DO SHARED S-MINUS FUNCTIONS AMONG STIMULI LEAD TO EQUIVALENCE?

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We examined the claim that equivalence classes contain all positive elements in a reinforcement contingency by asking whether negative stimuli in a reinforcement contingency will also form an equivalence class, based on their shared function as S-minus stimuli. In Experiment 1, 5 subjects were tested for equivalence for positive and negative stimuli. Testing of positive stimuli preceded testing of negative stimuli. Two of five subjects demonstrated equivalence for positive stimuli, and three subjects demonstrated equivalence for negative stimuli. In Experiment 2, order of testing was reversed. Four of six subjects demonstrated equivalence for positive stimuli, and none demonstrated equivalence for negative stimuli. In Experiment 3, positive and negative stimuli were tested together. Only one of five subject demonstrated equivalence for positive and negative stimuli.

These data suggest that negative stimuli may enter an equivalence class, and so Sidman paradigm should be expanded. Order of testing was found as a meaningful variable.

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INTRODUCTION

Research in stimulus equivalence is concerned with the derived emergence of relations among stimuli after a few overlapping relations have been trained (Sidman & Tailby, 1982; Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982). Equivalence classes involve three defining properties: reflexivity, symmetry, and transitivity (Sidman & Tailby, 1982). Reflexivity means that each stimulus bears a conditional relation to itself. That is, given A1 as a sample stimulus and A1 and A2 as comparisons in a matching-to-sample (MTS) procedure, the subject will select A1 and not A2 (hereafter, A1:A1). Symmetry means that the relations between the stimuli are interchangeable or bidirectional. That is, having learned A1:B1, subject shows B1:A1. In a MTS procedure, symmetry reveals that the relation holds when we reverse the elements of a baseline conditional discrimination. By transitivity, we mean that each stimulus is substitutable for all other stimuli. In a MTS procedure, this is demonstrated by showing that the relation holds when we test new conditional discriminations in which samples come from one baseline conditional discrimination, and comparisons from another conditional discrimination. For example, having learned A1:B1 and B1:C1, the subject selects A1:C1 and C1:A1 (e.g. Sidman, 1986; Sidman, 1994; Green and Saunders, 1998b).

In considering the origins of equivalence relations, Sidman (2000) stated that reinforcement is responsible for equivalence classes. Specifically, reinforcement produces two types of outcomes: (a) it gives rise to analytic units – such as the 2-, 3-, and 4-term contingencies; and (b) it gives rise to equivalence relations among the elements of the contingency. Specifically, “the equivalence relation consists of ordered pairs of all positive elements that participate in the reinforcement contingency" (Sidman, 2000, p. 131). By positive elements Sidman (2000) includes not only the samples and comparison stimuli, which are the traditional members in equivalence classes, but also the reinforcers and the responses, if they are specific to the contingency. Supporting evidence for the inclusion of reinforcers (e.g., Dube & McIlvane, 1995; Dube, McIlvane, Mackay, & Stoddard, 1987; Dube, McIlvane, Maguire, Mackay, & Stoddard, 1989; and Reichmuth, 1997) and responses (Manabe & Kawashima,1993; Manabe, Kawashima, & Staddon, 1995) can be found in the literature (see Sidman, 1994; 2000 for reviews).

Another perspective on the origins of equivalence classes is that they represent a particular kind of functional class organization. The definition of equivalence (described above) shows that stimuli that have become interchangeable in the context of conditional discriminations are said to comprise stimulus equivalence classes. With respect to the stimulus functions that define the equivalence relations, then, equivalence classes are also functional classes (see Goldiamond, 1969, in Sidman, 1994) within the constraints of a conditional discrimination procedure. Are functional classes also equivalent in the sense required by the definition above? Sidman (1994) put a strong emphasis on efforts to bridge the gap between equivalence classes and functional classes:

> By showing empirically that functional classes do imply equivalence relations in behavior, in spite of their different definitions and testing procedures, we would achieve a remarkable degree of theoretical elegance, empirical predictability, and potential data integration. A finding of congruence between the mathematical and behavioral definitions of equivalence – and therefore, between the equivalence relation and the partition – would constitute the most powerful demonstration yet achieved of the utility of the mathematically derived formulation (p. 421).

A detailed consideration of the role of negative stimuli (or S- stimuli) in the preparation may shed some light on this question and the nature, origin, and maintenance of equivalence classes. Green and Saunders (1998a) stated that the intended outcome of MTS baseline training is a relation between the sample and the positive comparison (the relation is between every sample and its experimenter-designated correct comparison stimulus). MTS contingencies, however, do not guarantee the development of sample/positive comparison relation since alternate relations such as sample/negative comparison relations may develop instead or in addition. That is, subjects may learn to respond away from one or more negative comparisons in the presence of each sample.

The functions of negative stimuli have been well documented in the literature. Fields, Verhave, and Fath (1984) termed these kinds of relations sample -negative control relations. Fields et al. (1984) described a normative set of MTS training and testing procedures in which responses were made exclusively to the positive comparison, yet still two types of control could have taken place: either positive comparison (Co+) control or negative comparison (Co-) control. Carrigan and Sidman (1992) distinguished between “select” or “type S” relations (conditional relations between samples and positive comparisons) and “reject” or “type R” relations (conditional relations between samples and negative comparisons). Specifically, in the case of type S control, the subject touches the comparison that is related to its designated current sample; in the case of type R control, the subject touches away from the comparison that is not related to the sample. Each type represents a sample-comparison relation in which the positive or negative comparisons, respectively, control the subject's performance. Since the procedure neither restricts nor encourages each type, either types or neither types can be reflected in the subject's performance. Finally, Johnson and Sidman (1993) documented type R responding and showed that select and reject control yield different results in reflexivity tests and one-node equivalence and transitivity tests.

The important factor, with respect to the current study, is that S- or negative comparisons may play a functional role in the organization of behavior. The observation that negative stimuli may have a distinct function in MTS preparations allows a unique opportunity to ask questions about the nature of equivalence class formation. Specifically, if equivalence classes grow out of functional class organization, one would expect the negative stimuli to be equivalent as well as the positive stimuli. If, on the other hand, equivalence classes are made up only of the positive elements in a contingency, the negative stimuli should not fall into a class at all.

The following experiments were designed to investigate whether negative stimuli would form an equivalence class in a MTS preparation. If negative stimuli share a common function of S-, they should become equivalent to each other based on the connection of equivalence classes and functional classes. However, no such relations would be expected to occur based on Sidman's (1994, 2000) notion that only the positive elements participating in a reinforcement contingency will enter equivalence classes. Thus, if negative comparisons do form equivalence classes, then some adaptation, at least, of Sidman's paradigm should take place.

In order to investigate the role of negative stimuli in equivalence class formation, six baseline relations were trained using MTS procedure. Instead of using each comparison both in a positive role with its designated sample, and in a negative role, with it opposite sample, four designated comparisons were presented: in each relation, each designated positive comparison had a designated negative comparison, the two always appearing together, so that stimuli designated as A1B1C1D1, appeared always with X1Y1Z1, whereas A2B2C2D2, appeared always with X2Y2Z2. In the current experiments, "positive" and "negative" refer only those stimuli that were presented as the correct and incorrect stimuli during the training phase. In the testing phases for these stimuli, they were presented as both correct and incorrect comparisons. For ease of presentation, positive stimuli are those designated as A, B, C, and D; negative stimuli are those designated as X, Y, and Z.

It is also important to note that, in the current experiments, only two comparison stimuli were presented on each trial. Although there are several limitations to the use of only two comparison per trial (Carrigan & Sidman, 1992; Saunders & Green, 1992; Sidman, 1980), Carrigan and Sidman (1992) suggest that the use of three of more comparisons per trail is likely to prevent type R control, which is important to the formation of functional classes based on the negative function of the stimuli.

EXPERIMENT 1

Method

Subjects

Five undergraduate students, four men and one woman, ranging in age from 22 – 52 years, were recruited via announcements in an undergraduate class and an advertisement in the university newspaper. Participants were excluded only if they had Behavior Analysis course work in their background or if they could not be available for scheduled sessions. The individuals received $20.00 for participating. In addition, participants were informed, during the informed consent procedures, that the best performer would earn an additional bonus of $20.00. For all the subjects, the experiment lasted one session only, lasting an average of 51.8 min.

Setting and Apparatus

Experimental sessions were conducted in a small room (1 m x 3.2 m) furnished with a chair and a table. A personal computer placed on the table was used to present stimuli, detect responses, manage contingencies and collect data. Aside from typing the subject's name and pressing "Enter" to start the session, subjects interacted with the program using only the mouse.

Stimuli

The stimuli used in the experiment consisted of 17 Wingdings symbols (see Figure 1). From these, 14 stimuli were randomly chosen for each subject such that the particular symbols that comprised the experimenter-designated classes were different for each subject. For ease of description, stimuli are designated alphanumerically (e.g., A1, B2, X1) although these designations were not seen by the subjects. Following the notation described by Fields et al. (1984), numbers designate classes and letters designate stimuli within classes. All stimuli were 1.25 inches and presented as black symbols on a white background.

