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STIMULUS EQUIVALENCE AND RULE FOLLOWING

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The present study examined the occurrence of a novel behavior pattern with respect to a novel configuration of stimuli enabled by the participation of those stimuli in equivalence classes. In Experiment 1, functional substitutabilities were established via equivalence between two independent sets of musical stimuli. Aspects of stimuli from the two sets were then compounded to produce novel stimulus configurations. Behavioral components enabled by each separate class combined to produce novel musical performances and accurate descriptions of them. In Experiment 2, the impact of experimenter-provided names for equivalence classes on the musical performances was investigated in naive subjects by establishing similar classes without experimenter-provided names. The results indicated few differences in the playing performances under these conditions. These experiments demonstrated a possible method for the analysis of rule following.

Key words: stimulus equivalence, functional substitution, rule following, rule governance, linguistic meaning, novel behavior, humans

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Considerable ambiguity exists within behavior analysis about the nature of rules and rule governance. We have taken the position that rule following involves acting with respect to verbal stimulation at one point in time and, at a later point, acting in some other way with respect to other stimulus conditions (Hayes & Hayes, 1989; Parrott, 1987a). Further, for the second interaction to constitute an instance of rule following, the first and second interactions must be related in some way. Skinner (1969, pp. 146–152) has suggested a relation of "specification." More precisely, rule following implies functional substitutabilities among the stimuli constituting the rule and those constituting the conditions under which rule following is to take place (Hayes & Hayes, 1989; Parrott, 1987b). An uncontaminated instance of rule following implies a novel pattern of activity. This is the case because, if the pattern has a history, its occurrence and form may be attributable, at least in part, to selection by past consequences.

How rules and the conditions they specify come to be functionally substitutable has not been addressed adequately in the rule governance literature. Research has focused on the conditions under which rule following occurs, assuming that subjects already know what the rules refer to (e.g., Catania, Matthews, & Shimoff, 1982; Galizio, 1979; S. C. Hayes, Brownstein, Haas, & Greenway, 1986; S. C. Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986; LeFrancois, Chase, & Joyce, 1988). It is not yet known how subjects know what rules refer to, nor how they can identify prevailing conditions as those specified or not specified in previously encountered rules.

One process by which stimuli can become functionally substitutable has been addressed in the behavior-analytic literature under the rubric of stimulus equivalence. Functional substitutabilities among members of an equivalence class are demonstrated in the symmetrical and equivalence relations they sustain with other members of their class. In the case of symmetry, for example, the roles of conditional and discriminative stimuli (i.e., samples and comparisons, respectively) are functionally reversible (Sidman, 1986; Sidman & Tailby, 1982).

The functional substitution among members of an equivalence class has engendered analogies between equivalence and linguistic meaning (Hayes & Hayes, 1989; Lazar, 1977; Sidman & Tailby, 1982). The responses made to one member of an equivalence class may transfer to other members based in part on their relation to other members of that class (Wulfert & Hayes, 1988). In a functional sense,

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the "meaning" of one member includes responses originally acquired with respect to other members. For example, the meaning of the name for an object consists in part of responses acquired with respect to the object itself, as when one "sees" an apple upon hearing the word apple (Parrott, 1984).

If equivalence relations are analogous to linguistic relations, it may be possible to construct what would be considered a rule out of members of equivalence classes. A rule usually consists of a novel combination of familiar verbal elements. By this logic, a novel combination of elements of previously established equivalence classes may be considered a rule. The stimulus conditions in which novel performances are to take place would share membership in equivalence classes with the stimuli constituting the rule. Novel performances under these conditions would then be interpretable as rule following.

In the present study, two independent sets of equivalence relations among musical stimuli, one relevant to timing, the other placement, were established. Aspects of stimuli comprising those in both sets were then compounded as an occasion upon which the occurrence of novel musical performances, and descriptions of them, were assessed. Some of the functions operating in the terminal performances required derivation through the underlying equivalence classes (e.g., see Wulfert & Hayes, 1988). Others were trained directly.

