JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1995, **63**, 225–238 NUMBER 3 (MAY)

REVERSAL OF BASELINE RELATIONS AND STIMULUS EQUIVALENCE: I. ADULTS

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Following the emergence of two four-member equivalence classes (A1B1C1D1 and A2B2C2D2), 5 students were exposed to a series of phases including a baseline conditional discrimination reversal (i.e., choosing D2 was reinforced and D1 punished given Sample A1; choosing D1 was reinforced and D2 punished given Sample A2), the delayed introduction of CD/DC transitivity/equivalence probes, DE conditional discrimination training, a second baseline conditional discrimination reversal (i.e., choosing C2 was reinforced given B1, etc.), and a return to original baseline reinforcement contingencies. Results showed that baseline and symmetry probe performances were extremely sensitive to baseline modifications. In contrast, patterns on transitivity/equivalence probes remained predominantly consistent with the originally established equivalence classes, although there were exceptions on some E probe relations for 2 subjects. The dissociation between baseline and symmetry versus transitivity/equivalence patterns may have important implications because it is not easily accounted for by current models of equivalence phenomena.

Key words: stimulus equivalence, conditional discrimination reversal, complex stimulus control, object displacement, high school and college students

Equivalence classes are most typically established by training a set of interrelated conditional discriminations involving arbitrarily assigned stimuli. Untrained definitional properties of the set are then revealed by performances on no-reinforcement probe trials. Since Sidman and Tailby's (1982) classic analysis, the many demonstrations of basic equivalence phenomena have included a number of procedural variations designed to influence class formation and expansion (Bush, Sidman, & de Rose, 1989; Dube, McIlvane, Mackay, & Stoddard, 1987; Green, Sigurdardottir, & Saunders, 1991; Sidman, Kirk, & Willson-Morris, 1985; Wulfert & Hayes, 1988). In contrast, relatively few studies have focused on variables influencing the maintenance or loss of equivalence classes over time, especially given changes in baseline conditional discriminations, which are the theoretical determinants of equivalence (e.g., Sidman, 1986). Further, the studies that have been done raise some interesting questions about the nature of stimulus equivalence.

In studies that have examined the stability of equivalence classes over time, emergent patterns of stimulus control were maintained after 5 months or more without intervening training or practice (see Spradlin, Saunders, & Saunders, 1992). These results appear to be congruent with those from studies that have examined the stability of equivalence classes in the face of reversed prerequisite relations and found performances on transitivity probes unchanged (e.g., Saunders, Saunders, Kirby, & Spradlin, 1988; Spradlin et al., 1992). One interpretation of such outcomes is that equivalence classes are highly stable once established. However, other studies (see Spradlin et al., 1992), including one from our laboratory, have complicated this conclusion.

Pilgrim and Galizio (1990) trained adult subjects on two baseline conditional discriminations (A1-B1, A2-B2, A1-C1, A2-C2; the hyphen implies given the former, select the latter), and after equivalence-class patterns emerged on reflexivity, symmetry, and transitivity probes, the AC baseline was altered by either randomizing or reversing the AC reinforcement contingencies. When contingencies for the baseline relation were reversed (A1-C2, A2-C1), performance on symmetry probe trials for 3 of 4 subjects became immediately consistent with the modified base-

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Order of authorship was determined by the flip of a weighted coin. This material is based on work supported by the UNCW Faculty Research and Development Fund under Grant 2-13506 and by the National Science Foundation under Grant SBR-9309997. The authors wish to thank Lori Chambers, Jenny Buller, Diane Cutshall, and Andrew Innis for their many hours of patient assistance in conducting sessions and collecting data.

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line (e.g., subjects chose A1 given C2 and A2 given C1). Transitivity and reflexivity probe responding, however, remained unchanged. Thus, the Pilgrim and Galizio data reproduced the persistence of originally established transitivity patterns found by Saunders, Saunders, Kirby, and Spradlin (1988), but because the symmetry patterns exhibited concurrently consistently reflected altered conditional relations, interpretation in terms of the preservation of original equivalence classes seems incomplete. Indeed, the dissociation of baseline, symmetry, reflexivity, and transitivity probe patterns raises questions about the functional substitutability of stimuli that is a defining feature of stimulus equivalence, and thus, perhaps, about the integrated nature of "equivalence" as a behavioral unit.

The present study was conducted to test the generality of the findings of Pilgrim and Galizio (1990). Procedural variations were designed to help to determine the range of conditions under which dissociation between symmetry and transitivity would be observed, to analyze further the effects of prerequisite baseline-relation reversals on equivalence classes, and to address the possibility of extraneous sources of control in our previous procedures. In chronological order of their introduction, the following systematic variations were incorporated into the present procedures.

Baseline training differed from the first study, in that three conditional discriminations (A1-C1, A2-C2, B1-C1, B2-C2, A1-D1, A2-D2) were trained to mastery prior to presentation of the baseline modifications. The structure of this training arrangement replicated that of a study in which transitivity patterns changed in keeping with baseline manipulation (Spradlin, Cotter, & Baxley, 1973). Arranging for larger classes also provided the opportunity for parametric tests of reversal effects; the earlier study involved equivalence classes of the smallest possible size. In addition, this training format permitted a comparison of transitivity probes involving stimuli separated by one versus two nodes (e.g., AB vs. BD probes; Fields, Adams, Verhave, & Newman, 1990; Fields, Verhave, & Fath, 1984). Performances on one- and two-node probe tests should differ if a rejection form of stimulus control was induced by the reversal manipulation (see Carrigan & Sidman, 1992).

Also in the present study, the first baseline-relation reversal (A1-D2, A2-D1) was arranged immediately following class emergence; no other condition intervened that might have decreased the salience of the reversed relation. With respect to our earlier study, Spradlin et al. (1992) noted that the ambiguous context of the random-reinforcement condition arranged first for some subjects might have disposed them to maintain original probe patterns when reversal conditions followed.

Another parameter explored in the present study was the timing of reversal training with respect to a subject's history of responding on particular probe-trial types. As noted in Pilgrim and Galizio (1990), repeated practice of an emergent conditional discrimination prior to reversal could influence its probability following reversal. Indeed, there is one report of 2 subjects whose responses on transitivity tests involving a reversed relation were congruent with the new baseline when the reversal was arranged prior to tests for emergent relations (Spradlin et al., 1992). Unfortunately, only probe data involving the reversed relation were reported, making it impossible to tell whether the subjects had simply reversed all originally established relations (as 1 of the subjects had done previously) or were demonstrating reorganized equivalence classes. Therefore, in the present study the relation between probe practice and pattern modification was assessed by introducing one transitivity/equivalence probe type (CD/DC probes) for the first time after the reversed baseline had been mastered. Would novel probe trials be more likely than previously presented ones to generate responses in keeping with the modified baseline?