Instructions

After the subject was seated before the computer and typed his or her name, instructions (see appendix) were presented on the computer screen. The instructions stated the following: (a) subjects should click on the sample, then click on one of the two comparisons; (b) subjects' goal is to choose the correct comparisons, and there is always a correct response; (c) feedback will be delivered during some of the trials so it is important to attend to the feedback; (d) the experiment will become increasingly difficult, and each success later in the experiment would depend on what was learned earlier in the experiment.

Procedure

The experiment consisted of three phases: a training phase in which overlapping conditional discriminations were directly established and two testing phases in which various equivalence probes were conducted.

Training equivalence prerequisites. Subjects were taught six conditional relations using matching-to-sample procedures in a one-to-many format. A trial began with the presentation of a stimulus in the top center of the monitor (hereafter, sample). An observing response (placing the cursor anywhere on top of the stimulus and pressing the left mouse button) produced an array of two stimuli at the bottom right and left of the screen (hereafter, comparisons). After the comparison array was produced, responding to the sample stimulus had no programmed consequences. The subjects selected the comparison stimulus by positioning the cursor over a stimulus and pressing the left mouse button. Selection of the experimenter-designated correct stimulus during this phase resulted in the presentation of a box containing a check mark and the word “right” accompanied by a chime. The visual display remained on the screen for 1.5 s along with the three stimuli after which the display was cleared for 1 s before the next trial was presented. Selection of the incorrect stimulus resulted in the presentation of a box containing “x” and the word “wrong” accompanied by a short buzz.

The following six conditional relations were established in the manner described above: Given A1 (sample), select B1 not X1 (hereafter, A1-<u>B1</u> X1), A1-<u>C1</u> Y1, A1-<u>D1</u> Z1, A2-<u>B2</u> X2, A2-<u>C2</u> Y2, and A2-<u>D2</u> Z2. Note that each trained conditional relation involves a unique comparison array such that the incorrect comparison stimuli are always incorrect (unlike standard conditional discrimination procedures in which the incorrect comparison stimuli on one trial are correct on a trial with a different sample). The six baseline relations were randomly selected without replacement and presented in blocks of six trials (see Table 1). Training continued until subjects reached an accuracy criterion of 46/48 trials over eight consecutive trial blocks.

After subjects met the mastery criterion with 100% feedback, the probability of feedback was reduced to 50%, then 25%, then 0% on randomly selected trials each time the subject met the mastery criterion. Testing began after the subject reached the mastery criterion (46/48 correct trials) without feedback.

Equivalence testing with positive elements. The purpose of this phase was to test whether the sample and positive comparison stimuli (A1, B1, C1, and D1) and (A2, B2, C2, and D2) had entered into equivalence class (i.e. had become interchangeable or substitutable for each other). Probe trials were presented in the same fashion as in the Training phase with the exception that no feedback was provided following comparison choices. Each testing block consisted of 32 trials (8 reflexivity probes, 6 symmetry probes, 8 transitivity probes and 6 training trials, see Table 2). For each type of test, the sample and experimenter-designated correct comparison stimulus were from the same class (e.g., Set 1) and the incorrect comparison stimulus was from the alternative class (Set 2) and vice versa. Trials within a 32-trial block were selected randomly without replacement. This testing phase consisted of four presentations of the 32-trial blocks for a total of 128 trials.

Equivalence testing with negative elements. The purpose of this phase was to test whether negative comparison stimuli (X1, Y1, and Z1) and (X2, Y2, and Z2) had entered into an equivalence class (i.e., had become interchangeable or equivalent). Probe trials were presented in the same fashion as in the Training phase with the exception that no feedback was provided following comparison choices. Because the negative stimuli never appeared as samples in the training phase, it was impossible to test for symmetry in the traditional sense, and so symmetry and transitivity were combined to one trial type, designated "combined" trials. Each testing block consisted of 24 trials (6 reflexivity probes, 12 combined probes, and 6 training trials, see Table 3). For each type of test, the sample and experimenter-designated correct comparison stimulus were from the same class (e.g., Set 1) and the incorrect comparison stimulus was from the alternative class (e.g., Set 2). Trials within a 24-trial block were selected randomly without replacement. This test phase consisted of five presentations of the 24-trial blocks for a total of 120 trials.

Stimulus sorting task. Upon completing all testing trials, the computer notified the subjects that the session was over. The experimenter then presented the subjects with all the stimuli used in the experiment (the entire bank of 17 stimuli), typed on cards (size 5.08 cm.*5.08 cm.). The cards were shuffled and laid on the table in front of the subjects in 4*4 +1 rows. The subjects were asked if they recognized the symbols. After a positive answer, they were given the following request: “Please organize the cards to the best of your judgment”. If the subjects were not clear as to what they should do, the following clarification was given to them: “How do you think you should organize the cards?” Each subject’s card layout was later copied by the experimenter and compared to the four equivalence classes designed by the experimenter. Although each subject was presented with 14 stimuli during training and testing phases, there were 17 stimuli in the stimuli bank from which stimuli were randomly chosen to each class. Thus, during the organization task, subjects were presented with all 17 cards, only 14 of which were familiar. After finishing this assignment, the subjects were debriefed and paid.

Results

The results are presented and analyzed in blocks of testing (4 blocks in positive elements’ phase, and 5 blocks in the negative elements’ phase), according to trial types. Averaged accuracy of performance in each phase is also analyzed.

Accuracy was analyzed by calculating the percentage of correct responses. A total score of 80% or greater correct in the reflexivity, symmetry, and transitivity tests during the positive stimuli testing phase or in the reflexivity and combined tests during the negative stimuli testing phase was considered as an equivalence consistent performance.

The card sorting pattern assignment was analyzed by comparing the subjects' card sorting patterns to the four equivalence classes designed by the experimenter.

All five subjects progressed through the fading feedback training trials and achieved mastery after five blocks (i.e. 240 trials). All five subjects repeated the first block in the 100% feedback phase, and then progressed through 50% feedback, 25% feedback, and finally 0% feedback. Upon completion of the last training block of 0% feedback with at least 46 of 48 corrects, all five subjects started the testing trials.

During testing of positive comparisons (see Figure 2) trained relations remained intact for four of five subjects (S#1, S#2, S#4, and S#5); four of five subjects performed with greater then 90% accuracy on the reflexivity trials (S#1, S#2, S#3, and S#4); three of five subjects performed with greater then 80% accuracy on the symmetry trials (S#1, S#4, and S#5); and three of five subjects performed with greater then 85% accuracy on the transitivity trials (S#1, S#4, and S#5).

During testing of negative comparisons (see Figure 3) trained relations remained intact for four of five subjects (S#1, S#2, S#4, and S#5); four of five subjects performed with greater then 95% accuracy on the reflexivity trials (S#1, S#2, S#3, and S#4); and three of five subjects performed with greater then 80% accuracy on the combined trials (S#1, S#2, and S#4).

Three subjects demonstrated inconsistent equivalence performance, in which some of the derived relations appeared whereas other derived relations did not appear. In positive elements tests, subject #2's and subject #3's performance was evident of reflexivity relation without symmetry and transitivity relations, whereas subject #5's performance was evident of symmetry and transitivity relations without reflexivity. In negative elements tests, subject #3's performance was evident of reflexivity relation without symmetry and transitivity relations (combined trials). Delayed emergence of equivalence was demonstrated in positive elements tests by subject #1 and in negative elements tests by subject #1 and subject #2.

Finally, cards-sorting patterns are presented in Figure 4. All five subjects separated the 14 cards that were used in the experiment from the 3 cards that were not used in the experiment. Three of five subjects (S#1, S#2, and S#4) organized the cards in a manner which may suggest consistency with equivalence for both the positive elements and the negative elements. One of the five subjects (S#5) organized the cards in a manner consistent with equivalence for the positive elements only. For three of five subjects, the results of the cards-sorting task matched the results of the MTS testing trials: S#1 and S#4 data suggest equivalence for the positive and the negative elements in both levels, and S#3 failed to demonstrate equivalence for both elements in both levels. For two subjects, the results of the cards-sorting task differed for the results of the MTS testing trials: S#2's data suggest equivalence for both the negative elements and the positive elements in the cards-sorting task, but only for the negative elements in the MTS testing trials; S#5's data suggest equivalence for positive elements in the cards-sorting task, but no equivalence in the MTS testing trials.

Table 4 summarizes equivalence consistent and inconsistent performance for all five subjects with regard to the positive elements and the negative elements in the MTS testing trials and in the cards-sorting task.

Discussion

Three of the five participants demonstrated equivalence-consistent choices involving negative stimuli. These results counter Sidman's contention that equivalence classes are comprised of the positive elements in the reinforcement contingency (Sidman, 2000). However, other variables may have affected the formation of equivalence classes with regard to the negative stimuli. It may be that the negative equivalences had been the result of positive elements becoming categorized first and the negative elements becoming categorized via exclusion (i.e. establishment of the class of negative stimuli may have occurred as a function of the order of testing trials). This account is consistent with the data from subjects 1 and 4 but not with the data from subject 2, who showed equivalence-consistent choices with negative elements but no equivalence-consistent choices with positive elements (however, this subject's results with positive elements nearly reached criterion). Order of testing may also explain why results of the cards-sorting task showed evidence of the establishment of equivalence classes for four of five subjects whereas the results for MTS testing trials did not. However, a word of caution is in order with regard to results obtained via the cards' sorting task: this is the first documented usage of this procedure Each subject arranged the cards in a unique pattern and it was hard to quantify the criterion for successful equivalence formation, and to unequivocally compare the results of the subjects, Thus, in the general discussion, conclusions for negative equivalence formation were conservatively mainly based on the MTS procedure.

