing the comparison that "went with" a particular sample, subjects chose the other comparison. Little is gained by adding a hypothetical history to the description of the programmed contingencies, the biasing procedure, the controlling stimuli, and the recorded data. To extend to behavioral history a point that

Baer (1991) made about experimental control, one might argue that where a history is known, there is no need to invent one.

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