EXPERIMENT 1

METHOD

Subjects and Conditions

Nine right-handed undergraduates served as subjects in exchange for money at a rate of approximately minimum wage. Subjects had no previous training in music sight reading and no significant history of other musical performances. Subjects were assigned randomly to one of three conditions: timing and placement training ($n = 5$); timing only training ($n = 2$); and placement only training ($n = 2$).

The timing and placement training condition was the primary experimental condition. Subjects in this group received training that could give rise to both timing and placement equivalence classes. The timing only training and placement only training conditions were control conditions. In each, training that could give rise to only one type of equivalence class, timing or placement, respectively, was provided.

Apparatus and Setting

Sessions were conducted in a small room equipped with a one-way mirror, an audio speaker, an intercom, a video camera, and, during particular phases of the study, a Juno-6 Roland® polyphonic synthesizer, a metronome, and various sets of other stimulus materials, as described below.

General Procedures

All subjects participated in at least three sessions. During the first session, pretests of keyboard playing and of the equivalence relations, as described below, took place; during the final session, the posttest of keyboard playing and the descriptions of keyboard playing occurred. Between these two sessions, conditional discrimination training and equivalence testing took place across a variable number of sessions depending on the experimental condition in effect and the number of training trials required for individual subjects to acquire the conditional discriminations. Sessions lasted a maximum of 1 hr.

Subjects completed the pre- and posttests of keyboard playing and keyboard playing description alone in the experimental room, with instructions provided by way of an intercom. Conditional discrimination training and equivalence testing took place with an experimenter seated across from the subject. The experimenter presented stimuli and recorded the subjects' responses. A correct response was signaled by a green light flash. An incorrect response was signaled by a red light flash. Both the principal experimenter and the experimenter who conducted the reliability assessments were accomplished musicians. Decisions on feedback for correct and incorrect responding on the music-related conditional discrimination trials thereby required no experiment-specific training and presented no difficulties of execution.

Conditional Discrimination Training and Equivalence Testing

In all training and testing trials, for all groups, a sample appeared along with the correct comparison and two or more incorrect comparisons selected from a given stimulus set at random. Unless otherwise indicated, stimuli were drawn in black ink on sheets of white cover stock. Samples appeared alone on a single sheet, comparisons together on another sheet. Training on each relation continued until a criterion of 14 correct of 15 selections occurred. Each relation was tested over two blocks of 10 trials each.

Subjects were instructed as follows:

> You will receive a number of trials in which you will be shown a sample stimulus and will be required to point to one of three or more other stimuli that you think goes with the sample. During some phases, you will see a green light flash if you point to the correct one; a red light if you point to an incorrect one. During other phases you will not see any lights regardless of your answers. Remember your task is to point to the one that goes with the sample.

Timing classes. Six equivalence classes relevant to the issue of music timing were established in the timing and placement and timing only groups. An example of such a class is shown in Figure 1. The A stimulus in this example is a pattern of auditory stimuli making up four beats, specifically, one note held for two beats, followed by two notes each held for one beat. There were six rhythm patterns in Stimulus Set A, each made up of four beats. All stimuli were played at the same pitch (middle C) and at the same tempo on a Juno-6 Roland® polyphonic synthesizer. When stimuli from Set A occurred as comparisons in tests of the symmetrical relations BA and CA, they were presented sequentially with brief periods of silence between them; this presentation was then repeated a second time. A selection was required during the second presentation and was made by the subject's signaling the experimenter immediately following the chosen pattern.

The B stimulus in the example is a sequence of notes corresponding to the rhythm pattern shown as A. There were 12 different note sequences in Set B, six sequences representing four beats corresponding to the rhythm patterns in Set A and six sequences representing more or less than four beats. Correct timing involved both beats per note and beats per bar. Thus, incorrect comparisons included noncorrespondences of specific four-beat sequences and noncorrespondences of the number of beats in the sequence.