EXPERIMENT 2

The results of Experiment 1 suggest that negative elements can enter into equivalence relations; however, these outcomes may have been confounded by the testing order. Specifically, for three of five subjects, establishment of equivalence for negative elements may have come about only after and as a function of establishment of equivalence among the positive elements. This may be thought of as a “mirrored image” of type R control, such that instead of positive stimuli being grouped together via exclusion of negative stimuli, negative stimuli may have become equivalent via exclusion of the positive stimuli by virtue of positive elements’ exclusion. In order to minimize the possibility of responding on the basis of exclusion, the order in which the phases were tested was reversed during Experiment 2. In Experiment 2, subjects were presented with the testing trials with the negative stimuli before testing trials with the positive stimuli.

Method

Subjects

Six undergraduate students, two women and four men, ranging in age from 20 – 25 years participated in this experiment. For all the subjects, the experiment lasted one session, lasting an average of 51.8 min.

Setting and Apparatus:

The setting and apparatus were identical to those used in Experiment 1.

Procedure

The procedure was identical to Experiment 1 with the exception that the test for negative stimuli was presented before with the test for positive elements.

Results

All six subjects progressed through the fading feedback training trials and achieved mastery after five blocks (i.e. 240 trials). All subjects repeated the first block in the 100% feedback phase, and then progressed through 50% feedback, 25% feedback, and finally 0% feedback. After completion of the last training block of 0% feedback with at least 46 of 48 corrects, all six subjects started the testing trials.

During negative elements tests (i.e. testing of negative comparisons) (see Figure 5) trained relations remained at 100% correct for all six subjects; five of six subjects performed with greater then 95% accuracy on the reflexivity trials (S#7, S#8, S#9, S#10, and S#11); and no subjects achieved the success criterion of 80% correct for the combined trials.

During positive elements tests (i.e. testing of positive comparisons) (see Figure 6) trained relations remained intact for all six subjects; five of six subjects performed 100% accuracy on the reflexivity trials (S#7, S#8, S#9, S#10, and S#11); four of six subjects performed with greater then 95% accuracy on the symmetry trials (S#7, S#8, S#9, and S#10); and four of six subjects performed with greater then 80% accuracy on the transitivity trials (S#7, S#8, S#9, and S#10).

Inconsistent equivalence performance was demonstrated by all six subjects. In negative elements tests, subjects #7-#11 demonstrated reflexivity without achieving symmetry and transitivity (combined trials), and subject #11 demonstrated reflexivity without symmetry and transitivity in the positive elements test. Subject #6 failed to achieve equivalence for any relation.

Delayed emergence of equivalence was demonstrated in the positive elements test by subject #9.

Finally, cards-sorting patterns are presented in Figure 7. Four of six subjects (S#7, S#8, S#9, and S#11) separated the 14 cards that were used in the experiment from the 3 cards that were not used in the experiment, i. Two subjects (S#7, and S#8) organized the cards in a manner that was consistent with equivalence for both the positive elements and the negative elements. Three subjects (S#9, S#10, and S#11) organized the cards in a manner that was consistent with equivalence for the positive elements only. Sorting pattern of one subject (S#6) did not suggest the formation of equivalence classes for either the negative stimuli of the positive stimuli. For three subjects, the results of the cards-sorting task matched the results of the MTS testing trials: S#6's data suggest inconsistency with positive of negative equivalence in both the MTS testing phases and the cards-sorting task, and S#9's and S#10's data suggest consistency with positive equivalence only in both the MTS testing phases and the cards-sorting task. For three subjects, the results of the cards-sorting task differed for the results of the MTS testing trials: S#7's and S#8's data suggest equivalence for both the negative elements and the positive elements in the cards-sorting task, but only for the positive elements in the MTS testing trials; S#11's data suggest equivalence for positive elements only in the cards-sorting task, but no equivalence in the MTS testing trials.

Table 5 summarizes equivalence consistent and inconsistent performance for all six subjects with regard to the positive elements and the negative elements in the MTS testing trials and in the cards-sorting task.

Discussion

During MTS procedure in Experiment 2, when testing trials with the negative stimuli preceded testing trials with the positive stimuli, no subjects formed negative equivalences though four of six formed positive equivalences. These results suggest that order of testing may have been at least partially responsible for the establishment of equivalence classes among negative stimuli in Experiment 1.

Order of testing may also explain why the results for all subjects during the cards-sorting task were either the same as the results of MTS tests or exceeded these results.

EXPERIMENT 3

In order to further investigate the possible role of testing order in the establishment of equivalence classes comprised of negative stimuli, a third experiment was conducted in which testing trials with positive or negative sets were interspersed.

Method

Subjects

Five undergraduate students, three women and two men, ranging in age from 19 – 29 years participated in this experiment.

Setting and Apparatus

The setting and apparatus were identical to those used in Experiment 1.

Procedure

The experiment consisted of two phases: a training phase, identical to the procedures used in experiments 1 and 2, and a testing phase. Whereas positive comparisons tests preceded negative comparison tests in Experiment 1 and negative comparisons tests preceded positive comparisons tests in Experiment 2, subjects were exposed to all testing trials of both the negative comparisons and the positive comparisons together during Experiment 3. This testing phase was termed "mixed phase". In the mixed phase, each testing block consisted of 46 trials (6 N-reflexivity probes, 8 P-reflexivity probes, 12 combined probes, 6 symmetry probes, 8 transitivity probes and 6 training trials). The mixed phase consisted of five blocks of 46 trials for a total of 230 trials. All other procedures were identical to Experiment 1.

Results

All five subjects progressed through the fading feedback training trials and achieved mastery after five blocks (i.e. 240 trials). All subjects repeated the first block in the 100% feedback phase, and then progressed through 50% feedback, 25% feedback, and finally 0% feedback. Upon completion of the last training block with 0% feedback with at least 46 of 48 corrects, all five subjects started the testing trials.

During testing phase of both positive and negative comparisons (see Figure 8) trained relations remained intact for all five subjects; two subjects performed with 100% accuracy on the reflexivity trials for positive comparisons (S#13 and S#16) and with greater then 85% accuracy on the symmetry trials for positive comparisons; one subject (#13) performed with greater then 95% accuracy on the transitivity trials for positive comparisons; three of five subjects performed with greater then 85% accuracy on the reflexivity trials for negative comparisons (S#13, S#15, and S#16); and one subject (S#13) performed with 100% accuracy on the combined trials for negative comparisons.

Inconsistent equivalence performance was demonstrated by two of the six subjects: in negative elements tests, subjects #7-#11 demonstrated reflexivity without achieving symmetry and transitivity; subject #15 formed reflexivity relations but not symmetry or transitivity relations for the negative comparisons; and subject #16 formed reflexivity and symmetry relations but not transitivity relations with regard to positive comparisons, and reflexivity but not symmetry and transitivity (combined trials) with regard to the negative comparisons.

Finally, all cards-sorting patterns will be discussed separately for each subject, since each subject’s organization was unique (see Figure 9). It is important to note, though, that one subject (S#12) included one card that was designated as a positive comparison with the non-used cards, and two subjects (S#15, and S#16) included one non-used card in groups with used cards, so that they used 15 of the 17 cards. Two of the five subjects (S#13, and S#14) organized the cards in a manner that was consistent with equivalence for both the positive elements and the negative elements. Sorting patterns for the other three subjects (S#12, S#15, and S#16) did not suggest the formation of equivalence classes for either the negative stimuli of the positive stimuli. For four of five subjects, the results of the cards-sorting task matched the results of the MTS testing trials: S#13's data suggest positive and negative equivalence in both the MTS testing phases and the cards-sorting task; S#12's, S#15's, and S#16's data suggest positive or negative equivalence in one but not the other inconsistency with either positive or negative equivalence in both the MTS testing phases and the cards-sorting task. The sorting pattern for S#14 suggested equivalence among both the negative elements and the positive elements in the cards-sorting task, but no equivalence for either the positive elements or the negative elements in the MTS testing trials.

Table 6 summarizes equivalence consistent and inconsistent performance for all five subjects with regard to the positive elements and the negative elements in the MTS testing trials and in the cards-sorting task.

Discussion

Experiment 3 investigated the potential influence of order of testing on the establishment of equivalence classes comprised of negative stimuli by interspersing testing trials with positive and negative comparisons.

The results indicated that, during Experiment 3, equivalence was less likely to be observed among either the positive elements or the negative elements during MTS procedure than during experiments 1 or 2: of the five participants in Experiment 3, only one subject formed equivalence classes for both the positive stimuli and the negative stimuli. The other four subjects showed no equivalence-consistent behavior. These results suggest that the order of testing may influence formation of equivalence classes.

