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**EFFECTS OF UNREINFORCED CONDITIONAL SELECTION TRAINING,  
MULTIPLE NEGATIVE COMPARISON TRAINING, AND REINFORCEMENT ON  
EQUIVALENCE CLASS FORMATION**

by

**BARBARA J. ADAMS**

A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

1996

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## Abstract

EFFECTS OF UNREINFORCED CONDITIONAL SELECTION TRAINING,  
MULTIPLE NEGATIVE COMPARISON TRAINING, AND REINFORCEMENT ON  
EQUIVALENCE CLASS FORMATION

by

Barbara J. Adams

Adviser: Professor Lanny Fields

Eighty-eight college students learned a series of unlinked conditional discriminations designed to induce a repertoire of unreinforced conditional selection of comparison stimuli. The 80 subjects who completed this pretraining then learned the new conditional relations AB, BC, and CD in each of two stimulus sets. The A, B, and C stimuli were novel nonsense syllables. The D stimulus was a "short" line in one class and a "long" line in the other class. Half the subjects received response contingent feedback during baseline training trials; within this group, subjects were exposed to either 1, 2, 4, or 8 negative comparisons while the baseline relations were being presented. The other half did not receive response contingent feedback; within this group subjects were exposed to either 1, 2, 4, or 8 negative comparisons during the training of the baseline relations. On any given training trial, however, only two comparisons were presented. For subjects who received feedback during training, an increase in the number of negative comparisons used in training led to an increase in the number of subjects who formed classes. When feedback was used during training, the percentage of subjects who formed classes increased from 80 to 100% as the number of negative comparisons increased from 1 to 8. When feedback was not used during training, the percentage of subjects who formed classes decreased from 60 to 40% as the number of negative comparisons increased from 1 to 8. Thus, feedback influenced the likelihood of class formation and interacted with the number of negative comparisons used in training.

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## Effects of Unreinforced Conditional Selection Training, Multiple Negative Comparison Training, and Reinforcement on Equivalence Class Formation

An equivalence class is a group of stimuli that become related to each other as a result of training (Sidman, 1971). These stimuli need not share any common physical features. For example, the stimuli DOG, PERRO, CHIEN, and "A PICTURE OF A TERRIER" can be established as a 4-member equivalence class. There are 16 stimulus-stimulus pairs in a set of four stimuli, three of which must be directly trained (e.g., DOG-PERRO, PERRO-CHIEN, CHIEN-"PICTURE OF A TERRIER"). Once trained, these pairs are called baseline relations. After training, the 13 untrained stimulus-stimulus pairs are presented as tests to assess class formation. Taken as a whole, these untrained stimulus pairs are called emergent relations tests. Individual emergent relations tests assess reflexivity (e.g., "PICTURE OF A TERRIER"- "PICTURE OF A TERRIER"), symmetry (e.g., "PICTURE OF A TERRIER"-CHIEN), transitivity (e.g., PERRO-"PICTURE OF A TERRIER") and equivalence or the combined properties of symmetry and transitivity (e.g., "PICTURE OF A TERRIER"-DOG). Only after the emergent relations tests occasion class consistent responding are the stimuli said to function as an equivalence class (Fields & Verhave, 1987; Fields, Verhave, & Fath, 1984; Sidman, 1971, 1990; Sidman & Tailby, 1982).

In almost all studies of equivalence class formation, response contingent feedback has been used to establish the baseline conditional relations (e. g. Adams, Fields, & Verhave, 1993; Bush, Sidman, & de Rose, 1989; Devaney, Hayes, & Nelson, 1986; Dixon & Spradlin, 1976; Lazar, Davis-Lang, & Sanchez, 1984; Sidman, Kirk, & Willson-Morris, 1985; Saunders, Wachter, & Spradlin, 1988; Wulfert & Hayes, 1988). Two procedures, however, have resulted in the formation of equivalence classes in the absence of response contingent feedback: unreinforced conditional selection of comparison stimuli (Saunders, Saunders, Kirby, & Spradlin, 1988; Williams, Saunders,

Saunders, & Spradlin, 1995) and multiple negative comparisons (Harrison & Green, 1990).

Unreinforced Conditional Selection of Comparison Stimuli. Saunders et al. (1988), drawing upon their previous work (Saunders, Wachter, & Spradlin, 1988; Wetherby, Karlan, & Spradlin, 1983) noted that subjects who had a history of learning many different two-choice conditional discriminations with response contingent feedback came to respond consistently and conditionally to novel two-choice conditional discriminations based on the feedback provided for the selection made on the first trial alone.

For example, given P as a sample with Q and R as comparisons, the subject has a 50% chance of selecting Q, the positive comparison, on the first trial. If the subject does so, her selection will be followed by "Right" or "Correct." On the first trial in which S appears as a sample, the subject will select the other comparison R. She will continue throughout this block of trials to select Q given the sample P and R given the sample S. Throughout the block of trials, then, the subject will respond conditionally and consistently. Alternatively, the subject may select R on the first trial in which P appears as a sample. Selection of P will be followed by "Wrong" or "Incorrect." On the first trial where S appears as a sample, the subject will select R. When P again appears as a sample, the subject will now select Q. The subject will continue to respond in this manner throughout the block of trials. Either of these performances is called the "conditional selection of comparison stimuli" (Saunders, Saunders, Kirby, & Spradlin, 1988).

Once a subject demonstrates conditional selection of comparison stimuli, a new set of stimuli will occasion the consistent and conditional selection of comparison stimuli from the first trial. This will occur even though all trials are presented without feedback. For example, given the set of novel stimuli W, X, Y, and Z, where W and Z are samples

and X and Y comparisons, if the subject selects X given W and Y given Z on the first presentation of each trial, she will continue to make these selections as long as these trials are presented. Alternatively, if the subject selects Y given W and X given Z on the first presentation of each trial, she will continue to respond in this manner as long as these trials are presented. Recall that the experimenter has not selected a positive and negative comparison beforehand. Either of these performances is called the "unreinforced conditional selection of comparison stimuli" (Saunders, Saunders, Kirby, & Spradlin, 1988).

Saunders, Saunders, Kirby, and Spradlin (1988) showed that after subjects made unreinforced conditional selections, these relations could be used to merge previously established equivalence classes. For three developmentally delayed subjects in Experiment 2, two conditional relations formed through the unreinforced conditional selection of comparison stimuli led to the successful merger of four preexisting 4-member classes into two 8-member class. These new 8-member classes, however, were subject determined. That is, the stimuli that were assigned to a given 8-member class was dictated by a subject's selections in the baseline relation that was established without feedback.

In Experiment 3, two of the subjects (LM and SD) who participated in Experiment 2 also showed the emergence of equivalence classes where the baseline conditional relations were entirely subject determined through the unreinforced conditional selection of comparison stimuli. That is, the baseline relations were established without response-contingent feedback. These results demonstrated that equivalence classes could be formed without feedback in subjects with a repertoire of unreinforced conditional selection of comparison stimuli. Membership in these classes was entirely subject determined; the experimenter did not select positive and negative comparisons for each baseline trial prior to training.

The unreinforced conditional selection of comparison stimuli has also been observed with a three-choice matching-to-sample procedure (Williams et al., 1995). Three conditional relations formed through the unreinforced conditional selection of comparison stimuli led to the successful merger of six preexisting 3-member equivalence classes into three 6-member classes for three of five normally developing children. Again, these new 6-member classes were subject determined.

Multiple Negative Comparisons. Harrison and Green (1990) demonstrated that it was possible to establish experimenter-specified conditional relations without the presentation of response contingent feedback by using multiple negative comparisons. For each baseline relation, while a constant sample and positive comparison appeared together across trials, a variety of negative comparisons were presented across trials. For example, when A1 was the sample, B1 was the invariant positive comparison. On one third of the trials, B2 was the negative comparison, on one third of the trials, C2 was the negative comparison and on one third of the trials D2 was the negative comparison.

Three of the four subjects came to select the invariant comparison on the baseline relations that were the prerequisites for two 4-member equivalence classes. One of the three subjects (Subject CF), however, failed to learn AB baseline relation without feedback. For Subject CF, AB was learned only after response contingent feedback was introduced. Thereafter, Subject CF learned the AC and AD baseline relations without feedback.

Only one of the three subjects (FO) who learned the baselines also passed the BC, BD, and CD equivalence tests. These tests were responded to accurately upon their first presentation. The test trials, however, contained only one negative comparison; therefore, no inadvertent multiple negative comparison training could occur. Thus, Harrison and Green (1990) concluded that it was possible for experimenter-specified classes to form in the absence of response contingent trial-by-trial feedback when

multiple negative comparisons were used for the training of the baseline relations. Their training procedure, however, raises a question as to whether Subject FO's emergent relations test performances can be taken as evidence that equivalence classes formed.

In the Harrison and Green (1990) study, subjects first learned A1-B1 with B2, C2, and D2 as negative comparisons and A2-B2 with B1, C1, and D1 as negative comparisons. That is, all of the negative comparisons used in AB training were stimuli drawn from the opposing set. The same stimuli that were used as negative comparisons in AB training also served as negative comparisons in AC and AD training. During AB training, then, it was possible that subjects learned to not pick B2, C2, or D2 given A1 and to not pick B1, C1, and D1 given A2. Thus, subjects could have responded consistently and conditionally by rejecting each of the negative comparisons. Since the same negative comparisons were subsequently used during AC and AD training, the subjects could have also consistently selected the positive comparisons (C1 given A1 as a sample, etc.) by continuing to reject the negative comparisons that they had learned to reject during AB training (Carrigan & Sidman, 1992).

The three subjects who learned the baseline relations required between 5 and 41 blocks to learn the AB baseline relation. Subsequently, the AC and AD baseline relations were learned almost instantaneously. The rapid learning of AC and AD supports the notion that subjects were rejecting the negative comparisons during AC and AD training.

To form a 4-member equivalence class only three select stimulus-stimulus relations should be trained as prerequisites (Fields & Verhave, 1987). In the Harrison and Green (1990) study, however, it is plausible that subjects learned as many as six reject relations and one select relation for each of the three baseline conditional relations. As such, far more than the minimum number of stimulus-stimulus relations that should be trained as prerequisites to an equivalence class could have been established. The

potential training of more than the minimum number of stimulus-stimulus relations suggests that Subject FO's class-consistent responding on the emergent relations probes may not have demonstrated equivalence. At best, these data present a minimal demonstration of conditional discrimination learning as a result of multiple negative comparison training and the subsequent emergence of equivalence classes.

Summary. Equivalence classes can be both formed and expanded without response contingent feedback for selections made on the baseline trials. Subjects with a history of solving many conditional relations can form equivalence classes without response contingent feedback being provided for baseline trials. Their choices on the baseline trials are unreinforced conditional selections of comparison stimuli. Class membership follows from the unreinforced conditional selections made in the baseline trials. Thus, these baseline relations result in the emergence of subject-determined classes.

In subjects without such a history, multiple negative comparisons can be used to establish experimenter specified baseline relations in the absence of feedback. These baseline relations may result in the emergence of experimenter specified equivalence classes.

Since equivalence classes can emerge without response contingent feedback for responses made in the baseline trials, three questions arise. 1.) How is the likelihood of equivalence class formation influenced by the presence or absence of informative feedback for responses made on baseline trials? No study has made such a comparison. 2.) How is the likelihood of equivalence class formation influenced by the number of negative comparisons used in training? Again, no study has addressed this issue. 3.) How should the baseline trials be structured when multiple negative comparisons are used to avoid the potential problems encountered by Harrison and Green (1990)?

To assess the effects of response contingent feedback for selections made on baseline trials, half of the subjects received response contingent feedback during training, the other half did not. To explore the effects of multiple negative comparisons in a systematic manner, the number of negative comparisons used in training varied across groups from 1 to 2 to 4 to 8 under each feedback condition. To avoid the possibility of subjects learning additional reject relations, only one negative comparison was drawn from the opposing set. The remaining negative comparisons in the multiple negative comparison conditions were unique stimuli that did not serve as members of either class; in addition, different stimuli were used as the additional negative comparisons during the training of each baseline relation.

To assess the effects of these variables on equivalence class formation, subjects should begin equivalence class training with the same behavioral repertoire. In addition, equivalence classes should be formed under a single training protocol. To engender a constant behavioral repertoire prior to the start of equivalence class training, all subjects were given experience in the solution of unlinked conditional discriminations until they came to select comparison stimuli conditionally and consistently in the absence of reinforcement. At that point, the simple-to-complex protocol was used to induce 4-member equivalence classes in all subjects. The simple-to-complex protocol was selected because it has been shown to be an effective procedure for reliably establishing equivalence classes (Adams, Fields, & Verhave, 1993).

## Method

### Subjects

Eighty-eight Queens College/CUNY subjects were recruited from introductory psychology classes. They received extra credit for their participation in the experiment. Credit, however, was not dependent on performance. Each subject participated in four

to eight one-hour sessions. The subjects were randomly assigned to one of the eight training conditions.

### Apparatus

An MS-DOS compatible microcomputer and custom software controlled stimulus presentation and data collection. Each subject was seated at a table that held the computer, a monochrome monitor, and the keyboard. Responses were made by pressing specified keys on the keyboard.

All stimuli used during the pretraining phase were nonsense syllables. Six nonsense syllables and two lines were used as class member stimuli. The A, B, and C stimuli were nonsense syllables: A1=LEQ, B1=HUK, C1=POV, A2=MEV, B2=GUQ, C2=ZOJ. The D stimuli were horizontal lines composed of contiguous strings of ASCII character 176. Each character was 3 mm wide and 5 mm high on the computer monitor. In Class 1, the D stimulus was one character long, and was designated D1. In Class 2, the D stimulus was 25 characters long, and was designated D2. The numbers in the parentheses indicated the length of each stimulus. The additional negative comparisons for subjects who were exposed to multiple negative comparisons are listed in Table 1.