The C stimulus in the example is a sequence of words representing the notes corresponding to the rhythm pattern in A. There were 12 different word sequences in Stimulus Set C, six representing the notes corresponding to the rhythm patterns of Set A and six representing notes making up more or less than four beats. The words included: "quarter note," "half-note," and "whole note."

Twelve conditional discriminations were trained, six A-B relations and six A-C relations, as indicated by the solid arrows in Figure 1. Subsequently, tests for symmetry of these relations, and for equivalence involving stimuli in Sets B and C, were conducted, as indicated by the broken arrows. By these procedures, six three-member timing classes were established.

Placement classes. Four-member equivalence classes relevant to the issue of placement were established in the timing and placement and placement only groups, as shown in Figure 2. The trained relations are indicated by the solid arrows in Figure 2, the tested relations by the broken arrows. Each stimulus in Set D consisted of a musical staff with one of four positions marked on it, the position corresponding to the first F, G, A, or B notes above middle C.

The stimuli in Set E were four white keys on the synthesizer corresponding to the four staff positions making up Set D. These keys appeared with three black keys, the remaining keys being covered. During conditional discrimination training and equivalence testing, the synthesizer was turned off and comparisons were selected by pointing to one of the exposed keys.

The stimuli in Set F were four fingers on the subject's right hand, including the thumb, index, middle, and ring fingers. These stimuli represented the appropriate fingers with which to play the keys corresponding to the staff positions of Set D. Comparisons were selected by subjects pointing to one of their own fingers.

The stimuli in Set G were the letter names for the four notes corresponding to the staff positions of Set D: "F," "G," "A," and "B."

Pretest of Equivalence Relations

Prior to the onset of conditional discrimination training, the equivalence relations predicted as an outcome of training were pretested without feedback in a mixed series of match-to-sample trials. Each trial consisted of a sample stimulus drawn from a given set (e.g., B1) and three comparison stimuli, one correct and

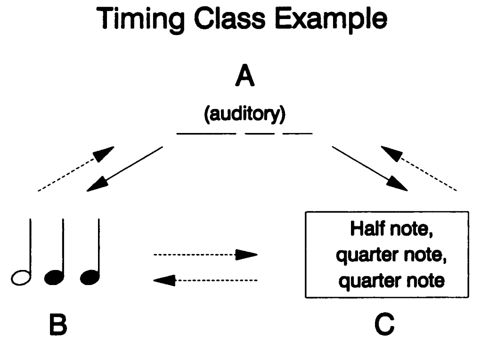


Fig. 1. An example of a music timing equivalence class. Trained relations are shown by solid arrows, tested relations by broken arrows.

two incorrect, drawn from another set (e.g., C1, C2, and C3).

Subjects in the timing and placement training condition received 40 test trials, 10 each on relations BC/CB, EF/FE, FG/GF, and EG/GE; those in the placement only condition received 30 trials, 10 each on relations EF/FE, FG/GF, and EG/GE; and those in the timing only condition received 10 trials on relation BC/CB.

Playing the Keyboard

Pretest. Prior to establishing the timing and placement equivalence classes, pretests of keyboard playing were conducted as follows. Subjects were seated in front of a synthesizer that produced a slow metronome beat, and on which only four white and three black keys were exposed. They were shown a musical score (described below), and told to "play it as well as you can." Five scores were presented during this test, a new score introduced after each playing attempt was completed, as indicated by the subject. Tests were videotaped and scored from the tape following the session.

Posttest. After establishing the timing and placement equivalence classes, subjects repeated the pretest. Each score was made up of 12 pitches, organized into seven bars with four beats to the bar. The 12 pitches were selected from among the first F, G, A, B sequence above middle C, such that three instances of each pitch were included in each sequence, their order determined randomly. Four notes of each type (i.e., quarter, half, and whole) appeared in each score, their order of occurrence also determined by random selection. The procedure by which these pitch sequences were constructed, plus the fact that the notes F, G, A, and B do not comprise a tonal sequence, guarded against the chance production of culturally familiar sound patterns.