GENERAL DISCUSSION

This series of experiments investigated potential variables involved in the formation of negative equivalence relations. The results of Experiment 1, in which testing for positive relations preceded testing for negative relations, suggested evidence of equivalence among negative stimuli for 3 of 5 subjects. The results of Experiment 2, in which testing for negative relations preceded testing for positive relations, produced mixed outcomes, with no evidence of equivalence among negative stimuli during Matching-to-Sample (MTS) testing and evidence of equivalence among negative stimuli for two subjects during the cards-sorting test. The results of Experiment 3, in which tests for positive relations were interspersed with tests for negative relations, showed evidence of equivalence class formation for negative stimuli for 1 of 5 subjects. Data from these experiments suggest that negative stimuli that participate in reinforcement contingencies may enter equivalence classes, but that their participation in those classes may be an artificial effect of testing conditions.

Is the demonstration of the formation of equivalence classes among negative stimuli a refutation of Sidman's paradigm? Sidman (1994, 2000) claimed that the equivalence relation will include all the positive elements of the reinforcement contingency; however, the outcomes of the current series of experiments indicate that negative stimuli may also form equivalence classes. Although these outcomes seem inconsistent with Sidman's paradigm, at least two arguments can be made to reconcile the current results with Sidman's account of equivalence.

First, Sidman's assertion that all positive elements may enter an equivalence class does not exclude the possibility that negative elements also may participate in equivalence relations. Logically, neither statement is inconsistent with the other. Therefore, it is possible that positive elements in a reinforcement contingency may enter into equivalence classes and negative elements in a reinforcement contingency also may enter into equivalence relations (either through independent or related mechanisms).

Secondly, in what sense are the negative stimuli considered negative? In this study, the only difference between the negative comparisons and the positive comparisons is that during the preliminary training trials, the negative comparisons never received positive feedback. Beside this difference, negative comparisons are no different than the positive comparisons, and during the negative comparisons' testing phase, the subjects' goal was to choose the correct one – just like they did with the positive stimuli. Thus, though they are negative comparisons by definition, these stimuli still entail some "positive" characteristics.

Thus, one expansion of the Sidman's paradigm would be to include in the equivalence class *all the elements participating in the reinforcement contingency that do not conflict with the establishment of the analytic unit itself.*

Although results of this series of studies indicate that negative stimuli may participate in equivalence classes, two other findings suggest that such outcomes are not robust across participants and may occur only under certain test conditions. First, whereas 7 of 16 subjects showed evidence of the formation of positive equivalence classes in the current experiments, only 4 of 16 demonstrated equivalence consistent performance with negative stimuli. Second, equivalence consistent performance with negative stimuli appeared to be, at least in part, a function of test procedures. When negative stimuli were tested after the positive stimuli, three of five subjects demonstrated negative equivalence in the MTS procedure; when negative stimuli were tested before the positive stimuli, none of the six subjects formed negative equivalence classes; when the trials were interspersed between positive and negative stimuli, only one subject demonstrated negative equivalence.

These outcomes suggest that testing of positive comparisons before testing of negative comparisons may enable and facilitate the formation of negative equivalence. There are three possible accounts for these findings. First, Fields, Verhave, and Fath (1984, in Wulfert & Hayes, 1988) have suggested that increased “associative” distance (i.e., number of stimulus “nodes” between the stimuli) between stimuli in equivalence classes results in longer latencies to respond to comparisons. In negative comparisons classes, there are no nodes; stimuli can be classified based on shared general functions rather than specific associations with particular stimuli. It would seem that responding to negative stimuli would thus be quicker and easier, but it is not. Because negative stimuli are defined based on their negative function relative to a class of positive stimuli, a “vicarious” node in the form of specific positive stimuli, or the class of positive stimuli, may exist between each negative comparison. To the extent that each negative comparison is also connected in nodes to a number of positive comparisons, the number of nodes in the class would be multiplied. Thus, negative equivalence would be based on a more complicated pattern of relations, bounded to positive equivalence and, so, more difficult to obtain. However, speculating the existence of an “unseen” vicarious node is not a sound scientific explanation and as such should be considered with the utmost care.

A second account of the failure of negative equivalence to occur prior to testing for positive equivalence is in terms of delayed emergence of equivalence. Sidman (1994) defined delayed emergence as the abrupt emergence of derived conditional discriminations with repeated nonreinforced testing. Saunders, Saunders, Kirby, and Spradlin (1988) found that an extensive history of two-choice conditional discrimination training and equivalence testing is “sufficient to produce performances that show the development of equivalence relations based on conditional, but unreinforced, selection of comparison stimuli” (p. 151). Sidman (1990) suggested that equivalence tests may provide additional experience that helps separate equivalence relations from others that are possible in the experimental situation. Usually, each stimulus is a member of many classes, besides the one designated to it by the experimenter. Each test trial gives the subject the chance to choose according to the relevant context, even if no reinforcement is available. In essence, “the one consistent sample-comparison relation is sorted out from the many relations that are possible” (Sidman, 1994, p. 277). Similarly, Green and Saunders (1998b) also regard testing as an influential variable in the formation of equivalence classes, and they claim that further training or testing may alter responding on test trials until it is consistent with the development of the intended equivalence classes (e.g. Sigurdardottir, Green, & Saunders, 1990, in Green and Saunders, 1998; Saunders, Wachter, & Spradlin, 1988, in Green and Saunders; Sidman, Kirk, & Willson-Morris, 1985). It is interesting to note that when positive and negative testing trials were interspersed (during Experiment 3), most subjects failed to demonstrate equivalence with either positive or negative stimuli. Thus, combining testing trials of both positive and negative stimuli may impair the development and/or expression of equivalence classes.

Although these accounts may describe variables related to the development of equivalence relations among negative stimuli for three of the four subjects who demonstrated equivalence consistent behavior, the remaining subject who demonstrated equivalence consistent performance (S#13) did so without extensive prior experience with equivalence tests for positive stimuli. A third account for the current data that accommodates this outcome is that all positive comparisons were categorized into equivalence classes (i.e., type S control), and the complementary sets of negative stimuli were grouped together by exclusion (i.e., the class of all stimuli presented during the experiment that were never S+). This account is consistent with the current finding that negative equivalence classes formed more readily in Experiment 1 than in experiments 2 or 3, and is consistent with S#13's outcomes showing simultaneous demonstrations of equivalence when both negative equivalence and positive equivalence were tested. However, this account seems inconsistent with S#2's outcomes (Experiment 1), who demonstrated equivalence consistent performances for negative stimuli in both MTS and cards-sorting tests but did not show evidence of equivalence with positive stimuli in the MTS test.

Important to note is that each of the above explanations does not exclude the others, and a combination of processes is always an option. For example, the best description of the negative equivalence development is that a combination of extensive history of testing accompanied by the categorization of positive comparisons into equivalence classes may comprise the prerequisites for establishing negative equivalence. Future research may account for the important of each of these variables.

Another finding of the current series of experiments is that subjects tended to demonstrate more equivalence consistent behavior in the cards-sorting task, relative to the MTS procedure. Six subjects who failed to demonstrated equivalence in MTS testing did so in the cards-sorting task; and the results of cards-sorting task corresponded with the MTS tests for the other 10 subjects. A potentially important difference between cards-sorting and MTS procedures is that all stimuli are simultaneously present during cards-sorting, and there are no designated roles assigned to any stimuli (samples or comparisons). In this task, there are endless ways of organizing the stimuli, and the ambiguity of the task may facilitate partitioning of the stimuli according to equivalence.

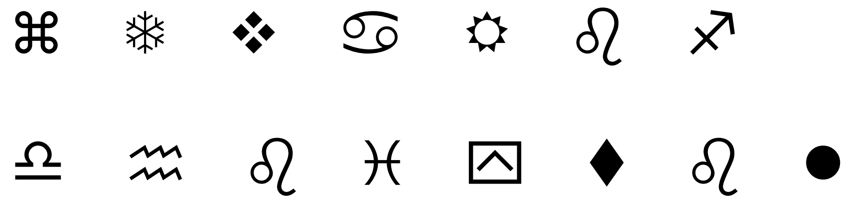
Another potential reason for the difference in results between and the cards-sorting and the MTS procedures may be the order of testing. The cards-sorting task always followed the MTS procedure, occurring after extensive exposure to hundreds of conditional discrimination trials. Thus, if equivalence relations developed during MTS testing (Sidman, 1994), then those relations would more clearly be seen in tests that occurred following MTS tests, as in the current experiments. Future research should present the sorting task after training of baseline discriminations but before the testing trials begin in order to test this account.

The cards-sorting test presented challenges in terms of data analysis and comparison due to unique ways of sorting the cards across participants. That is, because the subjects' responses were relatively unconstrained by the experimental procedures and apparatus, a myriad of response patterns was possible. Thus, procedures for organizing and interpreting the results were impossible to develop until the patterns had been produced. In the current study, the data are presented in relatively raw, visual depictions, allowing the reader to respond to their organization directly. Although quantitative precision is compromised and interpretation is necessarily more subjective than with MTS, the order in patterns of sorted cards is striking. Future research should investigate the general utility of this type of test to identify classes of stimuli.

Future studies may also investigate the effects of different reinforcers and responses for each set of positive comparisons. Sidman (1994, 2000) claimed that using both differential responses and differential reinforcers for each class may facilitate the learning of baseline relations and formation of equivalence classes. Thus, investigating the influences of different reinforcers and responses on the emergence of negative equivalence relations should elaborate our knowledge of negative elements and their influence on our behavior.