A further manipulation was designed to provide an additional test for assessing the impact of baseline reversal on equivalence-class composition. Following the AD reversal, subjects learned a new conditional discrimination in which the reversed comparison stimuli served as samples (D1-E1, D2-E2). The question of interest here involved how E stimuli would be treated on transitivity/equivalence trials. Given that E stimuli could only become class members via their relation to D stimuli, and given that the original AD relations had been reversed, performances on transitivity trials involving E stimuli could provide an independent index of the relation between D stimuli and other class members. Would the newly emergent E relations be controlled by the current baseline or be consistent with previously established classes?

Finally, the larger equivalence classes established in the present study allowed for both a greater number of class challenges and for probe-trial arrangements that could unambiguously distinguish between actual class reorganization and simple disruption or reversal of all relations, independent of class membership. Specifically, a second original baseline relation was reversed (B1-C2, B2-C1), and probe trials (including one-, two-, and three-node transitivity/equivalence tests) assessed the impact of a more extensively modified baseline on equivalence-class performances.

METHOD

Subjects

Four introductory psychology students (3 female and 1 male) and a junior high school student (Tina, female) served as subjects.

Apparatus

Apparatus and procedures closely paralleled those used earlier (Pilgrim & Galizio, 1990). A modified Wisconsin General Test Apparatus (WGTA) was used. The WGTA was a wooden box (17 cm by 24 cm by 60 cm) open at both ends, allowing the experimenter and the subject access to one side of the apparatus. A guillotine door bisected the apparatus, and a partition prevented visual contact between the subject and experimenter.

Experimental stimuli were abstract three-dimensional objects mounted on cardboard squares (5 cm by 5 cm). Stimulus presentations were arranged manually by the experimenter, who then raised the guillotine door and slid a Plexiglas stimulus tray (25 cm in length) toward the subject. A sample stimulus in the center of the tray and two comparison stimuli on either side were presented simultaneously on each trial. Each stimulus object covered a small concave well in which tokens could be placed. The subject responded by displacing a comparison stimulus and removing the token underneath if one was present. Tokens were accumulated in small cups beside the WGTA, and each response was recorded by the experimenter.

Procedure

General procedures. Each trial was initiated when the experimenter raised the guillotine door of the WGTA and presented the stimulus tray to the subject. Subjects were instructed to pick up one of the two side objects and were told that any tokens uncovered would contribute to their earnings. White tokens added 1 cent, and black tokens subtracted 1 cent (see Pilgrim & Galizio, 1990, for verbatim instructions). A trial terminated when the subject replaced the stimulus object. The tray was retracted, the guillotine door closed, and a 15-s intertrial interval ensued.

Trials were organized in blocks of 16 during the initial stages of training. When one block was completed, the next began without interruption. Session duration was 50 min, and as many trial blocks were conducted in a session as was possible (range, five to seven blocks). Sessions were conducted 4 to 5 days per week, once or twice daily, with a minimum of 15 min between sessions. Subjects received a base payment rate of $3 per session, with an additional bonus of $1 per session when all contracted sessions were completed. Additional earnings were based on performance as described above. Cash payments were made at the end of the last session of each week. During the first two experimental sessions for the 4 college-student subjects, course credit but no monetary payment was given.

Phase 1: Original baseline conditional discriminations and equivalence testing. Subjects were initially taught two conditional discriminations (A1C1, A2C2, B1C1, B2C2). Initial trial blocks consisted of a mixed baseline of the four trial types (i.e., A1:C1C2, A2:C1C2, B1:C1C2, B2:C1C2). In a given trial block, each trial type was presented four times in a random sequence, with the constraints that no sample appear on more than three trials in succession and that no comparison stimulus appear in the same location for more than two trials in succession. Comparisons appeared on the left and right sides equally often. Displacing the comparison stimulus designated as correct for a given trial revealed a white token (+1 cent), and displacing the incorrect comparison revealed a black token (−1 cent).

Upon reaching mastery criterion (i.e., 14 of 16 trials correct), a third conditional discrimination was introduced (A1D1, A2D2). Trial blocks were expanded to 24 trials, which included AD trial types (A1:D1D2, A2:D1D2) mixed with AB and BC trial types (see above). Each trial type was presented four times in scrambled order, with side positions balanced within each block. When a criterion of 21 correct responses within a block of 24 trials was reached, the reinforcement rate was reduced. On six trials of each block, one trial per trial type, token wells were left empty. Upon reaching criterion (21 of 24 trials correct) at this level, frequency of reinforcement was further reduced to 50%; two trials per trial type were unbaited. In each phase of reinforcement-density reduction, "correct" comparisons on unbaited trials appeared on each side equally often.

Stimulus-class probes were introduced when subjects met criterion (21 of 24 correct) with 50% of the trials occurring with no reinforcement. From this point on, every trial block included probe trials that tested for either symmetry or transitivity and equivalence. Trial blocks consisted of six (for symmetry) or eight (for transitivity/equivalence) probe trials interspersed among 18 baseline trials (six AC, six BC, and six AD trials) in a quasi-random order. Two probe trials were never programmed in succession. On symmetry trial blocks, each possible symmetry arrangement was tested once (C1:A1A2, C2:A1A2, C1:B1B2, C2:B1B2, D1:A1A2, D2:A1A2). For transitivity/equivalence blocks, the following arrangements were each presented once: A1:B1B2, A2:B1B2, B1:A1A2, B2:A1A2, B1:D1D2, B2:D1D2, D1:B1B2, D2:B1B2. The other possible transitivity/equivalence probe types (C1:D1D2, C2:D1D2, D1:C1C2, and D2:C1C2) were not presented at this time. For 2 subjects (Neal and Tina), the emergence of transitivity/equivalence was incomplete after ten or more trial blocks. Restricted testing was then programmed in which the only transitivity/equivalence probes presented were those on which performances were most unstable. Otherwise, the symmetry and transitivity/equivalence trial blocks described above were presented in a quasi-random order, with the constraint that neither could be presented more than twice in a row. Token wells were never baited for the probe trials, and six of the baseline trials (one of each trial type) were also unbaited in any given trial block.