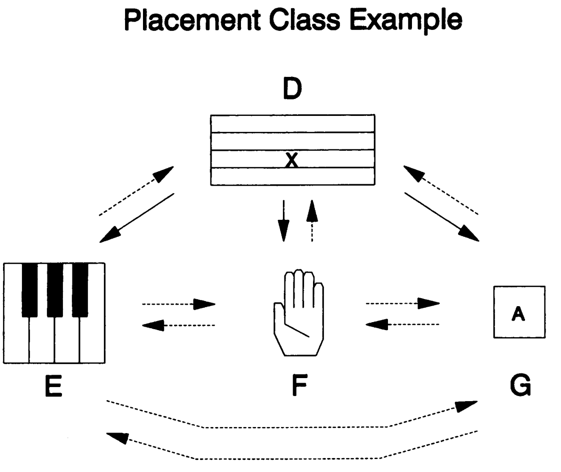


Fig. 2. An example of a music placement equivalence class. Trained relations are shown by solid arrows, tested relations by broken arrows.

In the posttest, subjects were required to play a given pitch sequence until a criterion of no more than four errors were made. For the timing and placement training group, three errors per note, including incorrect fingering, keyboard placement, and timing, were considered in calculating this criterion. For the timing only training group, one error per note, timing, was considered; for the placement only training group, two errors, fingering and keyboard placement, were considered. Explicit feedback on errors was not provided during the test; a new pitch sequence was simply introduced upon meeting the criterion. This procedure continued until all five pitch sequences had been played to criterion.

A correct response in this situation involved holding down particular keys for particular numbers of beats with particular fingers. Prior to this test, subjects had not held down any of the keys for any length of time with any fingers, nor had they seen notes on a musical staff.

These tests were videotaped and the numbers of errors made of each type were recorded from the tape. During the session itself, the experimenter counted errors as they occurred in a given playing attempt, recycling the score upon its completion if greater than the criterion number of errors had been tallied during the attempt, otherwise introducing a new score.

Describing Playing the Keyboard

After the keyboard-playing posttest, subjects in the timing and placement training condition were asked to describe keyboard playing by completing a questionnaire concerning the pitch sequences they had just played. For each note appearing on a score, five questions were asked: (a) What is the letter name of the note; (b) which finger is used to play the note; (c) on which key is the note played; (d) what kind of a note is it; and (e) how many beats does the note receive.

Reliability

Test segments were videotaped for the purpose of assessing the reliability of the data. Reliability on keyboard playing was calculated by dividing agreements with respect to key, fingering, and timing for each note of each pitch sequence for all subjects, and dividing by agreements plus disagreements on these measures. The reliability was 95%.

RESULTS

Acquisition of Equivalence Classes

Timing and placement training subjects (S1–S5). The results of equivalence training and testing for the timing and placement training subjects are shown in Figures 3a and 3b. No subject showed evidence of the equivalence relations in pretesting. All subjects showed symmetry and equivalence in the timing classes and symmetry of the placement classes. S1 failed to meet an 80% criterion on the placement equivalence tests. After retraining, the criterion was reached by this subject. All other subjects met criterion on the placement equivalence tests.

Timing training only subjects (S6 and S7). Results of equivalence training and testing for S6 and S7 are shown in Figure 4. Pretests of the timing equivalence relation showed no evidence of preexistence for either subject. Perfect symmetry and equivalence of the trained relations emerged for both subjects.

Placement training only subjects (S8 and S9). Results of equivalence training and testing for S8 and S9 are shown in Figure 4. Neither subject showed evidence of the placement equivalence relations in the pretest. Symmetry of all trained relations and all equivalence relations emerged for both subjects by the end of the second block of test trials.

Keyboard Playing

Pretests. None of the subjects in any of the groups showed correct timing, key selection, or fingering on any score during the pretest of keyboard playing.