In conclusion, the results of the current study suggest that all elements present in experimental arrangements, and not only those elements for which a “designated” role has been arranged, may enter into important relationships with behavior. There is no doubt that attending and responding towards those elements that are associated with the production of positive reinforcement is adaptive behavior. However, differential responding towards classes of stimuli that have systematically been correlated with the absence of reinforcement also may contribute to variability and creativity, and thus have adaptive value too.

Figure 1. Stimuli used in the experiment.



<u>Figure 2</u>. Experiment 1 - Equivalence class formation for positive comparisons (MTS). Dotted line shows chance level, and solid line shows success criterion (80% correct).

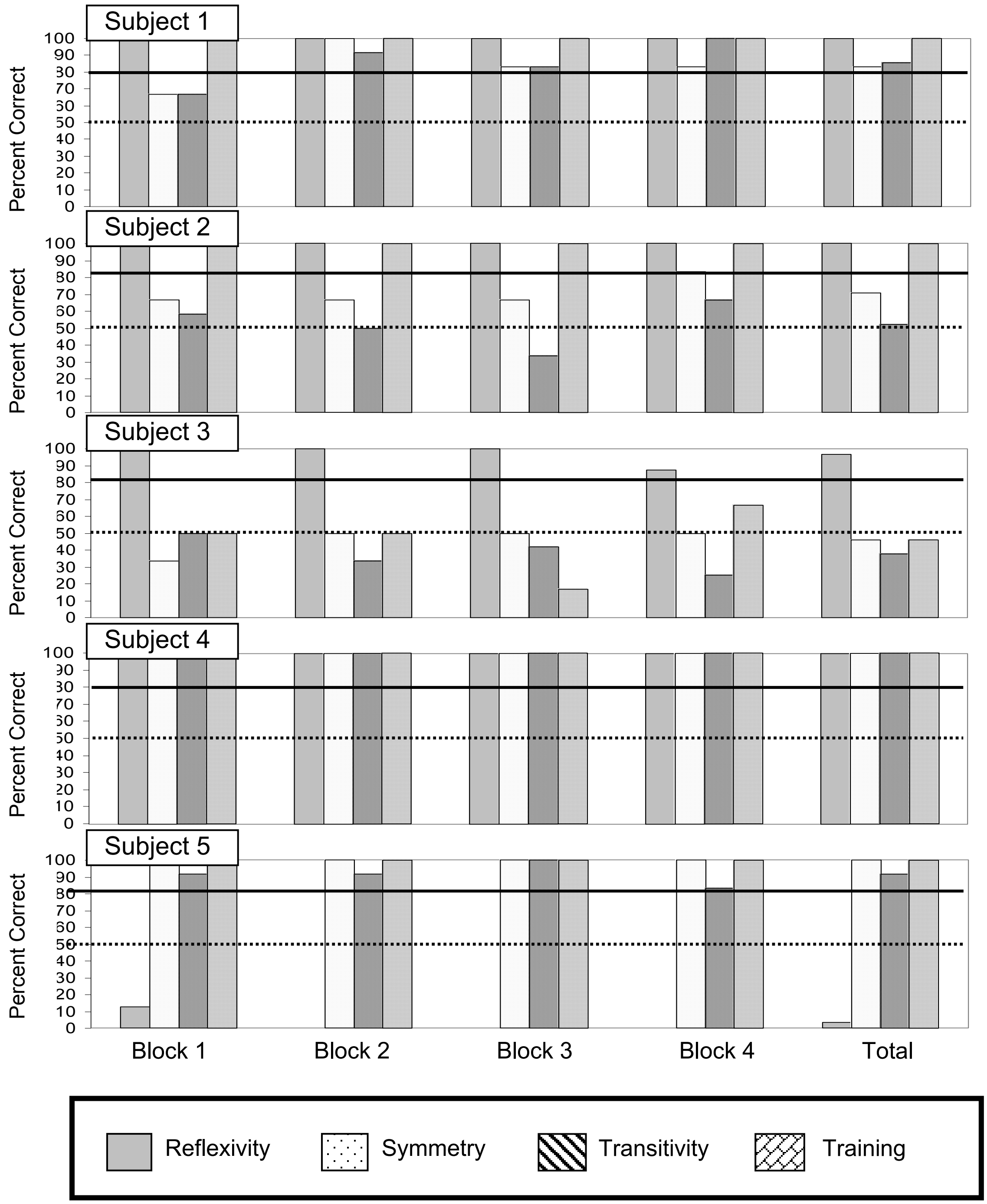


Figure 3. Experiment 1 - Equivalence class formation for negative comparisons (MTS). Dotted line shows chance level, and solid line shows success criterion (80% correct).

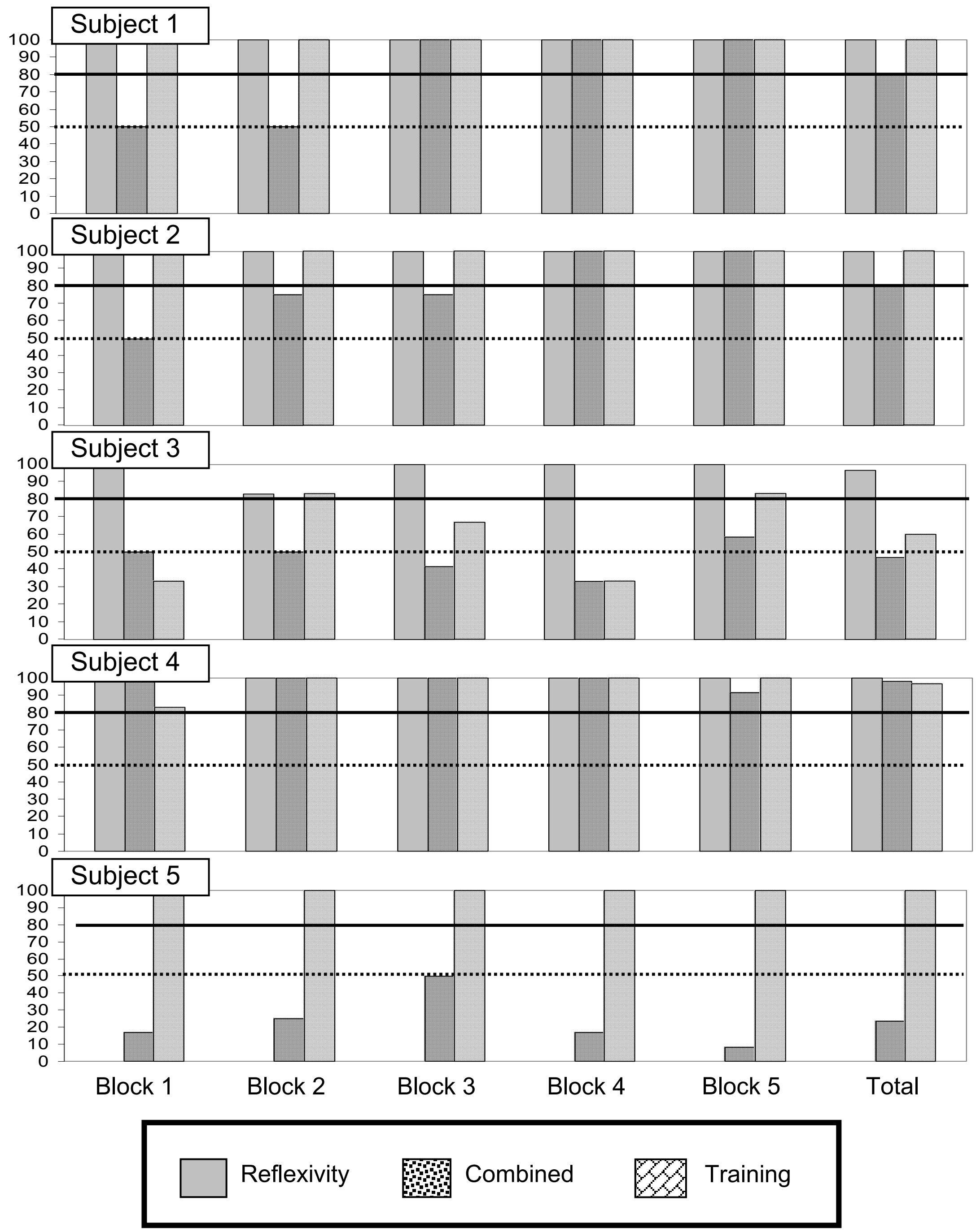


Figure 4. Experiment 1: Cards-sorting patterns of subjects #1-#5. Circles indicate groupings.