These conditions were in effect until stability criteria were met in either of two ways: when five successive trial blocks showed zero variance, or when the difference between the percentage of correct (or class-consistent) trials for the most recent three trial blocks of a particular type (i.e., symmetry or transitivity/equivalence) and the immediately preceding three trial blocks of that type was less than 10% of the grand mean for the six blocks. Thus, subjects were required to show stable performances on baseline, symmetry, and transitivity/equivalence trials concurrently for a minimum of 10 total trial blocks before conditions were changed. Changes in experimental conditions were not instructed or signaled in any way.

Phase 2: AD reversal. During this condition, contingencies for the AD conditional discrimination were reversed on baited AD trials. In the presence of Sample A1, selection of Stimulus D1 revealed a black token, whereas selection of Stimulus D2 revealed a white token. In the presence of Sample A2, selection of D1 was correct (white token) and D2 was incorrect (black token). Contingencies for the other baseline trial types (AC and BC) remained unchanged from the original conditions, as were all other dimensions of trial-block arrangement and composition (e.g., probe trials, baseline reinforcement density, etc.). Also as in Phase 1, all performances (i.e., baseline, symmetry, and transitivity/equivalence) had to meet stability criteria before the next phase was introduced, but as of this point, any stable pattern was sufficient; there was no requirement that responding be consistent with any particular class composition.

Phase 3: CD/DC probes. In Phase 3, CD and DC equivalence trials were introduced for the first time. Transitivity/equivalence trial blocks still included the eight probe-trial types described above (see Phase 1 description), but four new trial types were added: C1:D1D2, C2:D1D2, D1:C1C2, D2:C1C2). In addition to the 12 probe trials, each transitivity/equivalence trial block continued to include six unbaited and 12 baited baseline trials. The AD reversal and all other experimental conditions remained as they had been in Phase 2. Testing under these conditions continued until stable performances were exhibited on CD and DC probes as well as on the other probe and baseline trials.

Phase 4: DE training. During this phase a new conditional discrimination was explicitly trained: D1E1, D2E2. This was accomplished by adding six new baseline trials (three trials each of D1:E1E2 and D2:E1E2) into each symmetry and transitivity/equivalence probe block. Trial blocks now included four each (two baited and two unbaited) of AC, BC, and AD trials in addition to the six DE trials, in a quasi-random order. Thus, all trial blocks continued to include 12 baited and six unbaited baseline trials, as in the preceding phases. DE trials were first introduced in the context of symmetry trial blocks. Symmetry trial blocks now included eight probe trials (two trials each of ED, CA, CB, and DA). Five DE baseline trials were presented prior to the first ED symmetry probe.

Transitivity/equivalence probes were separated into two block types, as of this phase. In addition to the transitivity/equivalence blocks already described (including AB, BA, BD, DB, CD, and DC trial types), a new type of probe-trial block was added that included all of the transitivity/ equivalence probe types involving E stimuli: AE, EA, BE, EB, CE, and EC. Twelve transitivity/equivalence probes, including two of each trial type, were programmed during each of the new transitivity/ equivalence trial blocks. After responding on DE baseline trials had become stable, old and new transitivity/equivalence trial blocks alternated with symmetry trial blocks in a quasi-random fashion. For all trial blocks, the AD reversal remained in effect, and other baseline relations and experimental conditions were as originally programmed.

Phase 5: BC reversal. Four subjects were exposed next to a reversal of the BC baseline conditional discrimination. (Tina was not studied under these conditions.) On baseline trials in which B1 was the sample and reinforcement could occur, choice of Stimulus C1 revealed a black token, whereas selection of Stimulus C2 revealed the white token. Similarly, when B2 was the sample, choice of Stimulus C1 was reinforced, and selection of C2 was punished. Otherwise, conditions remained as in Phase 4.

Phase 6: Return to original baseline conditions. Three subjects were tested in this phase. Reinforcement contingencies for all original baseline conditional discriminations were returned to those programmed in Phase 1. All other experimental conditions continued unchanged from previous phases.

RESULTS

Figure 1 shows performances on baseline trials across all conditions of the experiment. Each data point represents the percentage of baseline trials per block on which responses were consistent with the contingencies programmed in Phase 1 (original). The left panels for each subject show performances under the original conditional discrimination conditions (A1C1, A2C2, B1C1, B2C2, A1D1, A2D2). Acquisition was rapid in most cases, and performances were maintained at virtually 100% accuracy throughout the original baseline conditions. (For clarity, when more than one data point is at 100%, points are offset.)

Figure 1 next shows performances during the AD reversal phase. Performances are plotted as a percentage of original baseline; thus, the rapid change from 100% to zero shown by all subjects on AD trials reflects a rapid adjustment to, and stable continued control by, the reversed contingency. Other baseline performances were generally unaffected by the AD reversal. The open squares, seen first in the AD reversal panels, show performance on the newly introduced DE conditional discrimination (D1E1, D2E2), and also reflect rapid acquisition with sustained accuracy for all subjects.

The BC reversal condition was arranged for 4 subjects, and performances were similar to those during AD reversal, with each subject showing a rapid decline in "original" responding on BC trials and little or no disruption on other trial types. Finally, 3 subjects again showed rapid adjustment when returned to original baseline conditions. In summary, baseline performances were highly sensitive to the contingencies in effect during each phase. Accurate performances on the initial discriminations adjusted rapidly and specifically in keeping with each contingency reversal.