### Procedure

Trial structure, contingencies, and responses within a trial. All pretraining, training and testing was conducted using two-choice matching-to-sample trial. Each trial began when "Press ENTER" appeared on the screen. Pressing the ENTER key replaced the message with the sample. Pressing the SPACE BAR in the presence of a sample added two comparisons (one Co+ and one Co-) in an isosceles triangular array with the sample at the vertex and the comparisons at the corners of the base. Subjects pressed the number "1" or "2" key on the top row of the keyboard to choose the comparison on the left or the right, respectively. Either selection replaced all stimuli with a feedback message. On trials in which informative feedback was scheduled, if the Co+ was

selected, "RIGHT" appeared on the screen until the subject pressed the "R" key. If the Co- was selected, "WRONG" appeared on the screen until the subject pressed the "W" key. On trials in which noninformative feedback was scheduled, either selection response produced the letter "E" on the screen. It remained until the subject pressed the "E" key. Pressing the R, W, or E key cleared the screen and initiated the next trial. The "E" key was selected because it is between the "R" and "W" keys on the keyboard. See Fields, Adams, Verhave, & Newman (1990) for further details.

Trial block structure and mastery criterion. Trials were arranged in blocks of eight during pretraining, 32-48 during training, and 32-76 during testing. The trials in a block were randomized without replacement. The trials occurred in a different order each time a given block was presented. The mastery criterion for training and testing was 100% class-consistent responding in a block of trials, except where noted otherwise. The mastery criterion for pretraining is described in detail below.

For subjects who received informative feedback, when a training block was introduced, the selection of a comparison on each trial was followed by informative feedback ("RIGHT" or "WRONG"). The block was repeated until the mastery criterion was reached. As long as performance within a block was maintained at 100% accuracy, the percentage of trials that occasioned informative feedback was reduced in successive blocks from 100%, to 75%, to 25%, and finally to 0%. Choice responses on the remaining trials were followed by non-informative feedback (E). For subjects who did not receive informative feedback, when a training block was introduced, the selection of either comparison on each trial was followed by non-informative feedback (E).

A given test block was repeated until the mastery criterion was met or for six successive presentations. During test blocks, the selection of either comparison was followed by non-informative feedback (E).

Keyboard familiarization. At the start of the experiment the subject was shown the following instructions on the computer monitor:

Thank you for volunteering to be a subject in this experiment.  
PLEASE DO NOT TOUCH ANY OF THE KEYS ON THE  
KEYBOARD YET. In this experiment, you will be presented with many  
trials. Each contains three CUES. These will be common words, or three  
letter nonsense words such as ZEQ or WUV. YOUR TASK IS TO  
DISCOVER WHICH WORDS GO TOGETHER.

Initially, there will also be instructions that tell you how to  
respond to the cues as well as LABELS that will help you to identify the  
cues on the screen. The instructions and labels that tell you which KEYS  
to press will slowly disappear. Your task is to RESPOND CORRECTLY  
to the CUES and INSTRUCTIONS by pressing a key on the computer  
keyboard. The experiment is conducted in phases. If you want to take a  
break at the end of a phase, please call the instructor. When you are  
ready to start, press the key with the word ENTER written on it.

Subjects were then trained to emit the appropriate within-trial keyboard  
responses by the serial deletion of the instructional prompts that appeared on the screen  
(see Fields, Adams, Verhave, & Newman, 1990). The prompts and the sequence in  
which they were deleted are shown in the trial displays illustrated in Figure 1. In this  
phase of the experiment, familiar words were used as samples and comparisons. The  
stimuli used during keyboard familiarization are listed in Table 2.

Independent Variables. Prior to equivalence class formation, all subjects received  
pretraining to establish a repertoire of unreinforced conditional selection of comparison  
stimuli. The subjects who successfully completed pretraining were then assigned to one  
of eight training conditions which studied the effect of feedback and the number of

negative comparisons. Ten subjects were assigned to each group. These conditions are listed in Table 3. Half the subjects received response contingent feedback for selections made on baseline training trials; the other half did not. Within each feedback group, subjects were exposed to either 1, 2, 4, or 8 negative comparisons while each of the baseline relations were presented.

On any given training trial, however, only two comparisons appeared; these were the positive comparison and one of the negative comparisons. With subjects who were exposed to multiple negative comparisons, the negative comparison varied across trials. For example, with the subjects who were exposed to four negative comparisons in training, when A1 (LEQ) was the sample, B1 (HUK) always appeared as a comparison. The negative comparison varied among B2 (GUQ), NUJ, XUG, and JUC. On all test trials, only two comparisons appeared; these were the positive comparison and the negative comparison that was a member of the other class. For example, when testing BA symmetry, the comparisons were always A1 and A2.

Pretraining: The induction of unreinforced conditional selection of comparison stimuli. Pretraining provided all subjects with experience in solving conditional discriminations using nonsense syllables as stimuli. It was conducted to establish the repertoire of unreinforced conditional selection of comparison stimuli. Training and testing was conducted in blocks of eight trials. Two conditional discriminations were introduced per stimulus set; thus, each stimulus set contained four novel stimuli. For example, E and H were presented as samples and G and F appeared as the comparisons in the first stimulus set. The subjects were taught to select comparison stimulus F when E was the sample and comparison stimulus G when H was the sample.

When a stimulus set was introduced, all selections made in a block occasioned informative feedback. Once a subject responded correctly to the last seven out of eight trials in the 100% feedback block, feedback was reduced over successive blocks for that

set according to the program described above. Thus, a given stimulus set appeared in at least four trial blocks. Once a stimulus set was responded to with 100% choice accuracy in the absence of informative feedback, a second set of novel stimuli was introduced. For example, subjects were taught  $I \rightarrow J$  and  $L \rightarrow K$ . Additional stimulus sets were presented until the subject responded correctly to the last seven out of eight trials in the 100% feedback block and performance remained at 100% choice accuracy during the reduction of feedback blocks for two consecutive stimulus sets. This criterion was selected because a subject has a 50% chance of selecting the experimenter specified positive comparison on the first trial presented in a new stimulus set. If all subsequent trials occasion correct responding, performance is suggestive of the development of unreinforced conditional selection of comparison stimuli. If the subject did not reach the training criterion after the presentation of 26 novel stimulus sets, pretraining was terminated and the subject was excluded from the experiment.

Once the training criterion was satisfied, assessment of the unreinforced conditional selection of comparison stimuli repertoire was conducted. The subjects were presented with a group of five probe stimulus sets each consisting of novel stimuli. Each probe stimulus set was presented once in a single block of eight trials. In probe blocks, informative feedback was never provided for responses. If the subject's choices were consistent and conditional for all trials of last four out of the five stimulus sets in a probe group, it demonstrated the development of an unreinforced conditional selection repertoire. Therefore, pretraining was terminated; the subject was randomly assigned to one of the eight training conditions and began 3-member equivalence class training. If responding was not consistent and conditional for the last four out of five stimulus sets in a probe group, it demonstrated that an unreinforced conditional selection repertoire had not yet developed. Therefore, assessment was terminated and the subject was exposed to a second cycle of training and testing.

During the second training and testing cycle, the subject was presented with new stimulus sets. Training procedures and criterion did not differ from those used during the first cycle with one exception. If the subject did not meet the training criterion after the presentation of 16 new stimulus sets, pretraining was terminated and the subject was excused from the experiment. If the subject satisfied the training criterion, a second probe group consisting of five novel stimulus sets was introduced. If the subject's choices were consistent and conditional on all trials for the last four out of five stimulus sets in this probe group, then pretraining was terminated. The subject was randomly assigned to one of the eight training conditions and began 3-member equivalence class training. If responding was not consistent and conditional for the last four out of five stimulus sets in this probe set, assessment was terminated and the subject was exposed to a third cycle of training and testing.

The third training and testing cycle was identical to the second cycle in all respects except that novel stimulus sets were used. A third probe group consisting of five novel stimulus sets was introduced when a subject satisfied the training criterion. If the subject's choices were consistent and conditional on all trials for the last four out of five stimulus sets in this probe group, then pretraining was terminated. The subject was randomly assigned to one of the eight training groups and began 3-member equivalence class training. If responding was not consistent and conditional for the last four out of five stimulus sets in a probe group, pretraining was terminated and the subject was excused from the experiment.

Three Member Equivalence Class Formation. For the 80 subjects who successfully completed pretraining, two 3-member equivalence classes were formed using novel nonsense syllables as stimuli. Training and testing were conducted with the conditional discrimination trials presented in the context of the simple-to-complex protocol (Adams, Fields, & Verhave, 1993; Fields, Reeve, Adams, and Verhave, 1991).

A flowchart illustrating the simple-to-complex protocol is shown in Figure 2. AB training was followed by the BA symmetry test. When criterion was met on BA symmetry tests, BC was trained after which CB symmetry was tested. When CB symmetry was passed, BA and CB symmetry were then reviewed in a single test block. AC transitivity test trials were presented until criterion was reached; this was followed by the presentation of CA equivalence tests. When the CA tests were passed, all emergent relations were presented in a review block or mixed test. Passing the mixed test confirmed the formation of the 3-member classes.

Remedial Protocol. If a subject did not meet criterion on the BA or CB symmetry tests or the AC transitivity test after the presentation of six blocks the session was interrupted and a remedial procedure was implemented for that test type. To illustrate, if the BA symmetry test was not passed, overall choice accuracy was calculated separately for the baseline relations and the symmetry probes in each class. If the baseline relations were not responded to with 100% choice accuracy, the subject was retrained and returned to the symmetry test. If the baseline relations were responded to accurately, a block of BA trials from the class that occasioned greater class-consistent responding was presented repeatedly until the test was passed. Thereafter, the BA trials from the other class were presented alone until performance reached criterion. Finally, the subject was returned to the main protocol by the presentation of the BA symmetry probe block.

Expansion of Class Size to Four Members. After subjects met criterion on the 3-member mixed test block, class size was expanded to four members by training CD (see Figure 2). After CD was learned, tests for DC symmetry, BD and AD transitivity, and DB and DA equivalence were presented in a mixed block to assess 4-member class formation. The 4-member mixed block was repeated until the subject made no more than one error in a single block. Meeting criterion on these emergent relations tests

demonstrated the formation of two 4-member equivalence classes. Symbolic representations of the stimuli used in each stage of training and testing are listed in Table 4.

## Results

### Pretraining

Figure 3 shows the number of subjects who met the assessment criterion for unreinforced conditional selection of comparison stimuli after the first, second, and third probe groups. The open bars indicate the number of subjects who met the assessment criterion in each probe group. The shaded portion of each bar indicates the number of subjects who respond conditionally and consistently on the first probe stimulus set and continued to do so throughout the probe group. The difference between the two bars for a given probe group indicates the number of subjects who did not respond conditionally and consistently on the first probe stimulus set, but did so in the remaining four sets.

Of the 88 subjects who began the first pretraining cycle, one did not meet the training criterion after the presentation of 26 stimulus sets and was excused from the experiment. The remaining 87 subjects, who required the presentation of an average of 4.73 stimulus sets to meet the training criterion, were exposed to the first probe group. In total, 40 subjects met the criterion for the unreinforced conditional selection of comparison stimuli during exposure to the first group of probe stimulus sets. Thirty-two of these subjects responded conditionally and consistently from the first trial of the first probe stimulus set. This performance was maintained for the remaining four stimulus sets. Eight subjects did not respond conditionally and consistently in the first probe stimulus set, but did so in the remaining four sets.

The 47 subjects who did not demonstrate the unreinforced conditional selection of comparison stimuli on the first probe group were retrained with additional stimulus

sets. Four subjects did not meet the retraining criterion after the presentation of 16 stimulus sets and were excused from the experiment. The remaining 43 subjects, who required the presentation of an average of 4.30 stimulus sets to meet the training criterion, were exposed to the second probe group. In total, 27 subjects met the criterion for the unreinforced conditional selection of comparison stimuli during exposure to the second group of probe stimulus sets. Sixteen of these subjects responded conditionally and consistently responded conditionally and consistently from the first trial of the first probe stimulus set. This performance was maintained for the remaining four stimulus sets. Eleven subjects did not respond conditionally and consistently in the first probe stimulus set, but did so in the remaining four sets.

The 16 subjects who did not demonstrate the unreinforced conditional selection of comparison stimuli on the second probe group were retrained with additional stimulus sets. One subject did not meet the retraining criterion after the presentation of 16 stimulus sets and was excused from the experiment group. The remaining 15 subjects, who required the presentation of an average of 5.38 stimulus sets to meet the training criterion, were exposed to the third probe group. In total, 13 subjects met criterion during presentation of the third group of probe stimulus sets. Twelve of these subjects responded conditionally and consistently on responded conditionally and consistently from the first trial of the first stimulus set. This performance was maintained for the remaining four stimulus sets. One subject did not respond conditionally and consistently in the first stimulus set, but did so in the remaining four sets. Two subjects did not meet criterion and were excused from the experiment.

In summary, 80 subjects demonstrated the emergence of unreinforced conditional selection of comparison stimuli. This repertoire emerged only after retraining and repeated testing with a number of stimulus sets for some subjects. Appendix A lists the

number of conditional discriminations and probe groups presented to each subject prior to the development of an unreinforced conditional selection repertoire.

### Equivalence Class Formation

Overall Class Formation. Figure 4 shows the percentage of feedback and no-feedback subjects who formed two 4-member equivalence classes. The data are plotted as a function of the number of negative comparisons used during training of the baseline relations.

Regardless of the number of negative comparisons used in training, 87.5% of the subjects who received feedback during training of the baseline relations learned two 4-member equivalence classes. Only 47.5% of the no-feedback subjects learned two 4-member equivalence classes. Subjects who received feedback during training of the baseline relations were more likely to form classes than those who did not. Thus, providing feedback for responses made on baseline trials significantly increased the likelihood of equivalence class formation,  $\chi^2(1, N = 40) = 14.88, p < .001$ . When one negative comparison was used in conjunction with feedback, 80% of the subjects formed classes; however, when one negative comparison was used without feedback, only 60% of the subjects formed classes.