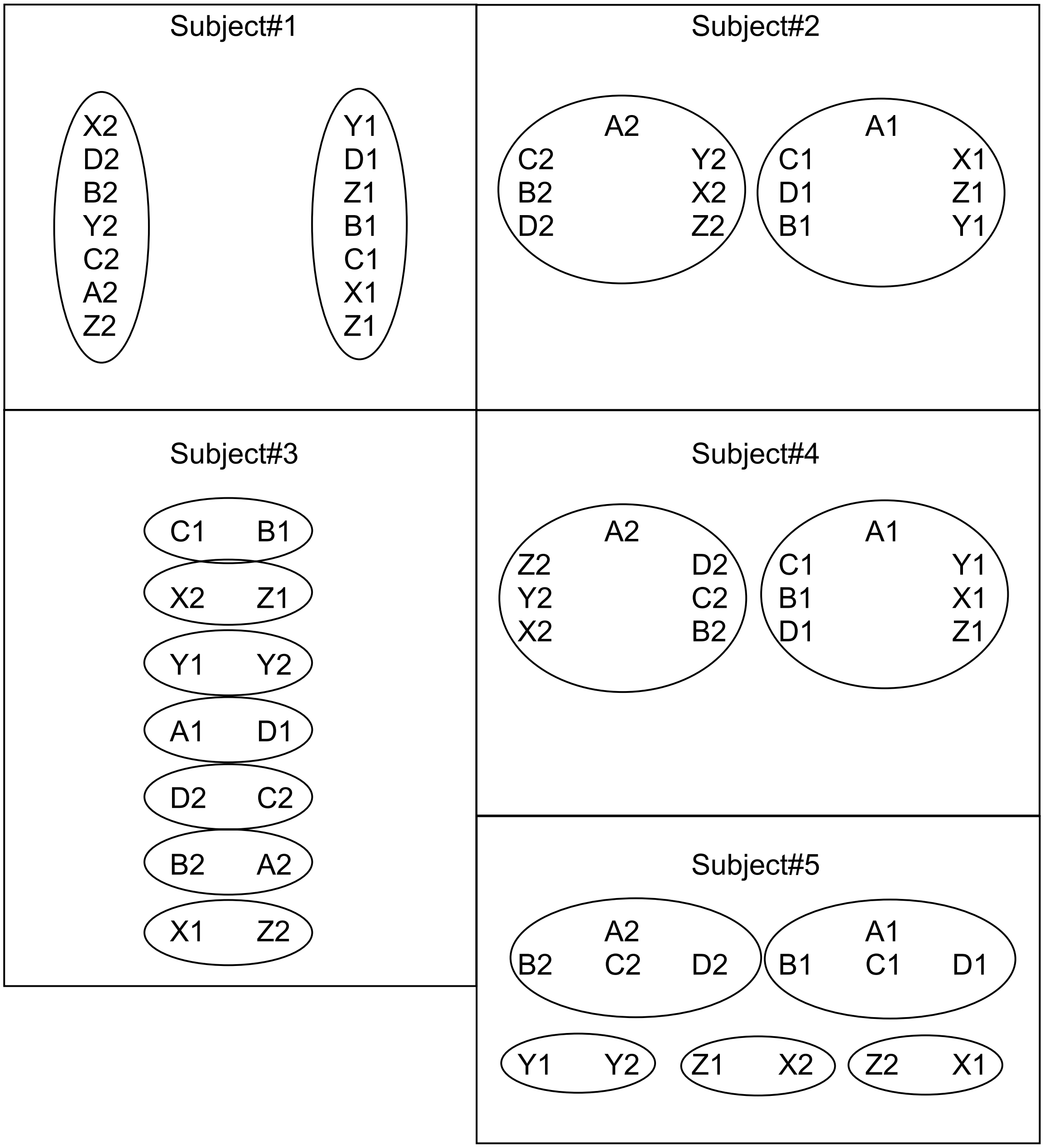


Figure 5. Experiment 2 - Equivalence class formation for negative comparisons (MTS). Dotted line shows chance level, and solid line shows success criterion (80% correct).

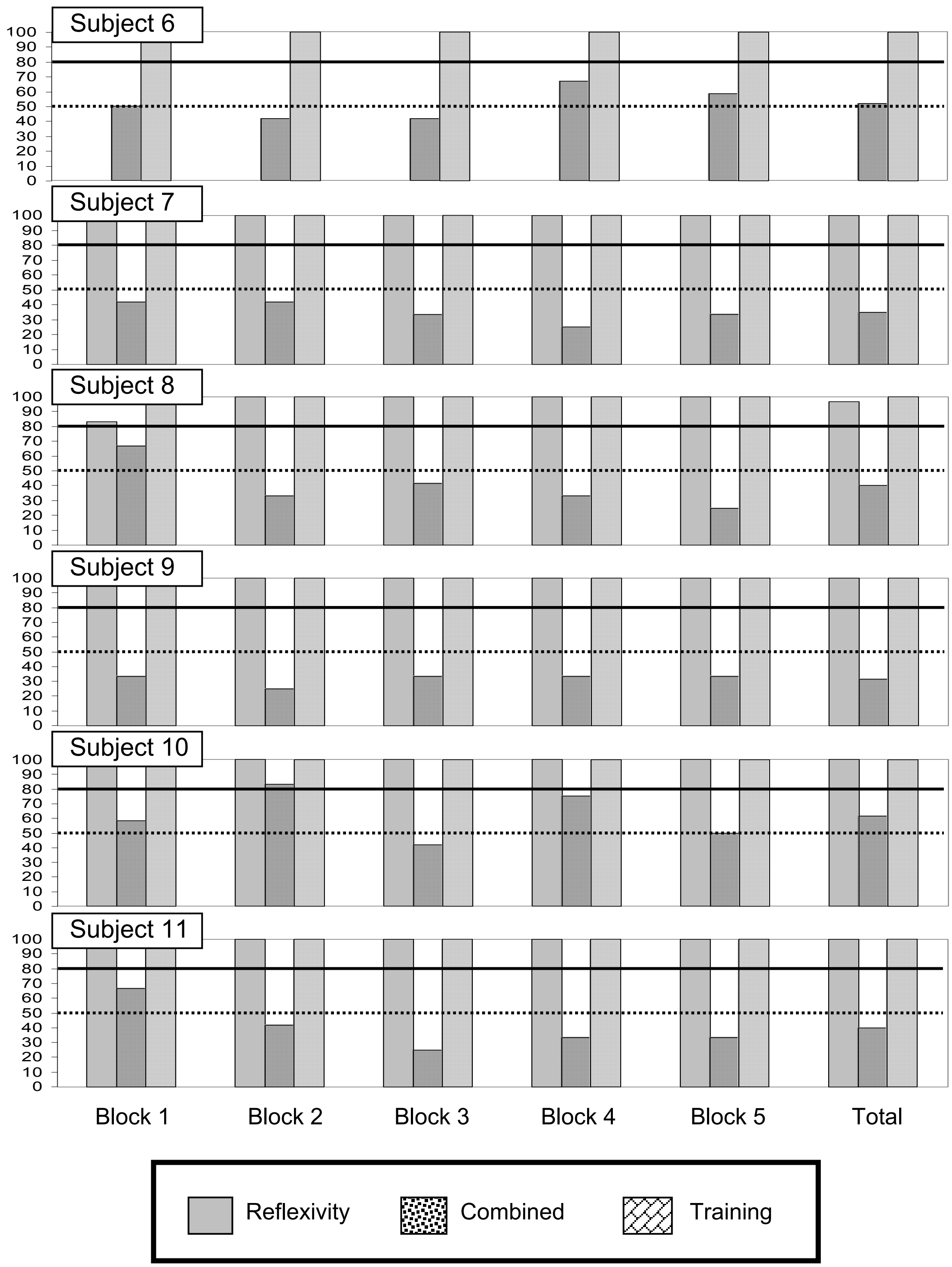


Figure 6. Experiment 2 - Equivalence class formation for positive comparisons (MTS). Dotted line shows chance level, and solid line shows success criterion (80% correct).