Figure 2 shows comparable performances

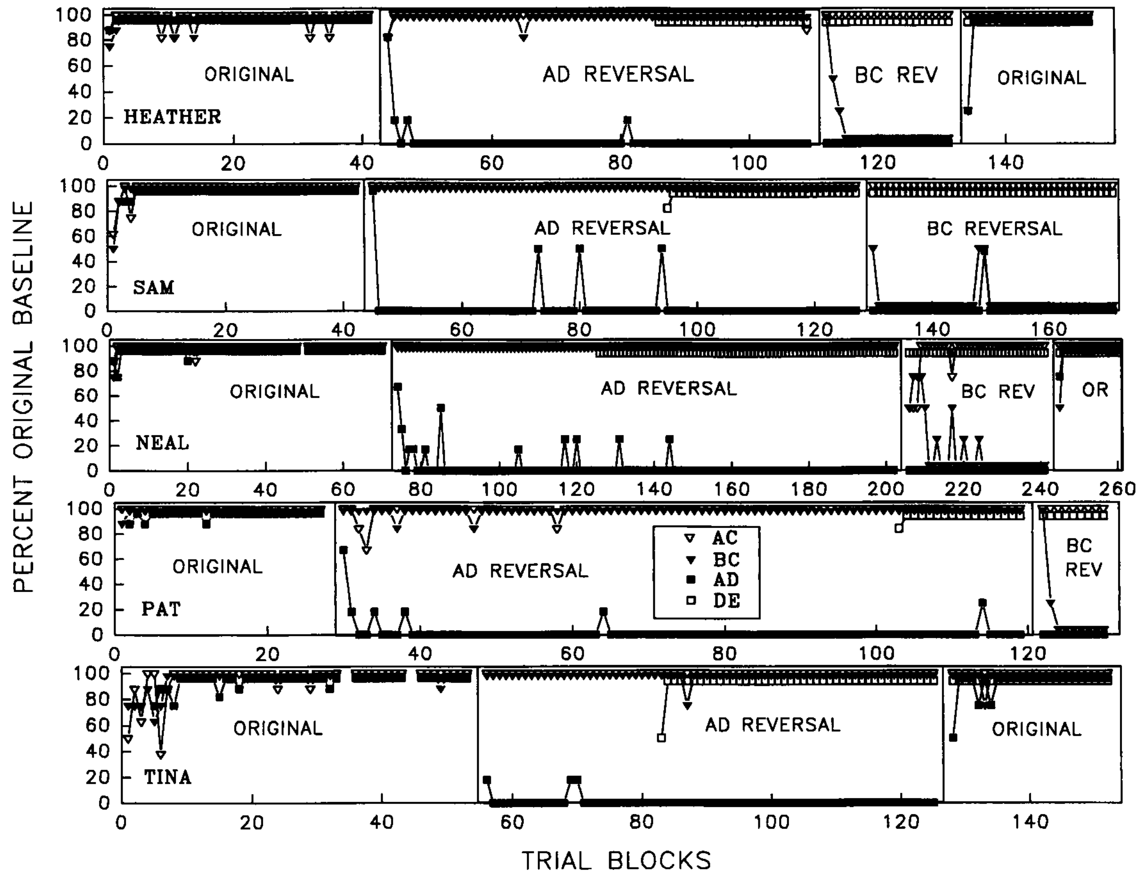

Fig. 1. Performances on the AC (open triangles), BC (filled triangles), AD (filled squares), and DE (open squares) baseline conditional discrimination trials of every trial block. Consecutive trial blocks are represented on the horizontal axis. Prior to DE training, each data point represents a percentage of six trials; AC, BC, and AD data points represent a percentage of four trials beginning with the DE training phase. The vertical axis represents the percentage of trials of each type on which responses were consistent with the original training contingencies.

on symmetry probes across experimental conditions. Plotted on the vertical axis is the percentage of probes within each symmetry trial block on which responses were consistent with the equivalence classes that would follow from the original conditional discriminations (i.e., A1B1C1D1, A2B2C2D2). Each data point represents a percentage of the two trials on which each symmetry probe type was presented within each block. Class-appropriate symmetry patterns were shown under original baseline conditions for all symmetry trial types by all subjects. When the AD reversal conditions were introduced, pattern changes occurred only on DA symmetry probes. The performances of 4 subjects (Heather, Neal, Sam, and Tina) stabilized with consistently reversed responding (i.e., they chose A2 given D1 and A1 given D2). Pat's original pattern of DA symmetry responding was also significantly altered by the AD reversal, although complete reversal was less consistently shown than for the other subjects.

The introduction of DE training permitted a new symmetry trial type, ED, to be assessed. Class-appropriate symmetry responding (i.e., D1 given E1 and D2 given E2) was immediately apparent for all subjects. Other symmetry performances, including those on DA probes, were unaffected by the introduction of DE trials.

The BC reversal had an immediate impact on CB symmetry performances for each of the 4 subjects studied. All 4 subjects showed completely reversed patterns on CB probes, in keeping with the baseline change, al-