For subjects who received feedback during training, an increase in the number of negative comparisons used in training led to an increase in the percentage of subjects who formed classes. Class formation yield (percentage of subjects who formed classes) for these subjects was a gradual direct function of the number of negative comparisons used in training. The yields ranged from 80% for the one-negative-comparison group to 100% for eight-negative-comparison groups.

For subjects who did not receive feedback in training, an increase in the number of negative comparisons used in training led to a decrease in the percentage of subjects who formed classes. Class formation yields for these subjects were a mild inverse

function of the number of negative comparisons used in training. Class formation yields for these subjects ranged from 60% for the one-negative-comparison group to 40% for eight-negative-comparison groups.

Thus, these data show an interaction between the number of negative comparisons and the level of feedback used in training. When used in conjunction with feedback, increasing the number of negative comparisons resulted in an increased likelihood of class formation; in the absence of feedback, increasing the number of negative comparisons resulted in a decreased likelihood of class formation. To quantify these differences, chi square values comparing the yield for each multiple negative comparison group, with and without feedback were calculated. The difference in yield between the eight-negative comparison groups was statistically significant,  $\chi^2 (1, N = 10) = 8.57, p < .01$ . The difference in yield between the four-negative comparison groups was also statistically significant,  $\chi^2 (1, N = 10) = 5.49, p < .02$ . The difference in yield between the two-negative comparison groups was not statistically significant,  $\chi^2 (1, N = 10) = 1.99, p > .05$ . In addition, the difference in yield between the one-negative comparison groups was not statistically significant,  $\chi^2 (1, N = 10) = .95, p > .05$ .

Locus of Failures. Failure to form classes did not result solely from failure to meet criterion on the 4-member mixed test block. Due to the serial nature of the simple-to-complex protocol, students who did not meet criterion on a given baseline relation or emergent relations test were not exposed to the subsequent phases of the training protocol. Therefore, failures to form 4-member equivalence classes could have been due to failure to meet criterion on any of the baseline relations or emergent relations test. In addition to the overall effect on yield shown in Figure 4, the presence or absence of feedback and the number of negative comparisons used in training could also have had an effect on the likelihood of learning particular baseline relations and passing individual

emergent relations tests. These possibilities were explored by considering the likelihood of subjects meeting criterion in each phase of the training and testing protocol.

Figure 5 shows the number of subjects who met criterion on each baseline relation and emergent relations test. Each training condition is plotted separately. The shaded bars indicate the number of subjects who were exposed to a given baseline relation. The white bars indicate the number of subjects who were exposed to a given emergent relations test. The interior black bars indicate the number of subjects who met criterion in that phase of the simple-to-complex protocol or class expansion procedure.

For the feedback subjects, failures to form classes were the result of failure to meet criterion on the AC transitivity test during 3-member class formation. This occurred regardless of the number of negative comparisons used in training. As the number of negative comparisons used in training increased, however, subjects were more likely to pass the AC transitivity test, and thereby form classes. For the no-feedback subjects who were exposed to only one negative comparison in training, failure to form classes was also the result of failure to meet criterion on the AC transitivity test. Thus, their performances were similar to those of the feedback subjects.

For the no-feedback subjects who were exposed to more than one negative comparison in training, failures occurred in the baseline training phases, the CB symmetry test, the AC transitivity test, or the 4-member mixed test. With increases in the number of negative comparisons used in training, failures were observed in an increasing number of experimental phases. Table 5 lists the number of subjects in each training condition who failed to meet criterion in each phase of the experimental protocol.

AB Baseline Relations. The AB baseline relations were learned by all subjects who received feedback during training. This occurred regardless of the number of negative comparisons used in training. In addition, the AB baseline relations were

learned by all no-feedback subjects who received only one negative comparison in training. Thus, their performances were similar to those of the feedback subjects.

Of the 30 no-feedback subjects who received more than one negative comparison in training, five did not learn the AB baseline relation. With regard to training condition, one subject in the two-negative-comparison group and two subjects in both the four- and eight-negative-comparison groups failed to learn the AB baseline relation. Thus, the differential effects of the presence or absence of feedback in training on class formation were first observed in the acquisition of the AB baseline relations. Failure to learn the AB baseline relations, however, only occurred when at least two negative comparisons were used in the no-feedback conditions.

BC Baseline Relations. As with the AB baseline relations, the BC baseline relations were learned by all subjects who received feedback during training. This occurred regardless of the number of negative comparisons used in training. In addition, the BC baseline relations were learned by all no-feedback subjects who received only one negative comparison in training. Thus, their performances were similar to those of the feedback subjects.

Among the 25 no-feedback subjects who received more than one negative comparison in training, three did not learn the BC baseline relation. With regard to training condition, one subject in the each of the two-, four- and eight-negative-comparison groups failed to learn the BC baseline relation.

CD Baseline Relations. The CD baseline relations were learned by all subjects in the feedback groups who formed 3-member classes. This occurred regardless of the number of negative comparisons used in training. In addition, the CD baseline relations were learned by all subjects in the one-negative comparison, no-feedback group who formed 3-member classes. Thus, their performances were similar to those of the feedback subjects.

Among the 19 no-feedback subjects who received more than one negative comparison in training and formed 3-member classes, three did not learn the CD baseline relation. With regard to training condition, one subject in each of the two-, four- and eight-negative-comparison groups failed to learn the CD baseline relation.

Baseline Errors. Table 6 lists the responses made during the baseline trials for subjects who did not learn either the AB, BC, or CD baseline relations. For the five no-feedback subjects who failed to learn the AB baseline relation, two specific error patterns were seen. These were 1) the selection of one or more of the additional negative comparisons on virtually all trials in which it appeared and 2) the selection of only the B1 or B2 class-member-comparison on all trials in which it appeared, regardless of the prevailing sample stimulus. All five subjects made the first type of error. Two of these five subjects also made the second type of error.

Both types of errors can be seen in the responses made by Subject 0801. In the presence of the A2 sample stimulus, this subject selected the negative comparison X on all trials in which X appeared. This illustrates the first type of error. In addition, this subject always selected the B2 comparison stimulus when it was paired with the B1 comparison, regardless of the prevailing sample stimulus. This illustrates the second type of error. For all subjects, either type of error made on AB baseline trials indicated idiosyncratic preferences for individual comparison stimuli.

Two of the three no-feedback subjects who failed to learn the BC baseline relation never selected the C2 comparison. For these subjects, the errors demonstrated idiosyncratic preferences for individual comparison stimuli. The errors made by the remaining subject who failed the BC baseline relation were unsystematic and were not included in Table 6.

For the three no-feedback subjects who failed to learn the CD baseline relation, D2 or the additional negative comparison was selected when C1 was the sample;

likewise, D1 or the additional negative comparisons was selected when C2 was the sample. That is, these subjects never selected the class-consistent positive comparison. These errors can be viewed as reversals of the conditional discrimination. Once the conditional discrimination was reversed, however, the subjects never selected the constant comparison.

In summary, for the AB and BC baseline relations, the errors indicated preferences for individual comparison stimuli. For the CD baseline relation, the errors indicated reversal of the conditional discrimination.

BA and CB Symmetry. All subjects who received feedback in training met criterion on the BA and CB symmetry tests as shown in Table 6. This occurred regardless of the number of negative comparisons used in training. All no-feedback subjects met criterion on the BA and CB symmetry tests with the exception of one subject in the four-negative comparison group who failed the CB symmetry test. Thus, neither the presence or absence of feedback, nor the number of negative comparisons used in training influenced performances occasioned by the symmetry tests.

AC Transitivity. In total, eleven subjects did not meet criterion on the AC transitivity test. For these subjects, one of two error patterns were observed: stimulus preference and reversal. No subjects showed an error pattern indicative of position preference. Table 7 indicates the type of error that led to failure to meet criterion on the AC transitivity probes for the subjects in each training condition. Six subjects made preference errors. That is, they chose a single comparison on almost all trials, regardless of the prevailing sample stimulus. Three of these subjects always selected C1; the remaining three subjects always selected C2. These response patterns, which demonstrated idiosyncratic preferences for one of the comparison stimuli, were observed in two subjects who received feedback and more than one negative comparison in

training. These response patterns were also observed in all four subjects in the one-negative-comparison, no-feedback group who failed to meet criterion.

The remaining five of the 11 subjects who did not pass the AC transitivity test made reversal errors. That is, they always selected C2 given A1 as a sample and C1 given A2 as a sample. Thus, their responses were conditional upon the sample stimulus and consistent across trials, but were not in accordance with transitivity as dictated by the experimenter defined classes. This type of error was made by the two subjects in the feedback, one-negative comparison group who failed to meet criterion. It was also observed in one subject who received multiple negative comparisons in combination with feedback during training and two no-feedback subjects who were exposed to more than one negative comparison in training.

CA Equivalence and 3-Member Mixed Test. Regardless of training condition, all subjects met criterion on the CA equivalence test as seen in Table 5. This is not surprising given the order of test introduction in the simple-to-complex protocol. Subjects did not receive the CA test unless they had demonstrated both symmetry and equivalence, the prerequisites to equivalence. All subjects, also passed the 3-member mixed test. Again, this is not surprising as this test served merely as a review of previously mastered relations.

4-Member Mixed Test. After CD training, a 4-member mixed block that contained the new emergent relations probes DC, BD, AD, DB, and DA was the only test used to assess the emergence of two 4-member equivalence classes. All surviving feedback subjects met criterion on the mixed test, thereby demonstrating the formation of two 4-member equivalence classes. Likewise, all surviving no-feedback subjects who received only one negative comparison in training met criterion on this test.

For the no-feedback conditions, three subjects who were exposed to multiple negative comparisons failed to meet criterion on the mixed test. These failures occurred

in the two-and eight-negative-comparison groups. Thus, there was no functional relationship between the number of negative comparisons used in training and the likelihood of subjects failing this test for the surviving subjects.

Table 8 lists the percentage of trials in which the positive comparison was selected for the emergent relations probes in the 4-member mixed test. Only the data for the three subjects who did not meet criterion on this test are shown. As there were no systematic differences across test blocks, the data for the six repetitions were combined. All three subjects made reversal errors on one or more of the emergent relations. Subject 0213 selected the class consistent comparison on the CB, AC, CA, AD, and DA probes in the first test block, but reversed these selections in the remaining five blocks.

Class Expansion. To demonstrate expansion of class size to 4-members, subjects had to learn the CD baseline relation, and meet criterion on the 4-member mixed test. Class expansion occurred for all subjects who received feedback in training, regardless of the number of negative comparisons used. In addition, class expansion occurred for the no-feedback subjects who received only one-negative-comparison in training.

In contrast, for the no-feedback groups where subjects were exposed to multiple negative comparisons, failures to expand class size were observed. The subjects in these groups either failed to learn CD baseline relations or failed to meet criterion on the mixed test of emergent relations. Thus, failures to expand classes were observed only when two or more negative comparisons were used during training in the absence of feedback.

Rate of Acquisition for Baseline Relations and Speed of Passing Emergent Relations Tests. There were marked differences in likelihood of class formation across the eight training conditions. To what extent did the presence or absence of feedback and the number of negative comparisons used in training influence the speed with which the baseline relations were learned and the emergent relations tests were passed?

Table 9 lists the average number of blocks required to learn each baseline relation and pass each emergent relations test for the subjects in each training condition. These averages include only data from the subjects who met criterion in each phase of the experiment. In addition, data for four subjects who required retraining and/or remedial testing before passing AC transitivity and one subject who required remedial testing before passing CB symmetry were not included. (Appendix B lists the number of blocks required by each subject to meet criterion in each phase of the experiment.)

Regardless of training condition, all subjects who learned the baseline relations did so rapidly. In addition, most subjects passed each emergent relations test in one or two blocks. Thus, while both the presence and absence of feedback and the number of negative comparisons used in training influenced the likelihood of learning, they did not influence speed of learning for the subjects who learned.

Prediction of Class Formation from Pretraining Performance. For subjects who received equivalence class training without feedback, 50% who required the presentation of one probe set to demonstrate an unreinforced conditional selection repertoire in pretraining went on to form 4-member equivalence classes. Fifty-eight percent who required the presentation of two probe sets in pretraining went on to form 4-member classes. Seventeen percent who required the presentation of three probe sets in pretraining went on to form 4-member equivalence classes.

For subjects who received equivalence class training with feedback, 83% who required the presentation of one probe set to demonstrate an unreinforced conditional selection repertoire went on to form 4-member equivalence classes. Ninety-three percent who required the presentation of two probe sets went on to form 4-member classes. Eighty-five percent who required the presentation of three probe sets went on to form 4-member equivalence classes.

Thus, for subjects who did not receive feedback in training, the likelihood of forming equivalence classes was an inverse function of the number of pretraining probe sets presented prior to the emergence of an unreinforced conditional selection repertoire. In contrast, for the feedback subjects, the amount of training required to induce an unreinforced conditional selection repertoire was not predictive of class formation.

Summary. Failure to form 4-member equivalence classes for subjects who received feedback resulted from failure of subjects to meet criterion on the AC transitivity test during the establishment of 3-member classes. The same was true for the no-feedback, one-negative comparison subjects.

For the no-feedback subjects who received multiple negative comparisons in training, failures to form 4-member equivalence classes resulted from a variety of sources. The most common source of failure was a failure to learn one of the three baseline relations. The AC transitivity test was the second most common source of failure observed. The third most common source of failure for these subjects was the 4-member mixed test.

The locus of failure, then, was influenced by the presence or absence of feedback. In addition, with the no-feedback subjects, it was influenced by the number of negative comparisons used in training. When only one comparison was used, the location of failures was identical to the feedback-subjects. As the number of negative comparisons used in training increased, the number of specific baseline relations and tests failed increased.

## Discussion

### Pretraining

The presentation of many unlinked conditional relations led to the development of an unreinforced conditional selection repertoire for 80 out of 88 subjects. More than half of the subjects did not demonstrate unreinforced conditional selection of comparison

stimuli on the first probe group. The majority of subjects who were retrained, however, met criterion on the second or third probe group.