Timing and placement training subjects. The number of practice trials to criterion (i.e., no more than four errors on trained elements, including timing, key selection, and fingering) on each of the five pitch sequences during the posttest for the timing and placement subjects is shown in Figure 5. In general, a pattern of decreasing numbers of trials to criterion across pitch sequences is shown for all subjects. S1 began with five trials to reach criterion on the first score, decreasing to two by the final score; S2 went from six to three, S3 from 17 to three, S4 from three to two and S5 from 10 to two.

Timing training only subjects. The number of practice trials to criterion on timing for both subjects was two trials on the first score, followed by one each on the other four scores. Neither subject responded correctly with respect to the untrained placement elements.

Placement training only subjects. The number of practice trials to criterion on placement elements for both subjects was one trial per score. Neither subject responded correctly with respect to the untrained timing element.

Describing Keyboard Playing

Timing and placement training subjects. Figure 6 compares the number of descriptive errors combined for all pitch sequences with the number of playing errors combined for all pitch sequences for the subjects in the timing and placement training group. Comparable errors were of three types: playing with or saying that one plays with the wrong timing; playing or saying that one plays the wrong key; and playing or saying that one plays with the wrong finger.

No subject showed fewer playing errors than descriptive errors on any of the error types. S1 and S5 showed fewer descriptive errors than playing errors on each type of error. S2 showed fewer descriptive errors of the key and finger types with no difference in timing. S4 showed fewer descriptive errors on timing and key selection, with no difference in fingering. S3