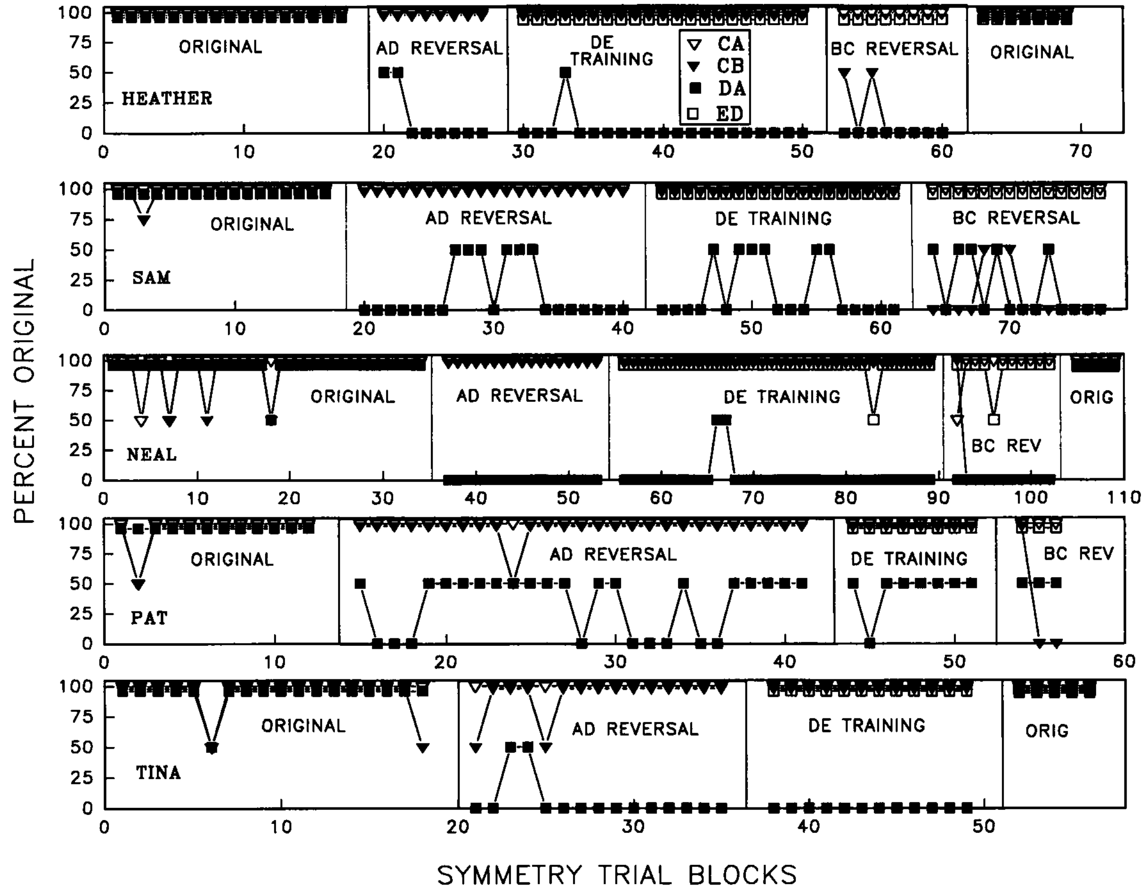

Fig. 2. Performances on CA (open triangles), CB (filled triangles), DA (filled squares), and ED (open squares) symmetry probe trials. Consecutive symmetry trial blocks are represented on the horizontal axis. The vertical axis represents the percentage of two CA, CB, DA, or ED symmetry trials on which responses were consistent with the equivalence classes established by the original training contingencies.

though Pat left the experiment during this phase before stability criteria were reached. Finally, when the original baseline conditional discriminations were reinstated for the 3 remaining subjects, symmetry responding returned immediately and completely to the patterns seen in the initial phase of the study. In summary, symmetry performances were highly sensitive to manipulation of the baseline conditional discriminations from which they emerged.

Figures 3 and 4 show performances on transitivity/ equivalence probe trials. Figure 3 shows AB and BA, BD and DB, and CD and DC probe-trial responding. The percentage of four trials on which responses were consistent with the originally established equivalence classes (i.e., A1B1C1D1, A2B2C2D2) is plotted for each probe type in each trial block. As Figure 3 shows, transitivity/equivalence patterns emerged gradually for all 5 subjects during the original training conditions. Near-perfect class-consistent performances on AB/BA and BD/DB probe types were demonstrated by the end of the condition for 3 of the 5 subjects (Heather, Sam, and Pat), but Tina and Neal continued to show occasional inconsistencies, despite the restricted testing noted earlier in the Method section (data from remedial trials are not plotted in Figure 3).

In general, there was little disruption in transitivity/equivalence patterns when the AD reversal phase began. Heather and Pat continued with the same patterns shown under original baseline conditions. Interesting-

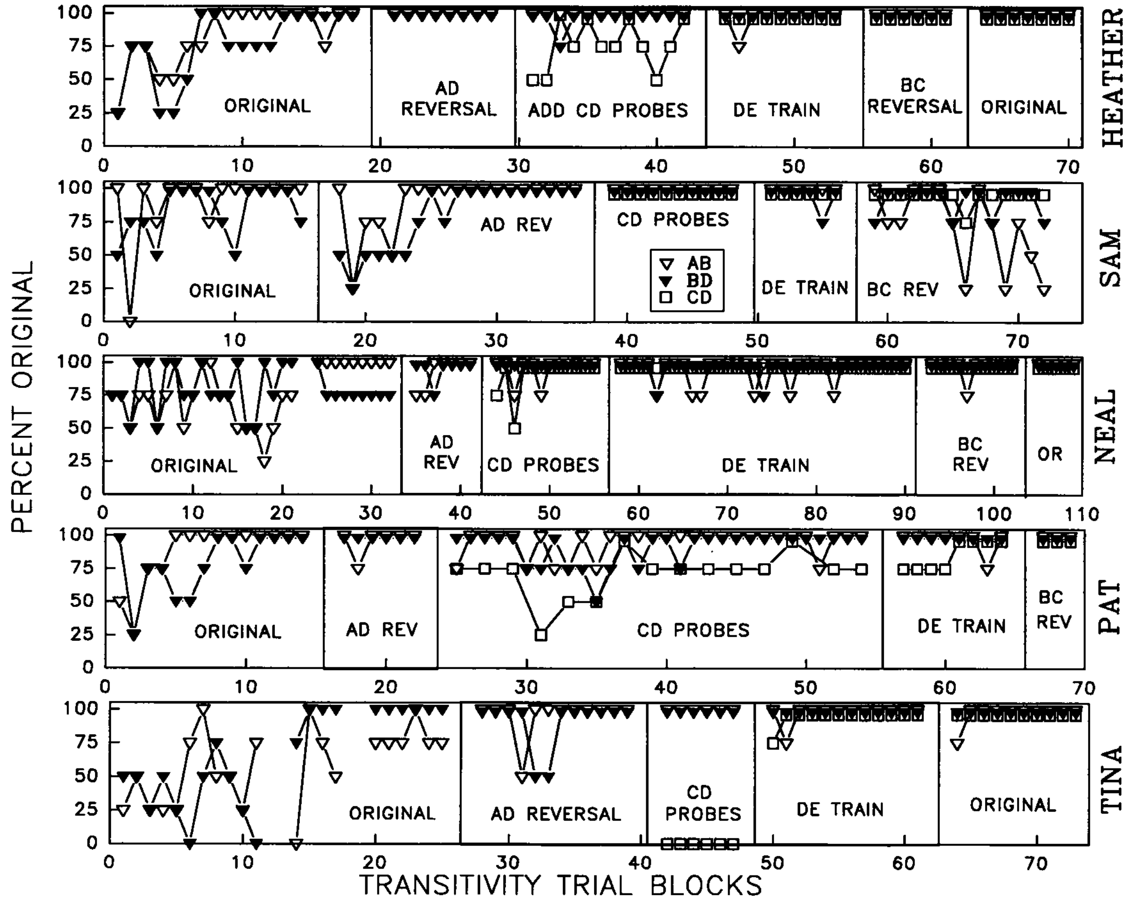

Fig. 3. Performances on AB/BA (open triangles), BD/DB (closed triangles), and CD/DC (open squares) transitivity/equivalence probe trials. Consecutive transitivity trial blocks are represented on the horizontal axis. The vertical axis represents the percentage of four AB/BA, BD/DB, and CD/DC transitivity/equivalence trials on which responses were consistent with the equivalence classes established by the original training contingencies.

ly, the performances of Neal and Tina became more consistent with the original classes than in Phase 1. Sam showed some initial disruption on both BD/DB and AB/BA trial types, but gradually returned to responding that was predominantly consistent with original patterns. It may be noted that although AB/BA and BD/DB patterns were equally disrupted, only BD/DB patterns would be expected to change if new equivalence classes had emerged in keeping with the baseline relations of the AD reversal condition (i.e., A1B1C1D2 and A2B2C2D1). Thus, the disruption that did occur was not consistent with equivalence-class reorganization.