These results demonstrate that some parameter of the training criterion was not sufficient to ensure the immediate emergence of the unreinforced conditional selection of comparison stimuli on the first presentation of novel stimulus sets under extinction conditions. This repertoire was induced by retraining with additional stimulus sets. This outcome suggests that training with a larger number of consecutive novel sets that must be responded to conditionally and consistently should increase the percentage of subjects who demonstrate the immediate emergence of unreinforced conditional selection of comparison stimuli

The pretraining procedure used to induce unreinforced conditional selection repertoires involved training with many exemplars. This procedure resulted in the spontaneous occurrence of conditional responding to new stimulus sets. When both relational and perceptual categories are formed, training consists of the presentation of many exemplars. Tests with novel stimuli under extinction conditions are then conducted to assess category formation. In terms of both procedure and outcome, the method used to establish unreinforced conditional selection repertoires is analogous to the multiple exemplar training regimens that have been used to establish both relational and perceptual categories (Hull, 1920; Keller & Schoenfeld, 1950; Wasserman, Kiedinger, & Bhatt, 1988; Wright, Cook, Rivera, Sands, & Delius, 1988). Thus, it is possible that unreinforced conditional selection is a class of behaviors that comes under the control of stimuli that are related to each other on a formal level.

It is impossible to determine whether pretraining established an unreinforced conditional selection repertoire, or simply presented the subjects with an opportunity to demonstrate a repertoire that existed pre-experimentally. This determination could not be made because unreinforced probe trials were not conducted prior to pretraining. It

would be surprising, however, if college students did not already respond conditionally and consistently to stimuli even in the absence of feedback.

If it is assumed that an unreinforced conditional selection repertoire existed, why did many subjects require retraining with many stimulus sets prior to the demonstration of an unreinforced conditional selection repertoire? Correct responding on training stimulus sets may have been the result of one of two forms of stimulus control: control by conditional relations between the sample and the  $Co^+$  or simple discriminative control by three-element compounds, each consisting of the sample, the  $Co^+$ , and the  $Co^-$ . When correct responding in training sets was the result of discriminative control by a conditional relation between the sample and  $Co^+$ , it is likely that this repertoire transferred immediately to the probe stimuli. This would account for subjects who demonstrated the emergence of unreinforced conditional selection on the first probe group.

When correct responding in training sets was the result of control by three-element compounds, it is unlikely that the probe trials would occasion consistent and conditional responding upon their initial presentation. This would account for subjects who did not demonstrate the emergence of unreinforced conditional selection on the first probe group but did so after retraining. Only after the training of many conditional relations was control by unique three-element compounds overridden. For these subjects, responses in the initial training sets were likely to have been under the control of the specific features of the stimuli. The particular features that controlled responding may have varied from set to set. Correct responding occurred, but it did not reflect selection of one comparison conditional upon one sample and selection of the other comparison conditional upon the other sample. With exposure to additional sets, subjects came to select comparison stimuli solely on the basis of conditionality, as this was the only formal property of the stimuli that was correlated with reinforcement for

correct selections across stimulus sets. Subjects, then, no longer made selections based on stimulus compounds in a given trial; instead, selections were based on the conditional relation between the stimuli in a set. This analysis is similar to Sidman's (1994) account of the delayed emergence during equivalence class formation. According to Sidman, a subject may select comparison stimuli for different reasons across trials. Eventually, the subject comes to select the class related comparison on all trials, because stimulus equivalence provides the only basis by which every trial can be responded to correctly. Finally, it is likely that control by unique three-element compounds was never overridden for the subjects who did not demonstrate the emergence of an unreinforced conditional selection repertoire.

#### Equivalence Class Formation

Overall, subjects who received feedback during training were far more likely to form two 4-member equivalence classes. In addition, when feedback was provided for responses on baseline trials, increasing the number of negative comparisons increased the likelihood of class formation; when feedback was not provided for responses on baseline trials, increasing the number of negative comparisons decreased the likelihood of class formation. When examined more closely, failure to form classes resulted from failure to meet criterion on the AC transitivity test for the feedback subjects. Failure to form classes for the no-feedback subjects resulted from failure to learn one of the baseline relations, pass AC transitivity test, or pass the 4-member mixed test. What aspects of the pretraining and training account for the differences observed in both overall yield and the location of the failures?

Baseline Relations. All subjects who received feedback learned the AB and BC conditional relations, regardless of the number of negative comparisons that were used in training. In addition, the CD baseline relations were learned by all subjects in the feedback groups who formed 3-member classes. This is not surprising. It can be

attributed to response-contingent feedback that is provided for selections on the baseline trials. Under such conditions, when only one negative comparison is used in training, virtually all college students learn the baseline relations. Since feedback maximizes learning, the acquisition of the baseline relations is insensitive to the effects of the number of negative comparisons.

All subjects in the one-negative-comparison, no feedback group also learned the AB and BC baseline relations. In addition, the CD baseline relations were learned by all one-negative comparison, no-feedback subjects who formed 3-member classes and went on to CD training. This result can be attributed to the transfer of the unreinforced conditional selection repertoire that emerged during pretraining to the equivalence class baselines. It is also possible, that unreinforced conditional selection would have occurred spontaneously on the baseline trials, even without pretraining. This possibility can be evaluated by examining performances for these subjects during the first pretraining probe group.

During pretraining, only six of the ten no-feedback, one-negative comparison subjects met criterion on the first probe group. Thus, the unreinforced conditional selection of comparison stimuli did not occur spontaneously in pretraining for the remaining four subjects. It is unlikely, then, that these subjects would have responded conditionally and consistently to the baseline conditional relations had they not received pretraining. Rather, their consistent and conditional responding to the baseline trials in equivalence class formation training can be attributed to the transfer of the repertoire established in pretraining.

Eleven of the no-feedback subjects who received multiple negative comparisons in training and who survived to CD training failed to learn one of the baseline relations. For these subjects, likelihood of learning the baseline relations was an inverse function of the number of negative comparisons used in training. What might account for the failure

to select the constant comparison across trials that differed in terms of the negative comparison? Secondly, why was this more likely to occur when an increasing number of negative comparisons were used?

The pattern of errors observed for 10 of the 11 subjects indicated that for each sample/Co+/Co- triad, the subjects responded consistently. That is, one comparison stimulus was selected across presentations of a given triad (see Table 6). Different comparisons, however, were selected across unique triads that contained the same sample and positive comparison. Thus, these subjects responded to each triad as an independent event.

This tendency to respond to triads in isolation may have been a carryover from pretraining. In pretraining, subjects learned a series of unlinked conditional relations. These conditional relations were unlinked; that is, stimuli in one set never appeared in another set. If a subject responded to the triads in baseline training as independent events, selection on each triad might well have been determined by preference for a single stimulus or by some combination of stimuli in the triad. The likelihood of selecting the comparison that is constant, with regard to the sample, across all triads should decrease with increases in the number of negative comparison used across trials. Thus, subjects who were exposed to a greater number of negative comparisons would be less likely to learn the baseline relations. Indeed, this was the case. This analysis, then, provides a plausible account of the failures to learn baseline relations.

AC Transitivity Tests. For subjects who learned both the AB and BC baseline relations, failure to meet criterion on the AC transitivity probes accounted for all but one failure to form 3-member classes. Across all groups, failure of the AC test was most likely among subjects in the one-negative comparison, no-feedback group. Overall, the subjects who received feedback in training were the most likely to pass the AC transitivity test. Regardless of feedback, increasing the number of negative comparisons

used in training resulted in an increase in the proportion of subjects who passed the AC test.

These results raise three questions. 1.) What procedural variables might account for these transitivity failures? 2.) Why were transitivity failures less likely to occur with increases in the number of negative comparisons used in training? 3.) Why were transitivity failures less likely to occur when feedback was used in training?

To answer these questions, the prerequisites to class-consistent responding in the AC transitivity test must first be identified. Two prerequisites must be satisfied for a subject to respond in a class-consistent manner on transitivity probes: 1.) the subject must learn the AB and BC baseline relations and 2.) the commonality of the B stimulus in the baseline relations must influence selections on the AC trials.

The AB and BC relations were learned by all subjects who received the AC transitivity tests. In addition, the AB and BC baseline relations continued to occasion class consistent responding at the start of AC testing for subjects who failed the AC transitivity test. Therefore, the AC transitivity failures cannot be attributed to a breakdown of the baseline relations. By elimination, then, transitivity failures in the present study were due to selections that were not influenced by the commonality of the B stimulus. How, then, did the pretraining and training procedures influence the establishment of the commonality of the B stimulus?

Pretraining Factors Contributing to Transitivity Failures. Pretraining consisted of the presentation of many unlinked conditional relations. Thus, pretraining may have inadvertently trained subjects to disregard the commonality of the B stimulus across the AB and BC baseline conditional relations during equivalence class training. While A and C were nominally linked by B, this link was disregarded. As such, the A1 and A2 sample stimuli did not occasion selection of the C1 or C2 comparison stimuli based on class-

consistency or linkage through B in the AC transitivity tests. Failure to meet criterion on the AC transitivity test, then, may have been a carryover from pretraining.

The effects of pretraining on performances in the transitivity test were seen most frequently among the subjects in the one-negative comparison, no-feedback group. For these subjects, pretraining had induced unreinforced conditional selection repertoires. Their responses to the AB and BC baseline trials were merely an extension of this repertoire. Thus, they were unlikely to attend to the appearance of B in both the AB and BC baseline relations; in turn, B did not serve a linking function. As a result, only 60% of these subjects met criterion on the AC transitivity probes. As a group, these subjects were no more likely than chance to pass the AC transitivity test.

Training Factors. The subjects in the remaining seven groups received feedback, multiple negative comparisons, or both during the training of the baseline conditional relations. The deleterious effects of pretraining were ameliorated by the presence of feedback and/or multiple negative comparisons for the subjects in the remaining seven groups.

The presence of the additional negative comparisons in training specified an experimenter-defined correct choice on the baseline trials. This increased attention to the positive comparison on the AB training trials. Thus, subjects who were exposed to multiple negative comparisons were likely to recognize that a given B stimulus was both the positive comparison in the AB trials and the sample stimulus in BC trials. In turn, the presence of the multiple negative comparisons increased the likelihood that B served a linking function in the AC transitivity probe trials. As a result, the no-feedback subjects who were exposed to two or more negative comparisons in training were more likely to meet criterion on the AC probes than the subjects in the no-feedback, one-negative-comparison group. Thus, exposure to multiple negative comparisons partially overrode

the disregard of the common stimulus across the linked baseline conditional relations (AB and BC).

Response-contingent feedback explicitly specified the experimenter-defined positive comparison during AB training. Thus, subjects who were exposed to feedback were likely to recognize that a given B stimulus was both the positive comparison in the AB trials and the sample stimulus in BC trials. Overall, then, the feedback subjects were the most likely to meet criterion on the AC probes. Thus, exposure to feedback in training also partially overrode the disregard of the common stimulus across the linked baseline conditional relations.

The combination of feedback and eight negative comparisons completely overrode the tendency to disregard common stimuli across different conditional relations. Indeed, the combination of feedback and a large number of additional negative comparisons ensured attention to the B stimulus and its linking function, thereby resulting in an increased likelihood of passing the AC transitivity probes. For all surviving subjects, regardless of feedback, an increase in the number of negative comparisons used in AB and BC training increased the likelihood of meeting criterion on the AC probes.

Class Expansion. All of the feedback-subjects who formed 3-member classes also formed 4-member classes. The same was true for the no-feedback, one-negative comparison subjects. The reliability of class expansion for these subjects suggests that any tendency to disregard relations between stimuli in different conditional relations had been overridden by the equivalence training and testing at the end of 3-member class formation. Alternatively, the failures of the AC transitivity test eliminated all subjects who had a tendency to disregard relations between stimuli in different conditional relations. According to this interpretation, only subjects who attended to relations

between stimuli in different conditional relations formed 3-member classes. Thus, only these subjects went on to CD training and the 4-member mixed test.

For the no-feedback subjects who received multiple negative comparisons in training, class expansion was less reliable. Again, this suggests that multiple negative comparisons, in the absence of feedback, did not completely override a tendency to ignore relations between stimuli across baseline relations.

Conclusions. In summary, 4-member equivalence classes can be established in the absence of response contingent feedback for responses made on the baseline conditional discriminations. This occurs both when classes form from baselines that result from a subject's unreinforced conditional selections and when multiple negative comparisons are used to establish the baseline relations. Classes are more likely to form, however, when feedback is provided for selections made in baseline trials.

When all sources of failure are considered, an increase in the number of negative comparisons used in training led to an increase in the number of subjects who formed classes when feedback was provided for responses on baseline trials. In contrast, an increase in the number of negative comparisons used in training led to a decrease in the number of subjects who formed classes when feedback was not provided for responses on baseline trials.

The presence or absence of feedback and the number of negative comparisons used in training also influenced the location of failures. When feedback was used in training, failure to form classes was a result of failure to meet criterion on the AC transitivity test. Failures of the AC transitivity test were less likely to occur when more than one negative comparison was used in training. This was also the case when one negative comparison was used in the absence of feedback. Thus, in terms of the sources of failure and likelihood of class expansion, the subject-defined classes were indistinguishable from experimenter-specified classes formed with feedback.

For the no-feedback subjects who received more than one negative comparison, increasing the number of negative comparisons increased both the number of different emergent relations that were failed and the number of subjects who failed to meet criterion on them. In addition, many subjects failed to learn the baseline relations. Those who did learn the baseline relations with multiple negative comparisons, however, were more likely to meet criterion on the AC transitivity test than the no-feedback, one negative comparison subjects.