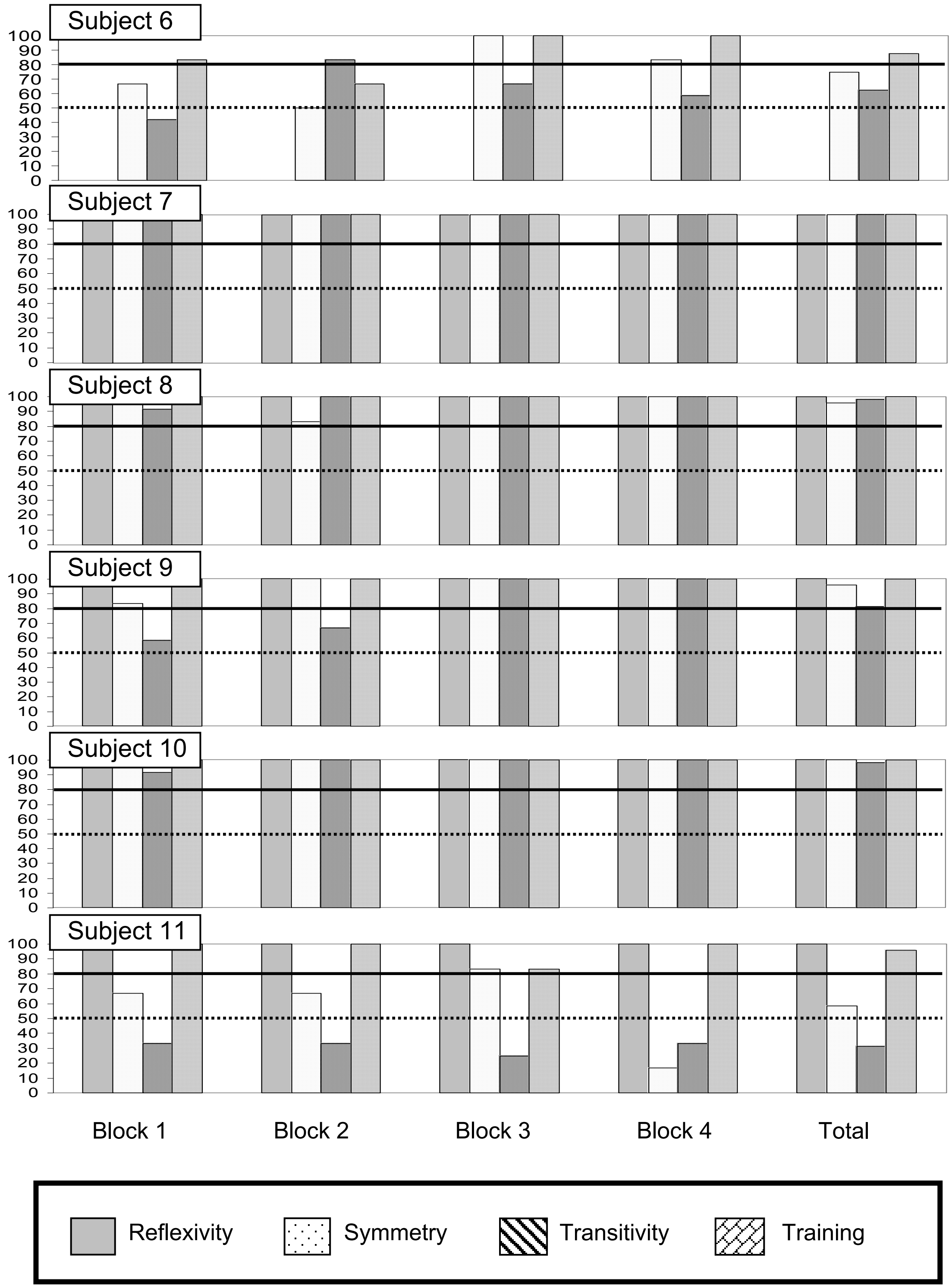


Figure 7. Experiment 2 - Cards-sorting patterns of subjects #6-#11. Circles indicate groupings. 00 designates stimuli that were not present during the MTS procedure but were nevertheless included in the sorting task.

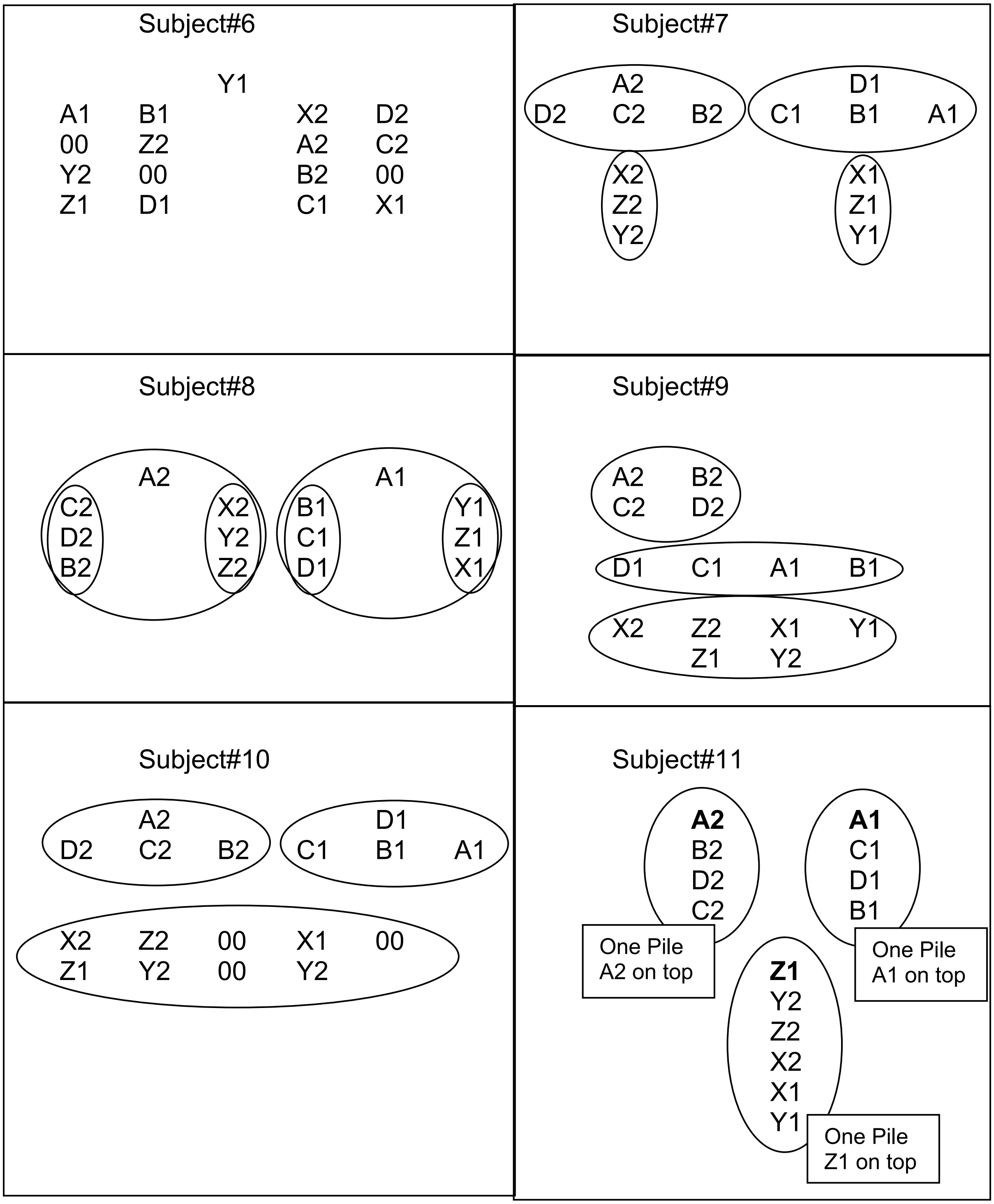


Figure 8. Experiment 3 - Equivalence class formation for both negative and positive comparisons (MTS). Dotted line shows chance level, and solid line shows success criterion (80% correct).

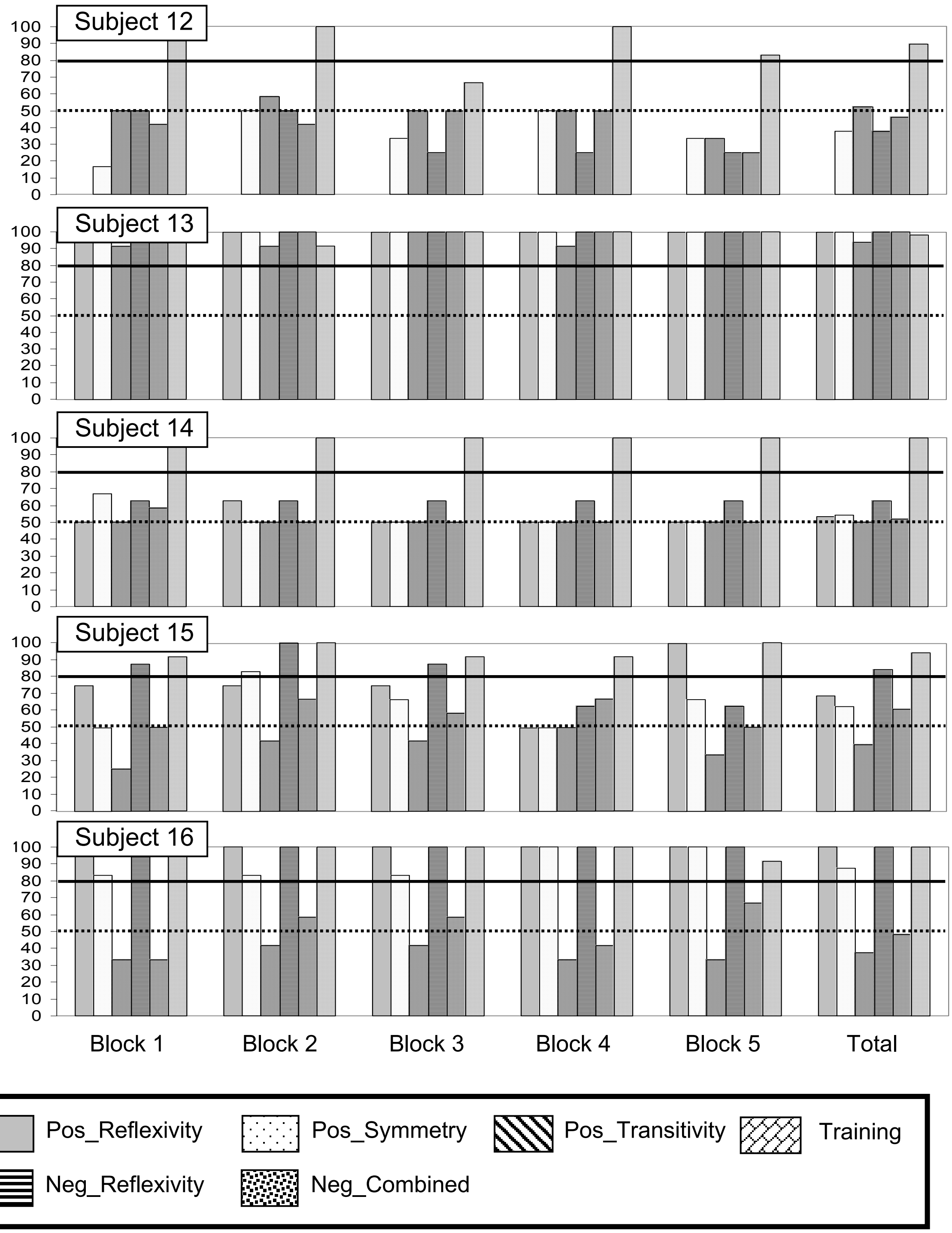


Figure 9. Experiment 3 -.Cards-sorting patterns of subjects #12-#16. Circles indicate groupings. 00 designates stimuli that were not present during the MTS procedure but were nevertheless included in the sorting task.