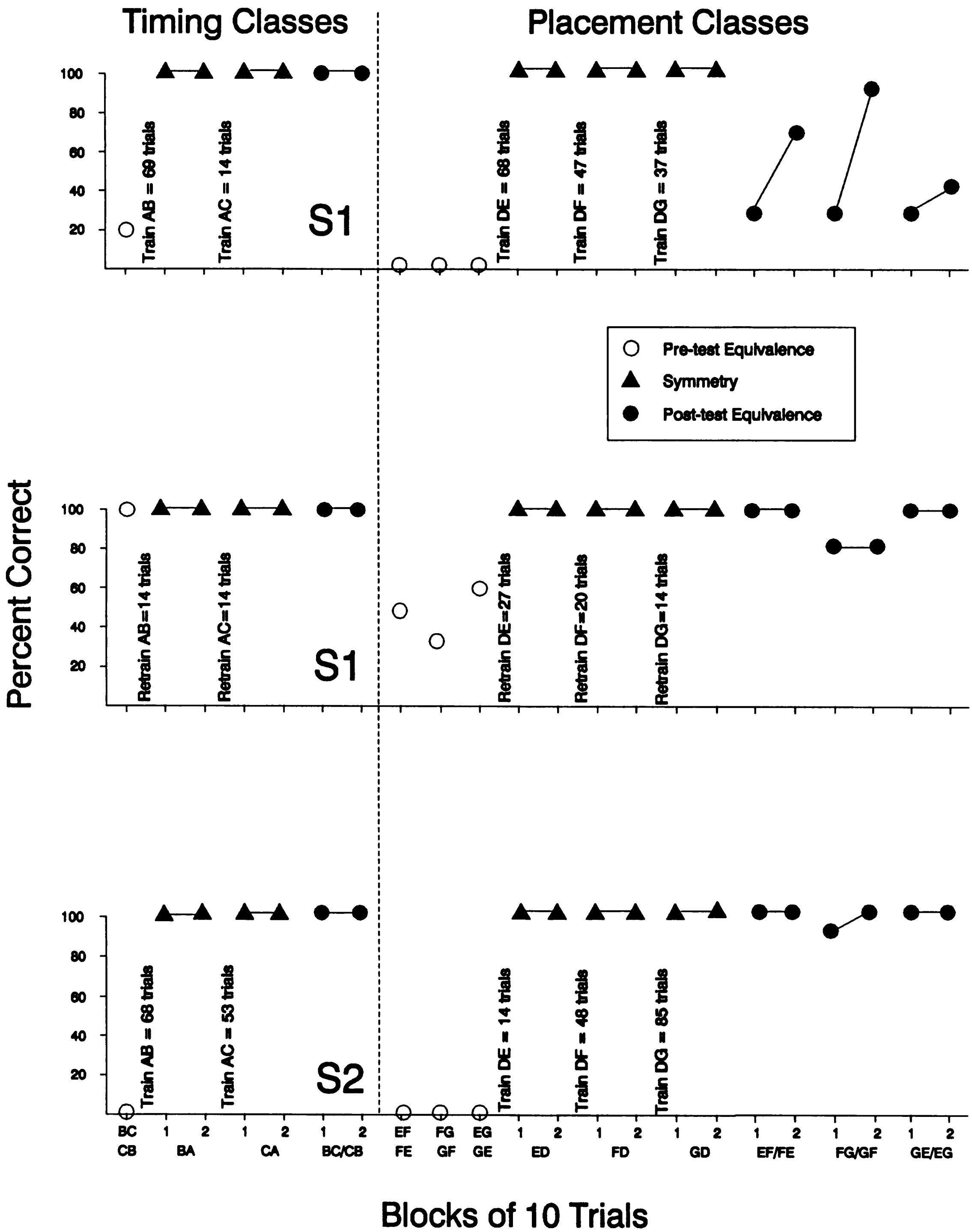


Fig. 3a. Individual training and testing data for Subjects 1 and 2 of the timing and placement training group. Test data are presented as percentages of trials correct (vertical axis) across blocks of 10 trials (horizontal axis). Numbers of training trials are shown in vertical text.