Due to the serial nature of the simple-to-complex protocol, subjects who did not meet criterion on a given baseline conditional relation or emergent relations test were not exposed to subsequent phases of the experiment. Thus, caution should be exercised when comparing performance on a given phase across experimental groups because of the possibility of selection artifacts (Cook & Campbell, 1979). Selection artifacts can arise when different types of subjects are eliminated from particular groups during an experiment. After differential elimination, the experimental groups may then be nonequivalent. Thus, this caveat does not apply to differences in performance seen across all groups during the first phase of the experiment, AB training. In addition, this caveat does not apply to differences in performance seen among the feedback-groups and the one-negative comparison, no-feedback group. All subjects in these five groups learned the AB and BC baseline relations and passed the BA and CB symmetry tests. Thus, there were no subjects eliminated prior to the AC test. Since the AC transitivity test was the only source of failure for the subjects in these five groups, comparisons of subsequent phases across these groups can be viewed as equivalent; that is, they are made between subjects who passed the AC transitivity test.. Furthermore, this caveat does not change the interpretation of the effects of the independent variables on the overall yields.

## General Discussion

Unreinforced Conditional Selection and Subject-Defined Classes. In Experiment 2 of the Saunders, Saunders, Kirby and Spradlin (1988) study and in the Williams et al. (1995) study, four 4-member experimenter-defined classes were merged into two 8-member classes. The conditional relation that linked the pre-existing classes was a subject-determined unreinforced conditional selection. These subjects, however, had received feedback for selections on the linked baseline conditional relations that were used to establish the original 4-member classes. Thus, the stimuli that constituted the unreinforced conditional relation that merged the classes a.) were embedded in linked conditional discriminations, b.) were familiar to the subjects, and c.) were members of previously established equivalence classes. In addition, the subjects had an experimental history of forming equivalence classes. To what extent do these four factors influence the establishment of unreinforced conditional selection repertoires and the emergence of equivalence class from unreinforced conditional selection baseline relations?

In Experiment 3 of their study, Saunders et al. (1988) demonstrated that equivalence classes consisting of novel stimuli could be established from baseline conditional relations that were the result of unreinforced conditional selection. This was shown with two of the subjects who had participated in Experiment 2. Thus, familiarity with the stimuli and their membership in previously established classes were not necessary to ensure that unreinforced conditional selections would occur and give rise to equivalence classes. These results, however, did not determine both the influence of reinforced practice with linked conditional discriminations and prior history of forming equivalence classes.

In the present study, subjects were exposed to a series of unlinked conditional discriminations in pretraining. The stimuli used in pretraining did not serve as members of any equivalence class. Novel stimuli were used as class members. Finally, the

subjects had no previous experimental experience forming equivalence classes. In the no-feedback, one-negative comparison group, all subjects demonstrated unreinforced conditional selection in the baseline trials; 60% of the subjects went on to form two 4-member classes. Thus, these results demonstrated that the establishment of unreinforced conditional selection repertoires and subject-defined equivalence classes did not depend on a.) pretraining with interrelated conditional discriminations, b.) familiarity with the stimuli, c.) their membership in previously established classes, or d.) prior experience learning equivalence classes in a laboratory setting. It is possible, however, that pretraining with interrelated conditional discriminations would result in a greater proportion of subjects forming equivalence classes.

Establishing Conditional Relations and Equivalence Classes via Multiple Negative Comparisons. The potential methodological problems encountered by Harrison and Green (1990) were avoided in the present study. In our multiple-negative-comparison conditions, only one negative comparison was drawn from the opposing set. The remaining negative comparisons were unique stimuli that did not serve as members of either class; in addition, different stimuli were used as the additional negative comparisons during the training of each baseline relation. As such, it was unlikely that our subjects learned additional reject relations. Therefore, the problem of interpretation of the emergent relations probe performances was not encountered. The results of the current study, then, show definitively that in the absence of feedback, multiple negative comparisons can be used to establish experimenter-defined conditional relations that give rise to equivalence classes.

Harrison and Green (1990) demonstrated that experimenter-specified conditional relations could be established in the absence of response-contingent feedback by the use of multiple negative comparisons. Since all of their subjects were exposed to three negative comparisons, this was only a demonstration. In the present study, we varied the

number of negative comparisons across training conditions and found that the likelihood of learning the baseline relations was an inverse function of the number of negative comparisons used in training. This functional relationship was obtained when response contingent feedback was not provided for selections on the baseline trials. These results demonstrate the generality of the multiple negative comparison effect and identify the number of comparisons as one of its controlling parameters.

It is possible that this functional relationship was influenced by pretraining, which predisposed subjects to treat each sample/positive comparison/negative comparison triad as an independent event. This is unlikely, however, given the results reported by Harrison and Green (1990). They found that only half of the subjects learned the baseline relations when multiple negative comparisons were used in the absence of feedback. This occurred even though their subjects were not exposed to pretraining with many unlinked conditional relations. Thus, regardless of pretraining many subjects enter equivalence experiments with the tendency to respond consistently to stimulus triads in isolation. This repertoire must be overridden by other sources of control if subjects are to come to select the constant positive comparison.

It is clear from our results, however, that increasing the number of negative comparisons alone is not sufficient to increase the learning of new conditional relations when multiple negative comparisons are used without feedback. If the use of multiple negative comparisons without feedback is to become widely used as a method of establishing equivalence classes, parameters that increase the efficacy of learning must be identified.

In contrast, when feedback was used in conjunction with multiple negative comparisons, all subjects learned the baseline relations. Increases in the number of comparisons had no effect on the likelihood of learning the baseline conditional relations. This result is not surprising and is most likely a ceiling effect. The likelihood of class

formation, however, increased with increases in the number of negative comparisons used in training. The combination of feedback and many negative comparisons, then, may enhance class formation by ensuring attention to the comparison stimuli and the linking functions they serve.

Equivalence Class Formation After Training With a Single Negative Comparison.

Adams et al. (1993) used the simple-to-complex protocol to establish 3-member equivalence classes. In that study, subjects were not exposed to pretraining with many unlinked conditional relations. In addition, a single, invariant negative comparison was used during training and all selections during training were followed by response contingent feedback. Under these conditions, 100% of the subjects formed 3-member equivalence classes.

Only 80% of the subjects formed classes when feedback and one negative comparison were used in training in the current experiment. These experimental conditions were identical to those used by Adams et al. (1993) with the exception of pretraining. Thus, the addition of pretraining alone resulted in a 20% decrease in class formation. This decrease in yield supports the notion that pretraining with many unlinked conditional relations predisposed some of the subjects to disregard relations between stimuli in trained conditional relations.

Only 60% of the subjects formed classes when one-negative comparison was used without feedback in the current experiment. These experimental conditions were identical to the one-negative comparison, feedback group except that feedback was not provided for responses on baseline trials. The even lower yield obtained when feedback was not used supports the notion that the absence of feedback was responsible for the reduction in yield. It would appear, then, that feedback increased the salience of the positive comparison and helped to override the tendency to disregard relations between stimuli in different trained conditional relations.

Confirmation of Equivalence Class Formation. A post-class-formation test can be viewed as a confirmation that equivalence classes have emerged (Lea, 1984). The expansion of class size from 3- to 4-members is one such test (Buffington, Fields, Adams, & Landon Jimenez, in press). Each D stimulus is linked by direct training to one of the C stimuli. After training, if the D stimuli occasion class consistent performances on all emergent relations tests, there is confirmation that A, B, and C function as a 3-member class. In addition, the 4-member mixed test introduces four new emergent relations in a single block. Thus, it is unlikely that it can be passed by responding to each emergent relation as an independent conditional relation, as many of our subjects may have been predisposed to do. Therefore, if a subject passed the 4-member mixed test on its first presentation, it can be reasonably asserted that 4-member equivalence classes have formed.

All feedback subjects, all subjects in the one-negative-comparison, no-feedback group, and the majority of the no-feedback subjects who received multiple negative comparison training passed the 4-member mixed test rapidly. Thus, it can be said with certainty that these subjects formed 3- and 4-member equivalence classes. Three no-feedback subjects who passed the 3-member mixed test and learned the CD baseline relation did not meet criterion on the 4-member mixed test. Thus, it must be questioned whether 3-member classes had been formed by these subjects. Three additional no-feedback subjects who passed the 3-member mixed test did not learn the CD baseline relation. Therefore, they did not receive the 4-member mixed test. For these three subjects, then, 3-member classes may or may not have actually emerged.

Summary. Conditional relations that have been established without response contingent-feedback can give rise to equivalence classes. When a single-negative comparison is used during training, the baseline relations can form as a result of unreinforced conditional selection of comparison stimuli. The resulting classes are, of

necessity, subject-defined. When multiple negative comparisons are used during training, experimenter-specified baseline relations can be established. The resulting classes are experimenter-specified. These results show that equivalence classes can emerge without response-contingent feedback for selections made on baseline trials.








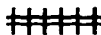
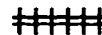





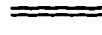











In the absence of response-contingent feedback for selections on baseline trials, the likelihood of class formation is an inverse function of the number of negative comparisons used in training. When feedback is used to establish baseline relations, likelihood of class formation is a direct function of the number of negative comparisons used in training. There is an interaction between feedback and the number of comparisons used in training. Regardless of the number of negative comparisons used in training, classes are more likely to form when feedback is used to establish the baseline relations. These results, then, broaden our understanding of the conditions that lead to the emergence of equivalence classes.

Table 1

Negative comparisons used during training of the AB, BC, and CD baseline relations.

<u>Relation</u>	<u>Symbol</u>	<u>Number of Comparisons</u>			
		<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>
A1-B1	B2	GUQ	GUQ	GUQ	GUQ
	M		NUJ	NUJ	NUJ
	N			XUG	XUG
	O			JUC	JUC
	P				ZUH
	Q				QUN
	R				VUH
	S				MUZ
A2-B2	B1	HUK	HUK	HUK	HUK
	T		QUD	QUD	QUD
	U			SUF	SUF
	V			WUM	WUM
	W				VUJ
	X				FUH
	Y				LUY
	Z				BUX
B1-C1	C2	ZOJ	ZOJ	ZOJ	ZOJ
	M		WOH	WOH	WOH
	N			YOL	YOL
	O			JOD	JOD
	P				SOF

(table continues)

<u>Relation</u>	<u>Symbol</u>	<u>Number of Comparisons</u>			
		<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>
B1-C1	Q				MOG
	R				QOX
	S				TOS
B2-C2	C1	POV	POV	POV	POV
	T		NOP	NOP	NOP
	U			WOR	WOR
	V			LOK	LOK
	W				XOQ
	X				VON
	Y				COL
	Z				ROH
C1-D1	D2				
	M				
	N				
	O				
	P				
	Q				
	R				
	S				
C2-D2	D1				
	T				
	U				
	V				

(table continues)

<u>Relation</u>	<u>Symbol</u>	<u>Number of Comparisons</u>			
		<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>
C2-D2	W				
	X				±
	Y				
	Z				=

Note. All negative comparisons for C1-D1 were actually 25 units long.

Table 2

The stimuli used as samples, positive comparisons, and negative comparisons in keyboard familiarization training.

<u>Sample</u>	<u>Positive Comparison</u>	<u>Negative Comparison</u>
ALCOHOL	DRUNK	MOUSE
ANT	BEE	COW
CANARY	SPARROW	STARS
CAT	MOUSE	DRAGONS
COMETS	STARS	FATHER
DOG	WOLF	DARK
DUNGEONS	CHAINS	PENCIL
EGGS	BACON	SPARROW
KINGS	QUEENS	CAMELS
LIGHT	DARK	SOCK
MOTHER	FATHER	BACON
MUD	PIG	HAT
PAPER	WRITE	OCEAN
RED	COLOR	PEAR
SOAP	WATER	THAT
THIS	THAT	KINGS

Table 3

Training conditions used to establish 4-member equivalence classes.

<u>Number of Co-s</u>	<u>Feedback</u>	
1	Yes	No
2	Yes	No
4	Yes	No
8	Yes	No

Table 4

Symbolic representation and number of trials used in baseline training and emergent relations testing. In each trial block, each Co+ and Co- appeared equally often on the left and right. All subjects, regardless of training condition, received the same test blocks.