Midway through the AD reversal, CD/DC probes were introduced for the first time. For Sam and Neal, responses on the CD/DC probes were consistent with the original equivalence patterns shown on the other transitivity/equivalence probes (e.g., D1 was chosen given C1, and D2 was chosen given C2). For Heather and Pat, a majority of the responses on CD/DC probes were consistent with the original classes, but more variability was exhibited. Tina, however, showed a very different pattern; her responses on CD/DC probes (i.e., D2 was chosen given C1, and D1 was chosen given C2) were consistent with the equivalence-class composition that would follow from the baseline relations of the AD reversal condition (i.e., A1B1C1D2 and A2B2C2D1). For all subjects, responding on

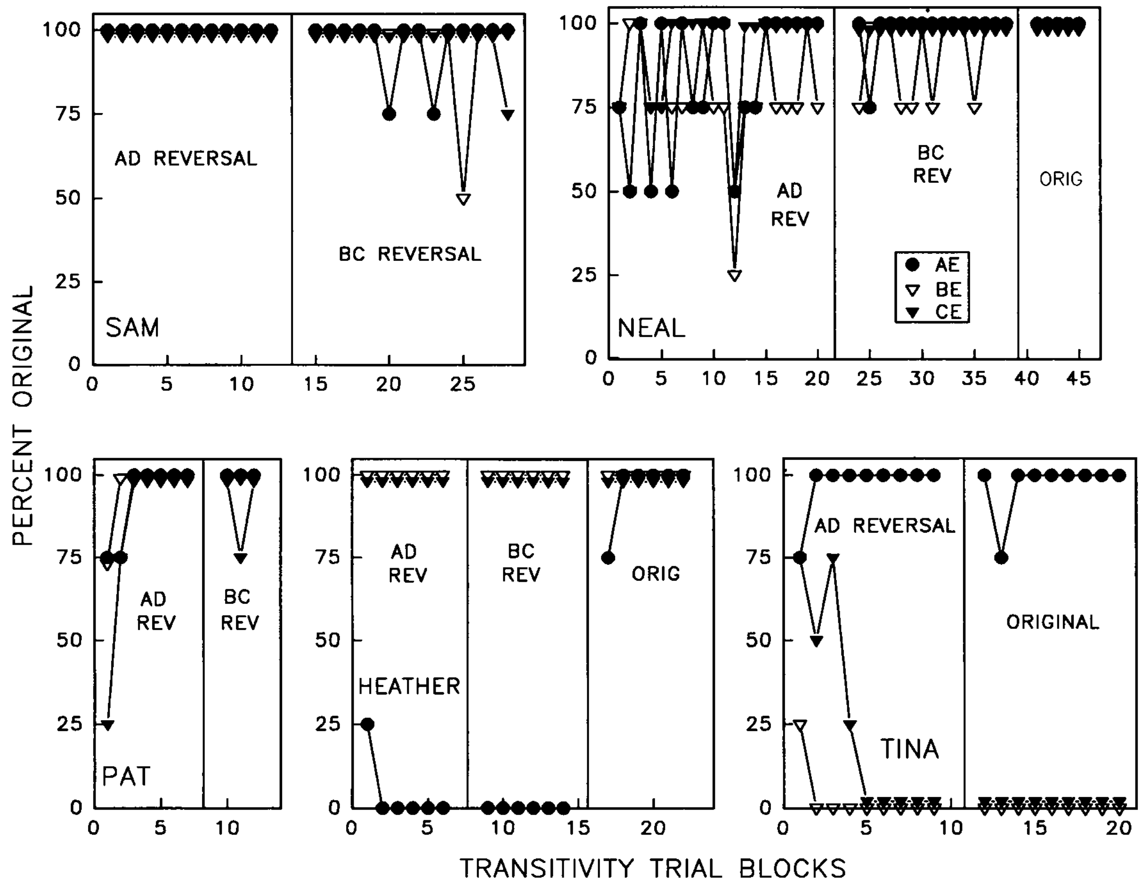

Fig. 4. Performances on AE/EA (filled circles), BE/EB (open triangles), and CE/EC (filled triangles) transitivity/equivalence probe trials. Consecutive transitivity trial blocks are represented on the horizontal axis. The vertical axis represents the percentage of four AE/EA, BE/EB, or CE/EC transitivity/equivalence trials on which responses were consistent with the addition of E stimuli to the original equivalence classes.

the other transitivity/equivalence probe types (AB/BA and BD/DB) was unchanged. This was particularly noteworthy in the case of Tina, because it meant that probe patterns shown within the same trial block were inconsistent with each other; responses on AB/BA and BD/DB probes were consistent with the original equivalence classes, whereas CD/DC patterns were not. Another interesting feature of Tina's performance occurred when DE training began. Surprisingly, after learning the new conditional discrimination, Tina's responses on CD/DC probes became completely consistent with both the original classes and with her responses to the other transitivity/equivalence probes. Interestingly, the introduction of DE training also tended to reduce the variability in CD/DC responding for Heather and Pat, whereas Sam and Neal continued their "original" patterns.

The BC reversal phase had no systematic effect on responding to AB/BA, BD/DB, or CD/DC probes for any of the 4 subjects tested. The performances of Heather, Neal, and Pat were completely consistent with the originally established equivalence classes, even with two baseline conditional discriminations reversed simultaneously. Sam occasionally made responses that were not "original," but her CD/DC patterns, which would also be expected to change if new classes had emerged (i.e., A1B2C1D2 and A2B1C2D1), remained completely consistent with the originally established classes.

Finally, when the original baseline discriminations were reinstated for Heather, Neal, and Tina, transitivity/equivalence performances were not altered in any way. To summarize Figure 3, original transitivity/equivalence patterns were predominant even when AD baseline performances were set in opposition, and even with the delayed introduction of CD/DC probes. Although 1 subject initially showed a new CD/DC pattern, performances became as in original baseline for all 5 subjects when a new conditional discrimination was trained, and they remained this way (except on one probe type for 1 subject) despite the reversal of a second baseline relation. Because original patterns were still predominant, a return to original conditions had no discernible impact.