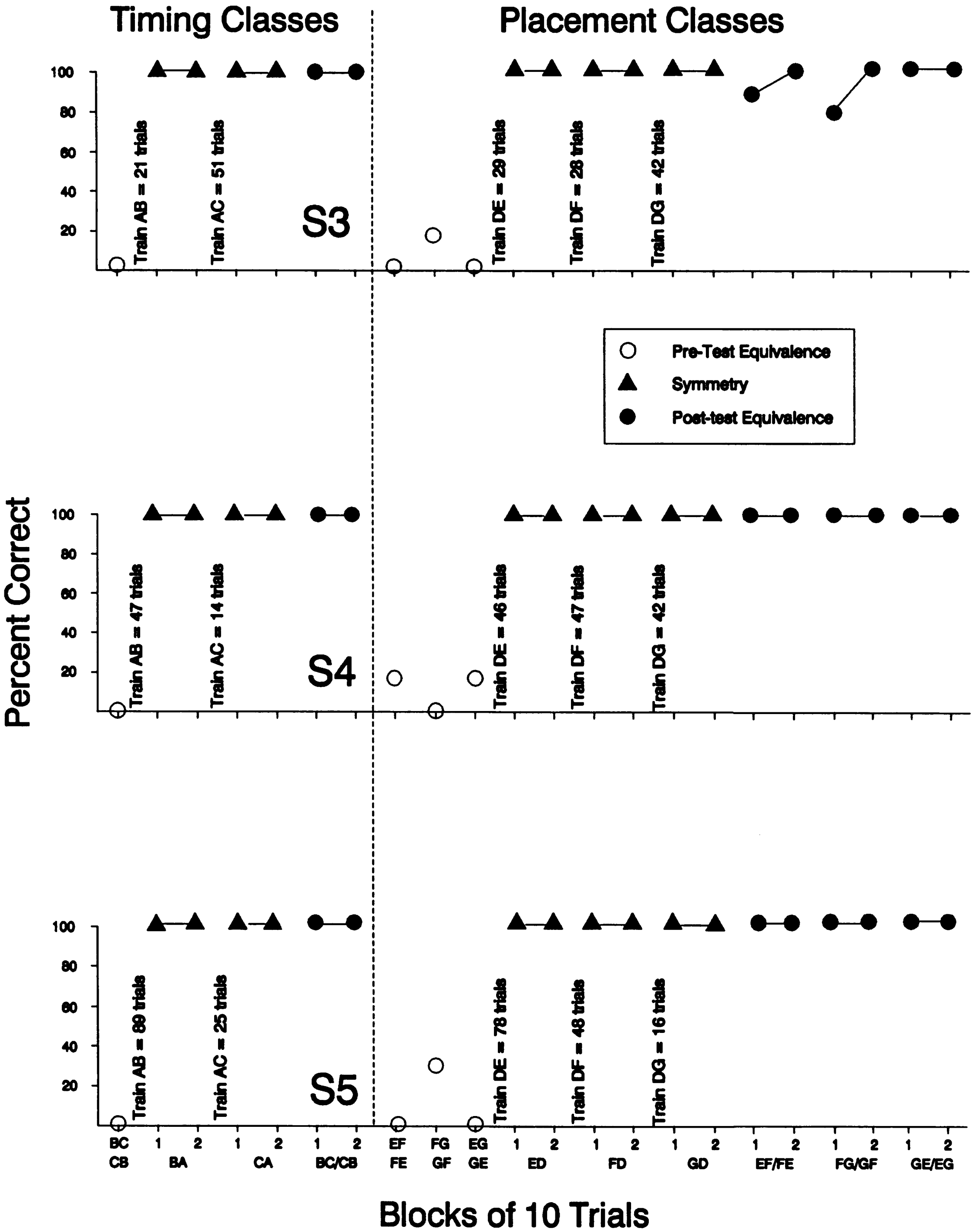
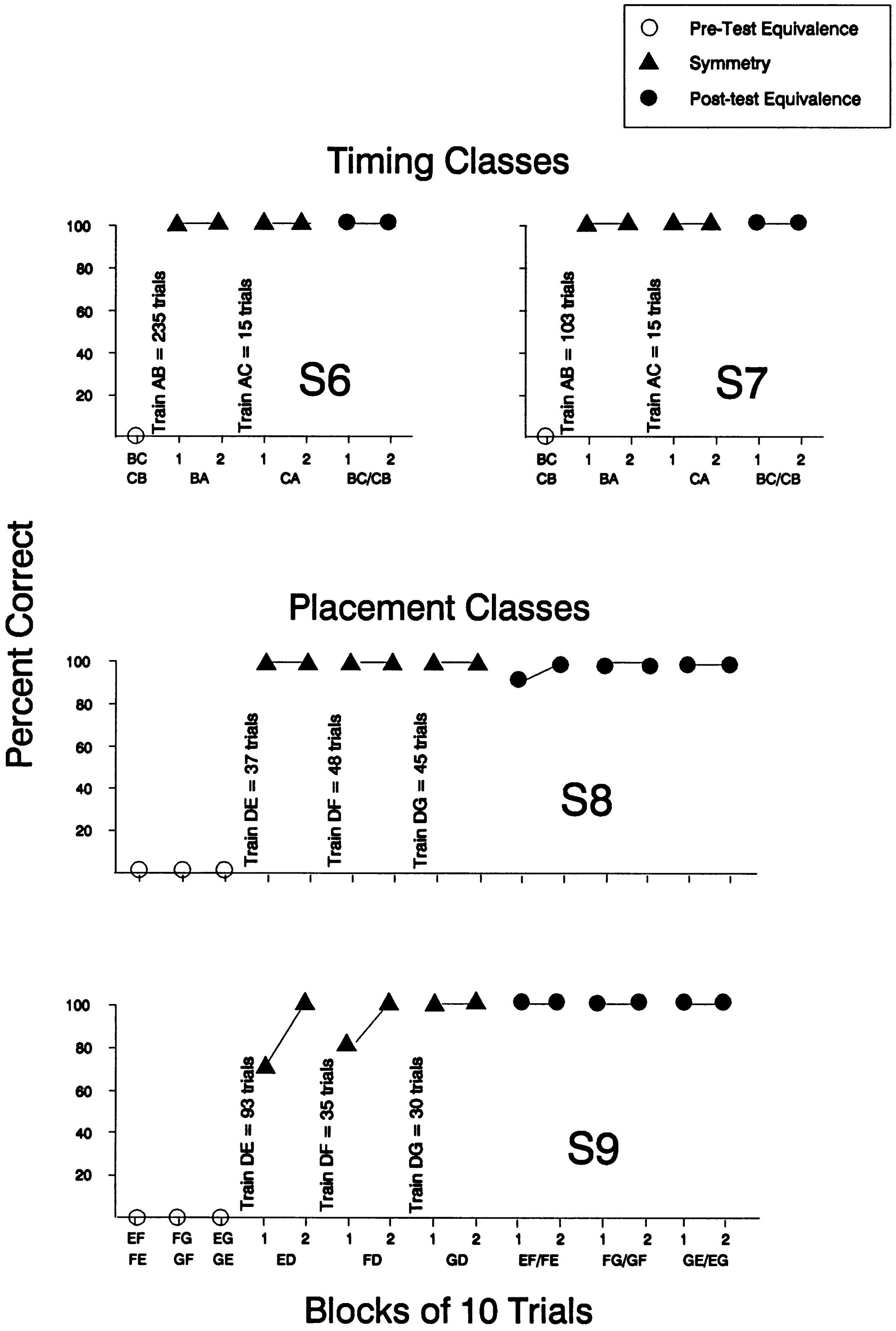