<u>Relation Type</u>	<u>Sa</u>	<u>Co+</u>	<u>Co-</u>	<u>No.</u>	<u>Sa</u>	<u>Co+</u>	<u>Co-</u>	<u>No.</u>
Train AB								
1Co-	A1	B1	B2	16	A2	B2	B1	16
2 Co-	A1	B1	B2	8	A2	B2	B1	8
	A1	B1	M	8	A2	B2	T	8
4 Co-	A1	B1	B2	4	A2	B2	B1	4
	A1	B1	M	4	A2	B2	T	4
	A1	B1	N	4	A2	B2	U	4
	A1	B1	O	4	A2	B2	V	4
8 Co-	A1	B1	B2	2	A2	B2	B1	2
	A1	B1	M	2	A2	B2	T	2
	A1	B1	N	2	A2	B2	U	2
	A1	B1	O	2	A2	B2	V	2
	A1	B1	P	2	A2	B2	W	2
	A1	B1	Q	2	A2	B2	X	2
	A1	B1	R	2	A2	B2	Y	2
	A1	B1	S	2	A2	B2	Z	2
Test BA Symm.	B1	A1	A2	8	B2	A2	A1	8
	B1	A1	A2	8	B2	A2	A1	8

(table continues)

<u>Relation Type</u>	<u>Sa</u>	<u>Co+</u>	<u>Co-</u>	<u>No.</u>	<u>Sa</u>	<u>Co+</u>	<u>Co-</u>	<u>No.</u>
Train BC								
1Co-	A1	B1	B2	4	A2	B2	B1	4
	B1	C1	C2	16	B2	C2	C1	16
2 Co-	A1	B1	B2	4	A2	B2	B1	4
	B1	C1	C2	8	B2	C2	C1	8
	B1	C1	M	8	B2	C2	T	8
4 Co-	A1	B1	B2	4	A2	B2	B1	4
	B1	C1	C2	4	B2	C2	C1	4
	B1	C1	M	4	B2	C2	T	4
	B1	C1	N	4	B2	C2	U	4
	B1	C1	O	4	B2	C2	V	4
8 Co-	A1	B1	B2	4	A2	B2	B1	4
	B1	C1	C2	2	B2	C2	C1	2
	B1	C1	M	2	B2	C2	T	2
	B1	C1	N	2	B2	C2	U	2
	B1	C1	O	2	B2	C2	V	2
	B1	C1	P	2	B2	C2	W	2
	B1	C1	Q	2	B2	C2	X	2
	B1	C1	R	2	B2	C2	Y	2
	B1	C1	S	2	B2	C2	Z	2
Test CB Symm.	A1	B1	B2	4	A2	B2	B1	4
	B1	C1	C2	4	B2	C2	C1	4
	C1	B1	B2	8	C2	B2	B1	8

(table continues)

<u>Relation Type</u>	<u>Sa</u>	<u>Co+</u>	<u>Co-</u>	<u>No.</u>	<u>Sa</u>	<u>Co+</u>	<u>Co-</u>	<u>No.</u>
Test AC Trans.	A1	B1	B2	4	A2	B2	B1	4
	B1	C1	C2	4	B2	C2	C1	4
	A1	C1	C2	8	A2	C2	C1	8
Test CA Eqv.	A1	B1	B2	4	A2	B2	B1	4
	B1	C1	C2	4	B2	C2	C1	4
	C1	A1	A2	8	C2	A2	A1	8
Test 3-Mixed	A1	B1	B2	4	A2	B2	B1	4
	B1	C1	C2	4	B2	C2	C1	4
	B1	A1	B2	2	B2	A2	B1	2
	C1	B1	B2	2	C2	B2	B1	2
	A1	C1	C2	2	A2	C2	C1	2
	C1	A1	A2	2	C2	A2	A1	2
Train CD								
1Co-	A1	B1	B2	4	A2	B2	B1	4
	B1	C1	C2	4	B2	C2	C1	4
	C1	D1	D2	16	C2	D2	D1	16
2 Co-	A1	B1	B2	4	A2	B2	B1	4
	B1	C1	C2	4	B2	C2	C1	4
	C1	D1	D2	8	C2	D2	D1	8
	C1	D1	M	8	C2	D2	T	8
4 Co-	A1	B1	B2	4	A2	B2	B1	4
	B1	C1	C2	4	B2	C2	C1	4
	C1	D1	D2	4	C2	D2	D1	4
	C1	D1	M	4	C2	D2	T	4

(table continues)

<u>Relation Type</u>	<u>Sa</u>	<u>Co+</u>	<u>Co-</u>	<u>No.</u>	<u>Sa</u>	<u>Co+</u>	<u>Co-</u>	<u>No.</u>
4 Co-	C1	D1	N	4	C2	D2	U	4
	C1	D1	O	4	C2	D2	V	4
8 Co-	A1	B1	B2	4	A2	B2	B1	4
	B1	C1	C2	4	B2	C2	C1	4
	C1	D1	D2	2	C2	D2	D1	2
	C1	D1	M	2	C2	D2	T	2
	C1	D1	N	2	C2	D2	U	2
	C1	D1	O	2	C2	D2	V	2
	C1	D1	P	2	C2	D2	W	2
	C1	D1	Q	2	C2	D2	X	2
	C1	D1	R	2	C2	D2	Y	2
	C1	D1	S	2	C2	D2	Z	2
Test 4-Mixed	B1	A1	B2	2	B2	A2	B1	2
	C1	B1	B2	2	C2	B2	B1	2
	A1	C1	C2	2	A2	C2	C1	2
	C1	A1	A2	2	C2	A2	A1	2
	D1	C1	C2	6	D2	C2	C1	6
	B1	D1	D2	6	B2	D2	D1	6
	D1	B1	B2	6	D2	B2	B1	6
	A1	D1	D2	6	A2	D2	D1	6
D1	A1	A2	6	D2	A2	A1	6	

Table 5

The number of subjects who failed to meet criterion in each phase of the training and testing protocol used to establish 4-member equivalence classes.

<u>Number of Co.-</u>	<u>Feedback</u>					<u>No Feedback</u>				
	<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>	<u>Sum</u>	<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>	<u>Sum</u>
<u>Relation Type</u>										
<b>Baseline</b>										
AB	0	0	0	0	0	0	1	2	2	5
BC	0	0	0	0	0	0	1	1	1	3
CD	0	0	0	0	0	0	1	1	1	3
<b>Symmetry</b>										
BA	0	0	0	0	0	0	0	0	0	0
CB	0	0	0	0	0	0	0	1	0	1
Transitivity: AC	2	2	1	0	5	4	0	1	1	6
Equivalence: CA	0	0	0	0	0	0	0	0	0	0
3 Mem. Mixed	0	0	0	0	0	0	0	0	0	0
4 Mem. Mixed	0	0	0	0	0	0	2	0	1	3

Table 6

Response patterns for subjects who failed to learn one of the baseline relations. The negative comparisons presented with Class-1 samples are labeled M through S; the negative comparisons presented with Class-2 samples are labeled T through Z. For each baseline relation however, different stimuli were used as the extra negative comparisons. (See Table 1.) For each trial, the comparison selected by the subject is underlined. Choices of a negative comparison are indicated by an asterisk. The errors made by Subject 0802 were not systematic and are not shown.

<u>Subject</u>	<u>Sample</u>	<u>Co+</u>	<u>Co-</u>	<u>Sample</u>	<u>Co+</u>	<u>Co-</u>
0207	A1	<u>B1</u>	B2	A2	<u>B2</u>	B1
	A1	<u>B1</u>	M	A2	B2	<u>T*</u>
0413	A1	<u>B1</u>	B2	A2	<u>B2</u>	B1
	A1	<u>B1</u>	M	A2	<u>B2</u>	U
	A1	<u>B1</u>	N	A2	<u>B2</u>	V
	A1	<u>B1</u>	O	A2	B2	<u>T*</u>
0415	A1	<u>B1</u>	B2	A2	<u>B2</u>	B1
	A1	<u>B1</u>	M	A2	<u>B2</u>	T
	A1	<u>B1</u>	N	A2	<u>B2</u>	V
	A1	<u>B1</u>	O	A2	B2	<u>U*</u>
0801	A1	<u>B1</u>	M	A2	<u>B2</u>	B1
	A1	<u>B1</u>	N	A2	<u>B2</u>	T
	A1	<u>B1</u>	O	A2	<u>B2</u>	U
	A1	<u>B1</u>	P	A2	<u>B2</u>	V
	A1	<u>B1</u>	Q	A2	<u>B2</u>	W
	A1	<u>B1</u>	R	A2	<u>B2</u>	Y

(table continues)

<u>Subject</u>	<u>Sample</u>	<u>Co+</u>	<u>Co-</u>	<u>Sample</u>	<u>Co+</u>	<u>Co-</u>
0801	A1	<u>B1</u>	S	A2	<u>B2</u>	Z
	A1	B1	<u>B2*</u>	A2	B2	<u>X*</u>
0813	A1	<u>B1</u>	B2	A2	<u>B2</u>	T
	A1	B1	<u>M*</u>	A2	<u>B2</u>	U
	A1	B1	<u>N*</u>	A2	<u>B2</u>	V
	A1	B1	<u>O*</u>	A2	<u>B2</u>	W
	A1	B1	<u>P*</u>	A2	<u>B2</u>	Y
	A1	B1	<u>Q*</u>	A2	B2	<u>B1*</u>
	A1	B1	<u>R*</u>	A2	B2	<u>X*</u>
	A1	B1	<u>S*</u>	A2	B2	<u>Z*</u>
0205	B1	<u>C1</u>	C2	B2	C2	<u>C1*</u>
	B1	<u>C1</u>	M	B2	C2	<u>T*</u>
0409	B1	<u>C1</u>	C2	B2	C2	<u>C1*</u>
	B1	<u>C1</u>	M	B2	C2	<u>T*</u>
	B1	<u>C1</u>	N	B2	C2	<u>U*</u>
	B1	<u>C1</u>	O	B2	C2	<u>V*</u>
0214	C1	D1	<u>D2*</u>	C2	D2	<u>D1*</u>
	C1	D1	<u>M*</u>	C2	D2	<u>T*</u>
0414	C1	D1	<u>D2*</u>	C2	D2	<u>D1*</u>
	C1	D1	<u>M*</u>	C2	D2	<u>T*</u>
	C1	D1	<u>N*</u>	C2	D2	<u>U*</u>
	C1	D1	<u>O*</u>	C2	D2	<u>V*</u>
0811	C1	D1	<u>D2*</u>	C2	D2	<u>D1*</u>
	C1	D1	<u>M*</u>	C2	D2	<u>T*</u>

(table continues)

<u>Subject</u>	<u>Sample</u>	<u>Co+</u>	<u>Co-</u>	<u>Sample</u>	<u>Co+</u>	<u>Co-</u>
0811	C1	D1	<u>N</u> *	C2	D2	<u>U</u> *
	C1	D1	<u>Q</u> *	C2	D2	<u>V</u> *
	C1	D1	<u>P</u> *	C2	D2	<u>W</u> *
	C1	D1	<u>Q</u> *	C2	D2	<u>X</u> *
	C1	D1	<u>R</u> *	C2	D2	<u>Y</u> *
	C1	D1	<u>S</u> *	C2	D2	<u>Z</u> *

Table 7

Frequency of error patterns for subjects who failed to meet criterion on AC transitivity probes.

<u>Number of Co.-</u>	<u>Feedback</u>					<u>No Feedback</u>				
	<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>	<u>Sum</u>	<u>1</u>	<u>2</u>	<u>4</u>	<u>8</u>	<u>Sum</u>
<u>Error Type</u>										
Preference (C1)	0	1	0	0	1	2	0	0	0	2
Preference (C2)	0	0	1	0	1	2	0	0	0	2
Reversal	2	1	0	0	3	0	0	1	1	2
Total	2	2	1	0	5	4	0	1	1	6

Table 8

Percentage choice of the class related comparison in the 4-member mixed test for subjects who failed to meet criterion.

<u>Relation Type</u>	<u>Subject 0212</u>		<u>Subject 0812</u>		<u>Subject 0213</u>	
	<u>Class 1</u>	<u>Class 2</u>	<u>Class 1</u>	<u>Class 2</u>	<u>Class 1</u>	<u>Class 2</u>
<b>Symmetry</b>						
BA	100	100	100	91	100	100
CB	100	100	0	0	85	85
DC	2	0	100	100	100	100
<b>Transitivity</b>						
AC	100	100	0	0	85	85
BD	2	0	2	0	0	0
AD	0	2	0	0	85	85
<b>Equivalence</b>						
CA	100	100	0	0	85	85
DB	2	0	0	2	0	0
DA	0	0	0	0	85	85

Table 9

Average number of blocks required by subjects in each group to meet criterion in each phase of training and testing to establish 4-member equivalence classes.

<u>Group</u>	<u>Relation Type</u>								
	<u>AB</u>	<u>BA</u>	<u>BC</u>	<u>CB</u>	<u>AC</u>	<u>CA</u>	<u>MIX</u> <sup><u>3</u></sup>	<u>CD</u>	<u>MIX</u> <sup><u>4</u></sup>
1Co-, NoFB	1.00	1.10	1.60	1.50	1.50	1.50	1.00	1.00	1.17
1Co-, FB	1.70	1.20	3.50	1.10	1.00	1.00	1.00	1.75	1.00
2Co-, NoFB	2.22	1.00	1.88	1.13	1.14	1.25	1.00	1.14	1.00
2Co-, FB	1.44	1.00	1.78	1.11	1.63	1.00	1.00	1.75	1.25
4Co-, NoFB	2.00	1.13	2.71	1.00	2.20	1.00	1.00	1.25	1.00
4Co-, FB	1.60	1.00	1.60	1.20	1.13	1.00	1.00	1.67	1.67
8Co-, NoFB	1.75	1.13	2.71	1.17	1.67	1.67	1.00	2.00	1.25
8Co-, FB	1.80	1.20	2.00	1.00	1.20	1.00	1.10	2.00	1.10