Figure 4 shows performances on AE/EA, BE/EB, and CE/EC probes by trial block. Each data point in Figure 4 represents the percentage of four trials on which responses were consistent with the addition of E stimuli to the original equivalence classes (A1B1C1D1E1, A2B2C2D2E2). For Sam and Pat, responses on E probes were predominantly consistent with the original classes during both the AD and BC reversal phases. Neal's results were similar, in that the majority of his responses were original for all three probe types, although his pattern was more variable. It may be noted that when variability was present for Neal and Sam, it was frequently inconsistent with the composition of equivalence classes that would be predicted from the baseline (i.e., A1B1C1D2E2 and A2B2C2D1E1 for AD reversal; A1B2C1D2E2 and A2B1C2D1E1 for AD plus BC reversal), and Neal's performance had stabilized with more than 90% of his responses consistent with original classes by the end of the BC reversal phase.

The other 2 subjects, however, reacted somewhat differently. During the reversal phases, Heather consistently made original responses on BE/EB and CE/EC probes but not on AE/EA probes, and completely original patterns were shown when those baseline discriminations were reinstated. Tina consistently responded on AE/EA probes with the original pattern but not on BE/EB or CE/EC probes, and this pattern was not affected by the return to baseline conditions. It may be interesting that Tina, who showed the most "new" responding on E probes, had also shown new patterns on CD/DC equivalence probes when they were introduced, perhaps indicating a greater impact of the AD reversal manipulation. However, not all E relations were new, which would have been expected given reorganized classes. Although Tina's performances on probes introduced postreversal seemed to be more sensitive to the baseline contingencies in effect than those of the other subjects, the lack of impact by the return to original baseline conditions reflects the same sort of dissociation between probe and baseline relations shown by the other subjects.

DISCUSSION

Following training with the original conditional discriminations in the present study, two four-member equivalence classes emerged, as defined by performances on symmetry and transitivity/equivalence probes. The trained conditional discriminations were immediately sensitive to changes in reinforcement contingencies. Responding on symmetry probe trials also appeared to be sensitive to changes in prerequisite baseline relations. In contrast, performances on the probes for transitivity/equivalence relations among original class members (i.e., AB/BA, BD/DB, and CD/DC probes) were much less sensitive to changes in the baseline conditional discriminations from which they had originally emerged, and provided little evidence of new equivalence relations as a function of new baseline conditional discriminations.

This set of findings closely parallels those of our earlier study (Pilgrim & Galizio, 1990) and permits several conclusions. First, it is clear that the stability of transitivity patterns reported previously was not due to exposure to a random reinforcement condition, as suggested by Spradlin et al. (1992). Subjects in the present experiment showed the same stability when a contingency reversal immediately followed the original baseline condition. Second, the stability of transitivity patterns and the dissociation between symmetry and transitivity were not a result of the particular training arrangement used or the size of the classes that were established. Where our 1990 study generated two three-member classes with a single-sample multiple-comparison training arrangement (i.e., AB and AC baseline relations; Saunders, Wachter, & Spradlin, 1988), the present study began with four-member classes generated by a single-sample multiple-comparison (i.e., AC and AD baseline relations) and multiple-sample single-comparison (i.e., AC and BC relations) training combination. Third, the effects of baseline contingency manipulations described previously were not limited to one baseline-relation reversal. Even with the majority of original baseline relations (i.e., four of the six originally established) reversed simultaneously, transitivity patterns remained generally unchanged, whereas symmetry patterns mirrored baseline performances. Network models of equivalence, such as that proposed by Spradlin et al. (1992), predict an increased probability of class reorganization as the number of baseline reversals increase. In the present case, however, if DE training established new stimulus relations in keeping with the original classes, the BC reversal would have marked a change in 50% of the class prerequisites, short of the majority that may be necessary to result in class modification according to Spradlin et al. (1992).

The present data also indicate that practice on particular transitivity/equivalence probes prior to reversal is not necessary in order to obtain original class-consistent patterns on those probes following reversal. In general, delayed probe introduction resulted in performances that were either completely consistent with the well-practiced probe patterns or became consistent with continued testing, as had original transitivity/equivalence patterns (see also Sidman, 1992). Although short-lived, Tina's CD/DC exception may be of some importance because this was the first instance from our laboratory in which a transitive or equivalence relation was completely in keeping with a modified baseline and the first time that inconsistencies across different transitivity/equivalence relations were obtained. Further exploration of the relation between probe practice and the timing of baseline reversals would provide interesting follow-up to the present study. CD/DC probes were not presented prior to the reversal, but other relations from the equivalence classes had been tested, including the two-node BD/DB tests that should theoretically require CD/DC relations. Delayed introduction of probes for relations unrelated to any that must have emerged prior to reversal would be an important comparison.

Certain features of the present data are also relevant to the argument that the reported symmetry-transitivity dissociation was due to Type R stimulus–stimulus relations (see Carrigan & Sidman, 1992). The Type R analysis emphasizes that on a match-to-sample task, subjects may either select a particular comparison when presented with a sample (a Type S or select relation) or they may learn to reject a particular comparison stimulus (a Type R or reject relation). The two types of stimulus control would be indistinguishable on symmetry and even-node transitivity or equivalence probe trials, but they would yield differing patterns on odd-node transitivity or equivalence tests. If Type R relations had been generated by the AD reversal of the present study, for example, transitivity/equivalence patterns would be expected to "toggle" back and forth from original to "reorganized" as a function of the number of nodes, or training stages, necessary to produce the relation (Carrigan & Sidman, 1992; Johnson & Sidman, 1993). However, the data revealed no consistent differences in the patterns on one-node (AB/BA) and two-node (BD/DB) transitivity/equivalence trials, either before or after reversals. Thus, it seems unlikely that stimulus control shifted completely from Type S to Type R at any point in the study. However, as Carrigan and Sidman point out, reversal of baseline conditional discriminations may result in a mixture of Type S and Type R relations. By their reasoning, tests across the two types of stimulus control would be invalid indicators of transitivity/equivalence, and resulting performances would be either unstable or a simple continuation of previously practiced patterns. Interestingly, neither of these predictions hold for the present data. Individual patterns were generally quite stable, and as discussed earlier, previous practice was not necessary in order for probe patterns to be consistent with the original equivalence classes. The patterns shown across subjects were also remarkably consistent for performances that should theoretically be undetermined by factors relevant to equivalence. Although the Type R analysis does not seem to offer a straightforward a priori account, the present results cannot rule out the possibility that a complex mixture of Type R and Type S relations was learned by these subjects (cf. Carrigan & Sidman, 1992; McIlvane et al., 1987). Study of this problem using more than two comparison stimuli would provide a further test of the extent to which Type R relations may have played a role. In contrast to the current strategy of testing predictions of the Type R hypothesis, employing three or more comparison stimuli should help to decrease the probability of such relations by virtue of the greater number of rejection, relative to selection, relations that would be required (see Sidman, 1987).