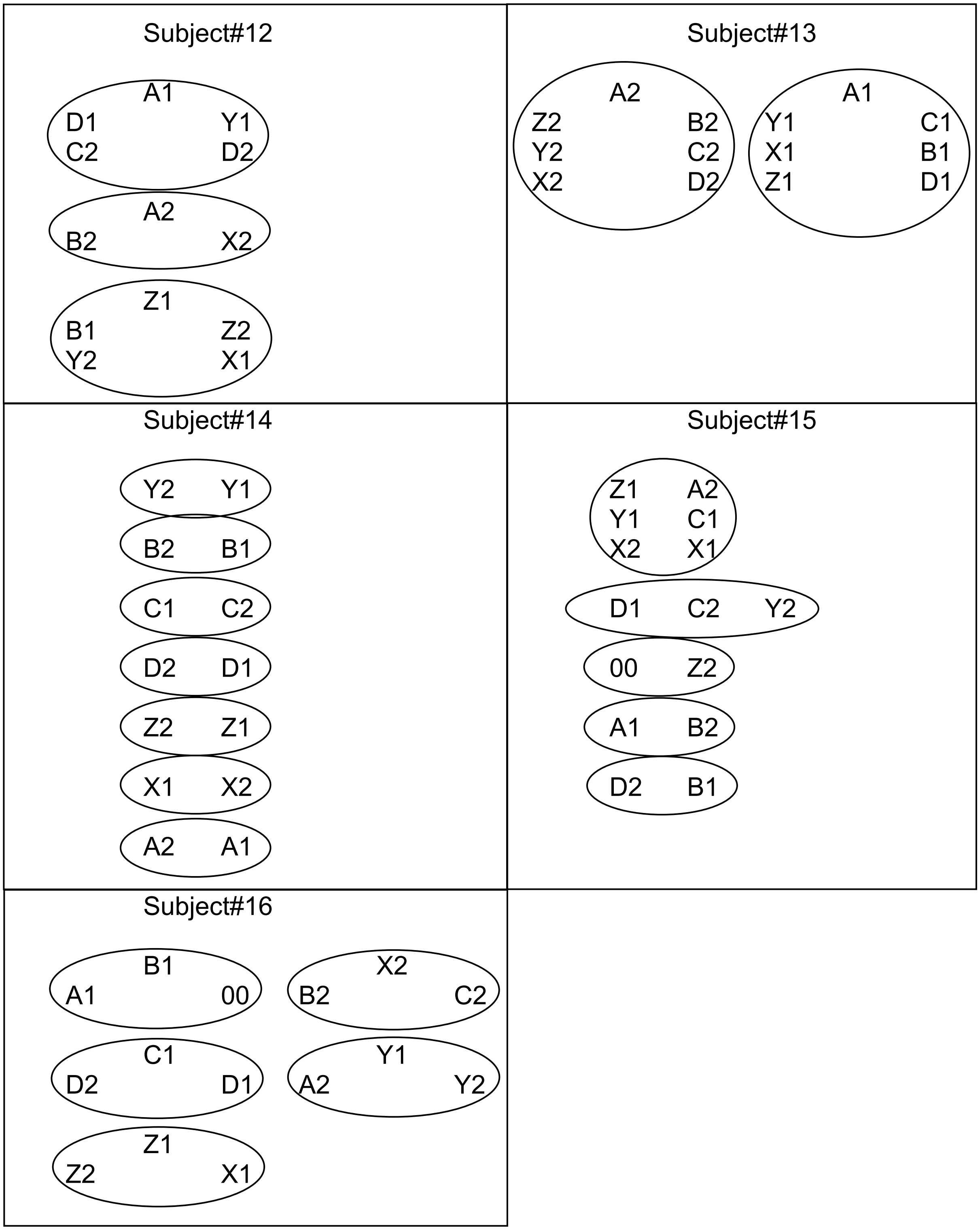


Table 1

Trial Types Used in Training (Exp.1-3)

Sample	Positive (Correct)	Negative (Incorrect)
A1	B1	X1
A1	C1	Y1
A1	D1	Z1
A2	B2	X2
A2	C2	Y2
A2	D2	Z2

Table 2

Trial Types Used in Testing Two Four-Member Equivalence Classes for the Positive Stimuli (MTS)

Relation Type	Sample	Positive (Correct)	Negative (Incorrect)
Reflexivity	A1	A1	A2
	B1	B1	B2
	C1	C1	C2
	D1	D1	D2
	A2	A2	A1
	B2	B2	B1
	C2	C2	C1
	D2	D2	D1
Symmetry	B1	A1	A2
	C1	A1	A2
	D1	A1	A2
	B2	A2	A1
	C2	A2	A1
	D2	A2	A1
Transitivity	B1	C1	C2
	C1	B1	B2
	B1	D1	D2
	D1	B1	B2
	C1	D1	D2
	D1	C1	C2
	B2	C2	C1
	C2	B2	B1
	B2	D2	D1
	D2	B2	B1
	C2	D2	D1
	D2	C2	C1

Table 3

<u>Trial Types Used in Testing Two Three-Member Equivalence Classes for the Negative Stimuli (MTS)</u>

Relation Type	Sample	Positive (Correct)	Negative (Incorrect)
Reflexivity	X1	X1	X2
	Y1	Y1	Y2
	Z1	Z1	Z2
	X2	X2	X1
	Y2	Y2	Y1
	Z2	Z2	Z1
Combined (Symmetry + Transitivity)	X1	Y1	Y2
	X1	Z1	Z2
	Y1	X1	X2
	Y1	Z1	Z2
	Z1	X1	X2
	Z1	Y1	Y2
	X2	Y2	Y1
	X2	Z2	Z1
	Y2	X2	X1
	Y2	Z2	Z1
	Z2	X2	X1
	Z2	Y2	Y1

Table 4

<u>Experiment 1: Equivalence Class Formation for Positive Stimuli and Negative Stimuli, in MTS Testing Trials vs. Cards-Sorting Task, for Subjects #1-#5</u>

Subject No.	Equivalence (positive st.) (MTS)	Equivalence (positive st.) in cards	Equivalence (negative st.) (MTS)	Equivalence (negative st.) in cards
1	Y	Y	Y	Y
2	N	Y	Y	Y
3	N	N	N	N
4	Y	Y	Y	Y
5	N	Y	N	N

Table 5

Experiment 2: Equivalence Class Formation for Positive Stimuli and Negative Stimuli, in MTS Testing Trials vs. Cards-Sorting Task, for Subjects #6-#11

Subject No.	Equivalence (positive st.) (MTS)	Equivalence (positive st.) in cards	Equivalence (negative st.) (MTS)	Equivalence (negative st.) in cards
6	N	N	N	N
7	Y	Y	N	Y
8	Y	Y	N	Y
9	Y	Y	N	N
10	Y	Y	N	N
11	N	Y	N	N

Table 6

Experiment 3: Equivalence Class Formation for Positive Stimuli and Negative Stimuli, in MTS Testing Trials vs. Cards-Sorting Task, for Subjects #12-#16

Subject No.	Equivalence (positive st.) (MTS)	Equivalence (positive st.) in cards	Equivalence (negative st.) (MTS)	Equivalence (negative st.) in cards
12	N	N	N	N
13	Y	Y	Y	Y
14	N	Y	N	Y
15	N	N	N	N
16	N	N	N	N

APPENDIX

INSTRUCTIONS

"WELCOME!

This is an experiment in human performance and decision making.

When the session begins, you will see one symbol appearing on the upper-middle section of the screen. Click the Mouse on that symbol.

After touching this symbol, two other symbols will appear on the bottom part of the screen – one symbol on the bottom-right and the other on the bottom-left. Click the Mouse on <u>one</u> of these two symbols.

Your task is to choose the correct symbol from the two symbols appearing on the screen. <u>There is always a correct answer</u>.

During some parts of the experiment you will get feedback on your answers, but on other parts of the experiment no feedback will be available!

So it is important that you will pay attention to the feedback, since the experiment will increase in difficulty, and choosing the correct answer in the latter parts of the experiment will depend on your knowledge from previous sessions.

After the experiment starts, there will be no breaks!

You will be notified when the experiment ends.

Do you have any questions?"

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