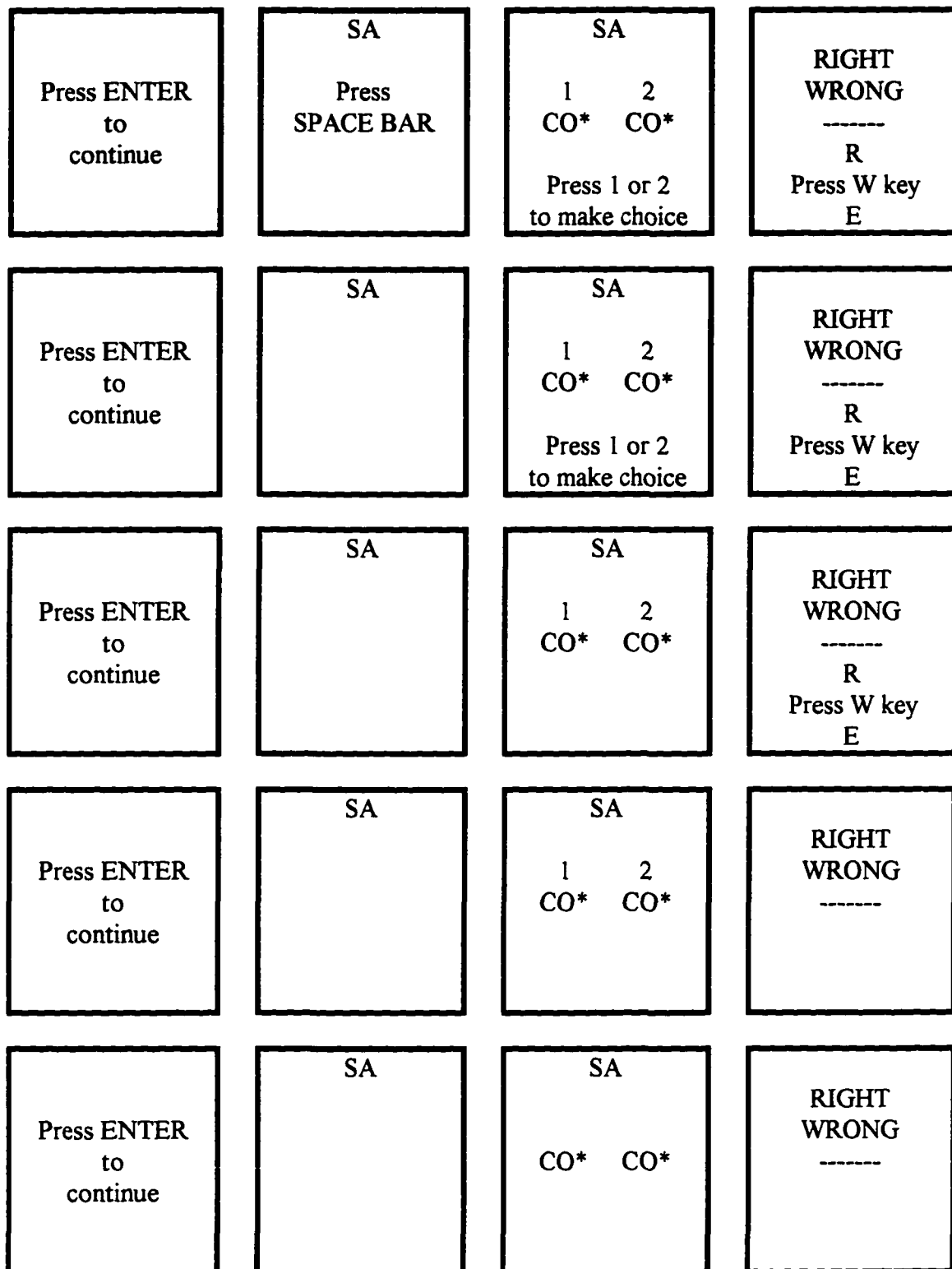
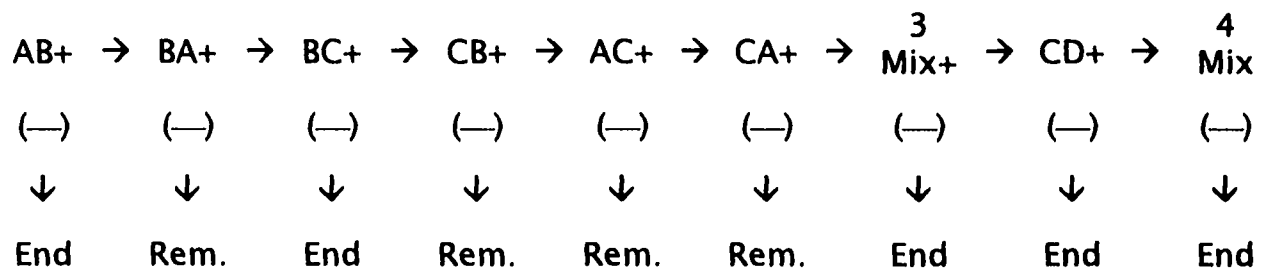
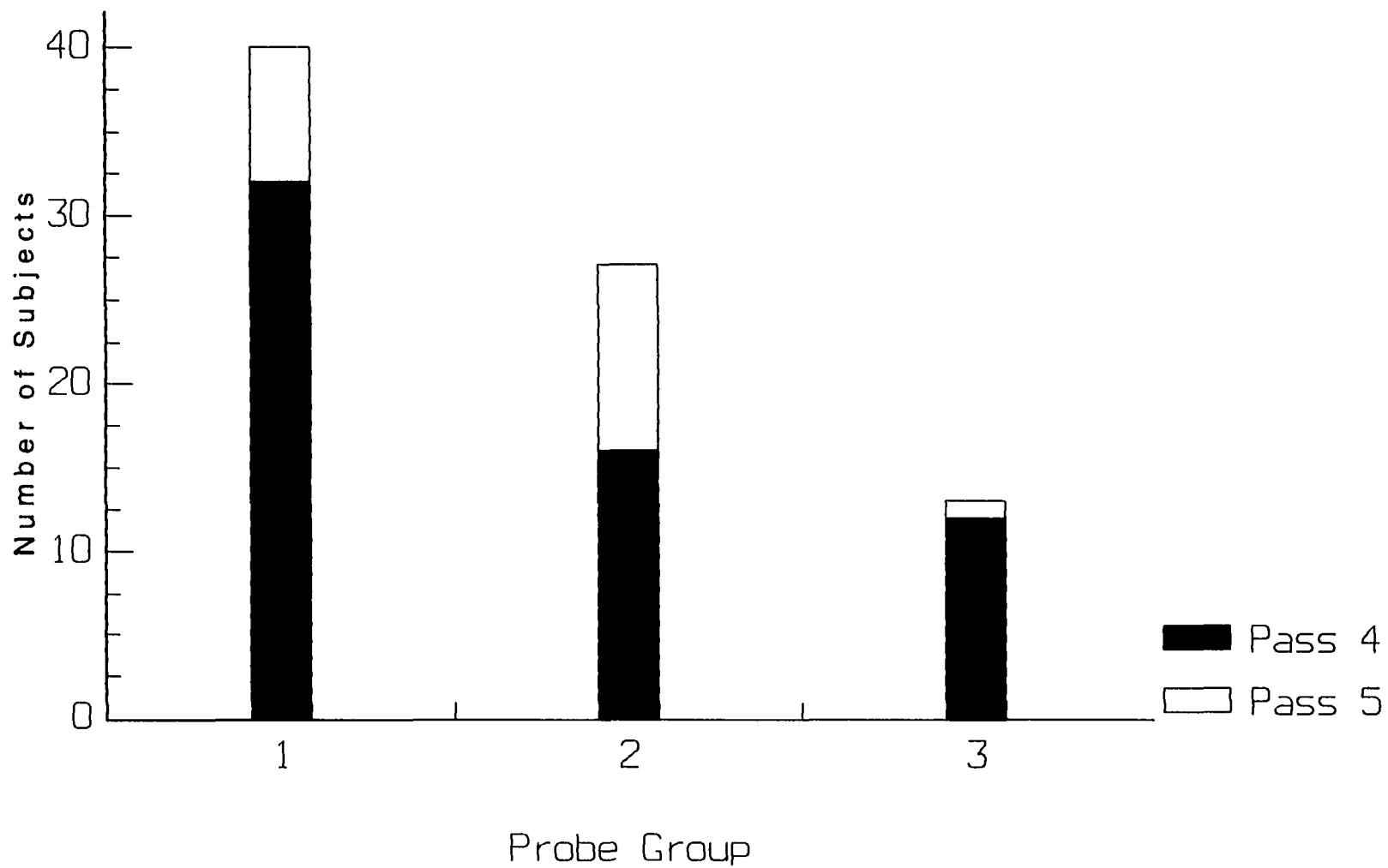


Figure 1. Sequential changes in prompts that were presented during a trial are shown across each row. The location of the sample stimulus is designated SA; the locations of the comparison stimuli are designated CO.

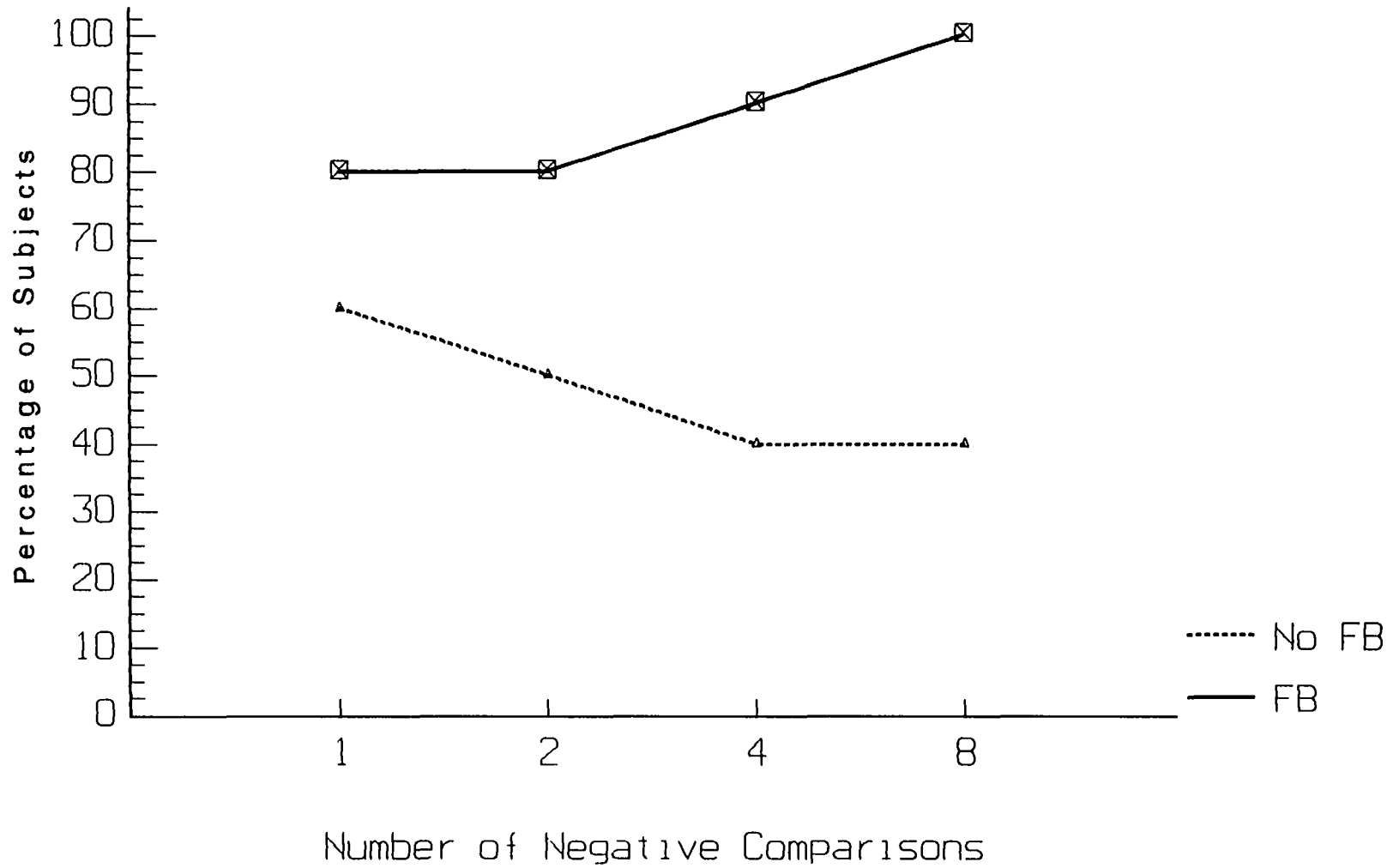
### Simple-to-Complex Protocol with Expansion to 4-Member Classes



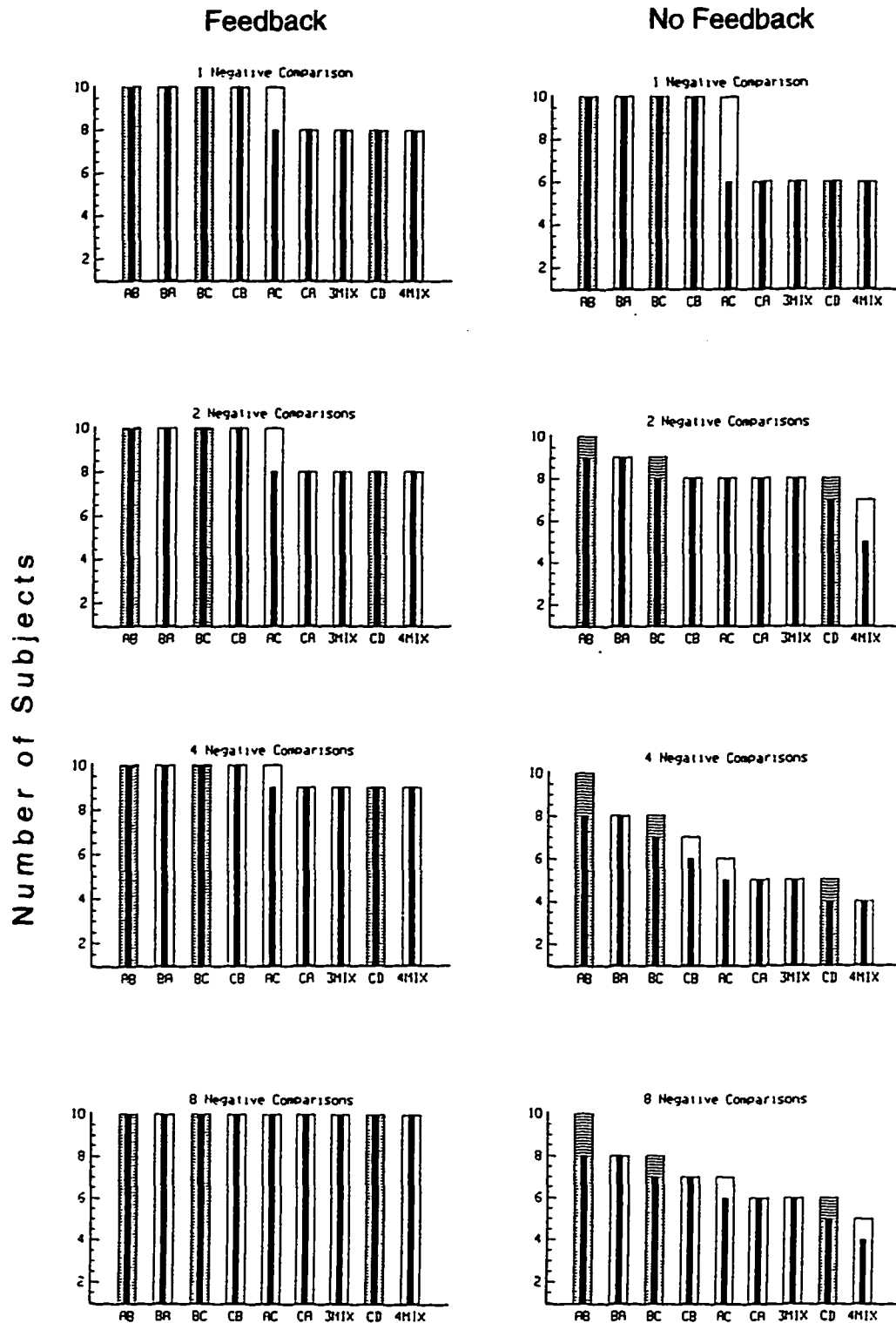
**Figure 2.** The order of presentation of the baseline relations and the emergent relations probes used during the training and testing of 4-member equivalence classes. REM indicate that the subject received the remedial protocol specific to that emergent relation. See text for details.