The present replication of baseline and symmetry pattern dissociation from transitivity/equivalence performances remains puzzling in light of current equivalence theory (see Pilgrim & Galizio, 1990, for further discussion). Even given that the training histories of these subjects make both original and reorganized equivalence classes possible, the consistency of original transitivity relations and new symmetry patterns across experiments, across subjects, and across the various probe types of each relation does not seem to fit the "up-for-grabs" hypothesis suggested by Spradlin et al. (1992) or the unpredictable nature of invalid probe arrangements suggested by Carrigan and Sidman (1992). And although it may be conceptually possible for contextual control over original versus reorganized relations to emerge even in the absence of explicit training, such an "explanation" seems a bit empty in the absence of specifying what such contextual stimuli might consist of, particularly given the level of complexity that would be necessary to account for the patterns of control shown here (see Pilgrim & Galizio, 1990). Indeed, given the present methods, the only combination of stimulus elements that might account for original versus reorganized patterns would necessarily include and perhaps even be isomorphic with probe-trial composition. In such a case, speaking of contextual control seems to offer very little beyond restatement of the fact that transitivity/equivalence patterns remained in their original state while symmetry performances varied with the baseline discriminations. Similarly, a nodal-distance account of these data, in which the relations most directly tied to reversed baselines are most strongly affected, would have somewhat limited explanatory usefulness given that the effect of reversal is limited to symmetry relations. Why relations might emerge over the same nodal distances but not be affected by reversals also needs to be addressed.

The results of transitivity/equivalence probes involving E stimuli represent perhaps the newest findings from the present work. One possibility suggested by the E probe data is that stimulus relations that could only have emerged after baseline-relation reversal may have been somewhat more sensitive to ongoing baseline composition than relations that could have emerged prior to baseline manipulations. Of the 15 sets of emergent E relations (AE/EA, BE/EB, and CE/EC relations for each of 5 subjects), performances on three were consistent with the modified baseline of the AD reversal condition (BE/EB and CE/EC relations for the youngest subject, Tina; AE/EA relations for Heather). Although a second baseline reversal had no further impact on E probe patterns, Heather did show a switch to patterns consistent with original classes when baseline relations were returned to original.

Still, the predominant pattern shown on E probes suggested that E stimuli had become part of the original and unmodified equivalence classes (i.e., A1B1C1D1E1 and A2B2C2D2E2). Even the subjects described above showed patterns consistent with original classes on one (Tina; AE/EA relations) or two (Heather; BE/EB and CE/EC relations) sets of E transitivity/equivalence probes. For the remaining 3 subjects, the occasional responses that were inconsistent with original classes gave little evidence of class reorganization. Given present training and testing procedures, distinguishing probe patterns should follow from original versus reorganized classes and for Type R versus Type S stimulus control in each of the reversal conditions (AD only, and AD plus BC reversals). Nevertheless, with the single exception of Heather's AE/EA responding, E transitivity/equivalence patterns were stable across conditions, and in all but the three exceptions described earlier, patterns were predominantly in keeping with original classes. These results seem to be particularly notable, given that DE relations were trained only after reversed AD relations had stabilized and that E transitivity/equivalence relations emerged in the context of reversed baseline and symmetry responding. In effect, patterns on D transitivity/equivalence probes, which had remained original, were more predictive of E probe performances than were baseline or symmetry patterns.

With respect to all transitivity/equivalence performances, a seemingly powerful history effect is evident, in which stimulus functions appear to be particularly resistant to change once they have been established. In contrast, emergent symmetric relations were quite sensitive to the same environmental manipulations that failed to change transitivity or equivalence responding. It may be possible to argue, perhaps in keeping with some of Sidman's (1992) recent writings, that equivalence was still the fundamental process here and that reversals served to break down or somehow alter the relations. How and why reversals should influence equivalence properties differentially, however, has yet to be explained satisfactorily. Thus, the present findings raise questions about the nature of equivalence as an underlying, fundamental, and integrated process. A methodological implication of the independence of symmetry and transitivity patterns is that caution must be exercised in interpreting any one probe performance (i.e., the equivalence probe) as simultaneously indicative of multiple properties, in lieu of independent tests. At a conceptual level and in contrast with prevailing analyses, this same independence signals caution in interpreting different probe performances in terms of a single integrated unit (i.e., equivalence).

The demonstrated stability of transitive performances even in the presence of reversed baseline and symmetry responding may also be interesting to consider with respect to the flexibility of verbal relations. This behavioral primacy effect may suggest that first "impressions," particularly emergent ones, do indeed "die hard," and unlearning seems once again to be more involved than initial acquisition. If equivalence performances are related to language phenomena, the present findings may represent a possible correlate of instances in which behavior under the discriminative control of verbal stimuli (e.g., rule-governed behavior) appears to be insensitive to contingencies.

The discrepancy between baseline contingencies and transitivity/equivalence performances is interesting to consider in relation to other analyses that have shown that equivalence patterns can be notably lacking even after explicit conditional discrimination training (e.g., D'Amato, Salmon, Loukas, & Tomie, 1985; Devany, Hayes, & Nelson, 1986; Hayes, 1991; Sidman et al., 1982), as well as work that has shown strong evidence of equivalence patterns in the absence of explicit conditional discrimination training (e.g., Harrison & Green, 1990; Sigurdardottir, Green, & Saunders, 1990). Collectively, these sorts of findings suggest that equivalence is not a simple by-product of the four-term discriminated operant. This seems to be clear with respect to the maintenance of equivalence patterns in the present study, and implications for initial emergence may also be considered. Irreversible behavioral phenomena certainly exist, but experimental reasoning often dictates a continued search for sources of control when the manipulation of an assumed controlling variable has only limited effects on the behavior in question.

As a final note, it is important to recognize the possibility that the present results may be limited to normal adult subjects, related perhaps to the demand characteristics associated with psychology experiments for this population. Indeed, the baseline training sequence of this study was identical to that used by Spradlin et al. (1973), who found that reversal of all prerequisite relations *did* alter transitive patterns in retarded individuals. Worth noting from the present study is that the subject who showed the greatest changes in transitivity patterns following baseline reversals was also the only non-college student (14-year-old Tina). In a follow-up paper, we present data on the effects of reversing baseline relations with normal children.

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Received November 23, 1993
Final acceptance January 12, 1995