**Figure 3.** Number of subjects who met criterion on each probe group. The dark part of each bar indicates the number of subjects who responded consistently and conditionally on all five stimulus sets. The white part of each bar indicates those who did so on the last four sets.



**Figure 4.** Percentage of subjects in each training group who formed 4-member equivalence classes.



**Figure 5.** Number of subjects in each training group who met criterion in each phase of training and testing. The wide bars indicate the number of subjects who began each training (filled) and testing phase (unfilled) of the experiment. The narrow bars contained within indicate the number of subjects who met criterion.

## Appendix A

Table A.

The number of conditional relations presented in pretraining to subjects prior to each probe group and the outcome of each probe group in pretraining. P-5 indicates that the subjects responded conditionally to all five stimulus sets in a probe group; P-4 indicates that a subject responded conditionally to the last four stimulus sets in a probe group. F indicates that a subject did not meet the criterion in that probe group.

<u>Group</u>	<u>Subj.</u>	<u>Cycle 1</u>		<u>Cycle 2</u>		<u>Cycle 3</u>	
		<u>Train</u>	<u>Probe</u>	<u>Train</u>	<u>Probe</u>	<u>Train</u>	<u>Probe</u>
1Co-, No Fb	0106	4	P-5				
	0101	5	P-5				
	0107	5	P-5				
	0108	5	P-5				
	0105	6	P-5				
	0102	3	P-4				
	0104	2	F	2	P-5		
	0103	4	F	3	P-5		
	0109	3	F	2	F	7	P-5
	0110	2	F	4	F	9	P-5
1 Co-, Fb	1104	2	P-5				
	1106	2	P-5				
	1113	3	P-5				
	1108	6	P-5				
	1112	2	P-4				
	1102	3	F	4	P-5		

(table continues)

<u>Group</u>	<u>Subj.</u>	<u>Cycle 1</u>		<u>Cycle 2</u>		<u>Cycle 3</u>	
		<u>Train</u>	<u>Probe</u>	<u>Train</u>	<u>Probe</u>	<u>Train</u>	<u>Probe</u>
1 Co-, Fb	1111	9	F	6	P-5		
	1114	3	F	4	P-4		
	1103	3	F	8	P-4		
	1115	3	F	6	F	4	P-5
2Co-, No Fb	0207	4	P-5				
	0206	6	P-5				
	0209	4	P-4				
	0211	3	F	3	P-5		
	0208	5	F	4	P-5		
	0212	4	F	2	P-4		
	0214	9	F	2	P-4		
	0213	6	F	3	F	3	P-5
	0205	5	F	7	F	9	P-5
	0210	4	F	3	F	7	P-4
2Co-, Fb	1207	3	P-5				
	1210	3	P-5				
	1201	6	P-4				
	1205	2	F	2	P-5		
	1204	5	F	5	P-5		
	1209	11	F	8	P-5		
	1206	5	F	2	P-4		
	1203	3	F	3	P-4		
	1202	15	F	4	P-4		

(table continues)

<u>Group</u>	<u>Subj.</u>	<u>Cycle 1</u>		<u>Cycle 2</u>		<u>Cycle 3</u>	
		<u>Train</u>	<u>Probe</u>	<u>Train</u>	<u>Probe</u>	<u>Train</u>	<u>Probe</u>
2Co-, Fb	1211	3	F	4	P-4		
4Co-, No Fb	0410	3	P-5				
	0415	3	P-5				
	0413	5	P-5				
	0411	7	P-5				
	0409	8	P-5				
	0407	3	P-4				
	0408	11	P-4				
	0412	3	F	2	P-5		
	0414	7	F	3	P-4		
	0406	3	F	15	P-4		
4Co-, FB	1413	2	P-5				
	1404	3	P-5				
	1406	3	P-5				
	1401	4	P-5				
	1402	12	P-5				
	1403	3	F	2	P-5		
	1407	5	F	3	P-5		
	1411	5	F	9	P-5		
	1405	6	F	2	F	6	P-5
	1409	8	F	5	F	8	P-5
8Co-, NoFb	0802	3	P-5				
	0804	3	P-5				

(table continues)

<u>Group</u>	<u>Subj.</u>	<u>Cycle 1</u>		<u>Cycle 2</u>		<u>Cycle 3</u>	
		<u>Train</u>	<u>Probe</u>	<u>Train</u>	<u>Probe</u>	<u>Train</u>	<u>Probe</u>
8Co-, NoFb	0807	3	P-5				
	0812	5	P-5				
	0801	6	P-5				
	0805	5	P-4				
	0813	6	F	6	P-5		
	0808	5	F	7	P-5		
	0803	7	F	14	P-4		
	0811	6	F	7	F	11	P-5
8Co- Fb	1807	2	P-5				
	1801	3	P-5				
	1803	5	P-5				
	1808	4	P-4				
	1811	4	P-4				
	1809	3	F	3	P-5		
	1810	4	F	2	F	2	P-5
	1806	8	F	2	F	2	P-5
	1804	5	F	3	F	2	P-5
1802	7	F	5	F	2	P-5	
Failures	0001	26	NA				
	0002	8	F	16	NA		
	0003	3	F	16	NA		
	0004	8	F	16	NA		
	0005	14	F	16	NA		

(table continues)

<u>Group</u>	<u>Subj.</u>	<u>Cycle 1</u>		<u>Cycle 2</u>		<u>Cycle 3</u>	
		<u>Train</u>	<u>Probe</u>	<u>Train</u>	<u>Probe</u>	<u>Train</u>	<u>Probe</u>
Failures	0006	6	F	2	F	7	F
	0007	5	F	7	F	3	F
	0008	5	F	2	F	16	NA

Note. NA indicates that a probe group was not administered because the subject did not meet the training criterion.

## Appendix B

Table B

Number of blocks presented in each phase of equivalence class training and testing. For feedback groups, the number of blocks for the training relations is the number to meet criterion under the 100% feedback condition.

<u>Group</u>	<u>Subj.</u>	<u>AB</u>	<u>BA</u>	<u>BC</u>	<u>CB</u>	<u>AC</u>	<u>CA</u>	<u>3Mix</u>	<u>CD</u>	<u>4Mix</u>
1Co-, No Fb	0102	1	1	1	1	1	1	1	1	1
	0104	1	1	1	1	1	1	1	1	1
	0103	1	1	1	1	2	1	1	1	1
	0101	1	1	2	1	1	1	1	1	1
	0106	1	2	1	1	1	1	1	1	1
	0108	1	1	1	6	3	4	1	1	2
	0109	1	1	1	1	Fail	NA	NA	NA	NA
	0105	1	1	1	1	Fail	NA	NA	NA	NA
	0110	1	1	4	1	Fail	NA	NA	NA	NA
	0107	1	1	3	1	Fail	NA	NA	NA	NA
	Avg.	1.00	1.10	1.60	1.50	1.50	1.50	1.50	1.00	1.17
1 Co-, Fb	1102	1	1	2	1	1	1	1	2	1
	1103	3	1	4	1	1	1	1	2	1
	1108	1	1	3	1	1	1	1	1	1
	1111	2	1	3	1	1	1	1	1	1
	1112	1	1	2	1	1	1	1	1	1
	1114	2	1	2	1	1	1	1	4	1
	1113	2	1	2	2	1	1	1	2	1
	1106	1	1	5	1	6 <sup>a</sup>	1	1	1	1

(table continues)

<u>Group</u>	<u>Subj.</u>	<u>AB</u>	<u>BA</u>	<u>BC</u>	<u>CB</u>	<u>AC</u>	<u>CA</u>	<u>3Mix</u>	<u>CD</u>	<u>4Mix</u>
1 Co-, Fb	1115	2	2	3	1	Fail	NA	NA	NA	NA
	1104	2	2	9	1	Fail	NA	NA	NA	NA
	Avg.	1.70	1.20	3.50	1.10	1.00 <sup>b</sup>	1.00	1.00	1.75	1.00
2Co-, No Fb	0211	1	1	1	1	1	1	1	1	1
	0206	1	1	1	1	1	1	1	1	1
	0209	6	1	1	1	1	1	1	1	1
	0210	2	1	1	1	1	2	1	1	1
	0208	2	1	1	1	2	2	1	1	1
	0213	1	1	1	1	1	1	1	1	Fail
	0212	4	1	1	1	6 <sup>a</sup>	1	1	2	Fail
	0214	1	1	6	2	1	1	1	Fail	NA
	0205	2	1	Fail	NA	NA	NA	NA	NA	NA
	0207	Fail	NA	NA	NA	NA	NA	NA	NA	NA
	Avg.	2.22	1.00	1.88	1.13	1.14 <sup>b</sup>	1.25	1.00	1.14	1.00
2Co-, Fb	1207	2	1	1	1	1	1	1	1	1
	1209	2	1	3	1	1	1	1	1	1
	1204	2	1	2	2	1	1	1	1	1
	1201	1	1	2	1	1	1	1	3	1
	1202	2	1	1	1	1	1	1	4	1
	1203	1	1	2	1	1	1	1	2	1
	1205	1	1	1	1	1	1	1	1	2
	1211	1	1	1	1	6	1	1	1	2
	1206	1	1	2	1	Fail	NA	NA	NA	NA
	1210	1	1	2	1	Fail	NA	NA	NA	NA

(table continues)

<u>Group</u>	<u>Subj.</u>	<u>AB</u>	<u>BA</u>	<u>BC</u>	<u>CB</u>	<u>AC</u>	<u>CA</u>	<u>3Mix</u>	<u>CD</u>	<u>4Mix</u>
2Co-, Fb	Avg.	1.14	1.00	1.57	1.11	1.63	1.00	1.00	1.75	1.25
4Co-, No Fb	0407	4	1	1	1	1	1	1	1	1
	0408	1	1	1	1	1	1	1	2	1
	0412	1	1	1	1	2	1	1	1	1
	0410	1	1	2	1	6 <sup>a</sup>	1	1	1	1
	0414	1	1	2	1	1	1	1	Fail	NA
	0406	1	1	4	1	Fail	NA	NA	NA	NA
	0411	5	2	8	Fail	NA	NA	NA	NA	NA
	0409	2	1	Fail	NA	NA	NA	NA	NA	NA
	0413	Fail	NA	NA	NA	NA	NA	NA	NA	NA
	0415	Fail	NA	NA	NA	NA	NA	NA	NA	NA
	Avg.	2.00	1.13	2.71	1.00	1.25 <sup>b</sup>	1.00	1.00	1.25	1.00
4Co-, FB	1402	2	1	1	1	1	1	1	1	1
	1403	1	1	1	1	1	1	1	2	1
	1406	2	1	1	i	1	1	1	1	1
	1411	2	1	1	1	1	1	1	1	1
	1413	2	1	2	1	1	1	1	2	1
	1401	2	1	2	1	2	1	1	2	1
	1407	1	1	2	2	6 <sup>a</sup>	1	1	3	1
	1409	2	1	2	2	1	1	1	2	2
	1405	1	1	2	1	1	1	1	1	6
	1404	1	1	2	1	Fail	NA	NA	NA	NA
	Avg.	1.60	1.00	1.60	1.20	1.13 <sup>b</sup>	1.00	1.00	1.67	1.67

(table continues)

<u>Group</u>	<u>Subj.</u>	<u>AB</u>	<u>BA</u>	<u>BC</u>	<u>CB</u>	<u>AC</u>	<u>CA</u>	<u>3Mix</u>	<u>CD</u>	<u>4Mix</u>
8Co-, NoFb	0807	2	1	3	1	1	1	1	1	1
	0808	2	1	2	1	2	1	1	1	1
	0805	1	1	4	6 <sup>a</sup>	1	1	1	2	1
	0803	2	1	7	1	1	2	1	4	2
	0812	1	1	1	1	1	1	1	2	Fail
	0811	1	2	1	1	4	4	1	Fail	NA
	0804	2	1	1	2	Fail	NA	NA	NA	NA
	0802	3	1	Fail	NA	NA	NA	NA	NA	NA
	0801	Fail	NA	NA	NA	NA	NA	NA	NA	NA
	0813	Fail	NA	NA	NA	NA	NA	NA	NA	NA
	Avg.	1.75	1.13	2.71	1.17 <sup>b</sup>	1.67	1.67	1.00	2.00	1.25
8Co-, Fb	1802	1	1	1	1	1	1	1	2	1
	1807	2	1	2	1	1	1	1	2	1
	1808	2	1	1	1	1	1	1	2	1
	1809	1	1	2	1	1	1	1	1	1
	1810	2	1	3	1	1	1	1	3	1
	1803	2	2	1	1	1	1	1	2	1
	1804	2	2	3	1	1	1	1	3	1
	1811	2	1	2	1	2	1	2	1	1
	1806	2	1	3	1	2	1	1	2	1
	1801	2	1	2	1	1	1	1	2	2
	Avg.	1.80	1.20	2.00	1.00	1.20	1.00	1.10	2.00	1.10

Notes.

<sup>a</sup> Subject required additional blocks of remedial training and/or testing before meeting criterion in this phase of the experiment.

<sup>b</sup> Average does not include data for the subject who required remedial training and testing in that phase of the experiment.

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