Fig. 3b. Individual training and testing data for Subjects 3 to 5 of the timing and placement training group. Test data are presented as percentages of trials correct (vertical axis) across blocks of 10 trials (horizontal axis). Numbers of training trials are shown in vertical text.


Pre-Test Equivalence
Symmetry
Post-test Equivalence
Timing Classes
Train AB = 235 trials
Train AC = 15 trials
S6
Train AB = 103 trials
Train AC = 15 trials
S7
BC CB
BA
CA
BC/CB
Percent Correct
Placement Classes
Train DE = 37 trials
Train DF = 48 trials
Train DG = 45 trials
S8
Train DE = 93 trials
Train DF = 35 trials
Train DG = 30 trials
S9
EF FE
FG GF
EG GE
ED
FD
GD
EF/FE
FG/GF
GE/EG
Blocks of 10 Trials

showed fewer descriptive errors on timing, with no difference in key selection and fingering.

Discussion

The purpose of Experiment 1 was to determine whether a compound stimulus, composed of elements from two independent sets of equivalence classes, could lead to the occurrence of a novel pattern of activity. All subjects exposed to these conditions, namely those in the timing and placement training group, showed this effect by playing the keyboard. Subjects trained only on timing or on placement relations were able to accomplish only those aspects of keyboard playing that the trained relations made possible, providing support for the contention that the keyboard performances were based on the previously acquired equivalence relations.

Subjects were instructed to "play it as well as you can" and although they were not musically knowledgeable, they surely had seen keyboards being played. This history and the general orienting instructions account for the subjects playing the keyboard in the pre- and posttests, rather than doing something else with it. Equivalence relations must be invoked, however, to explain *what* was played and *the manner* in which it was played.

Playing performances showed improvement across scores in the absence of explicit feedback, even though the scores were different. The verbal description data show that subjects could describe the correct performances quite well. Perhaps subjects could discriminate correct from incorrect performances well before they could execute the actual motor behavior. The timing requirement meant that subjects had to be concerned with speed as well as accurate placement. Practice may have been necessary to establish sufficient fluidity to their motor performance. We might say that the subjects knew the rule, but had to practice following it.

Successful performances in the present case also required classes of previously established relational responding to become more fully integrated. This integration, first with respect to the timing and placement classes and then of

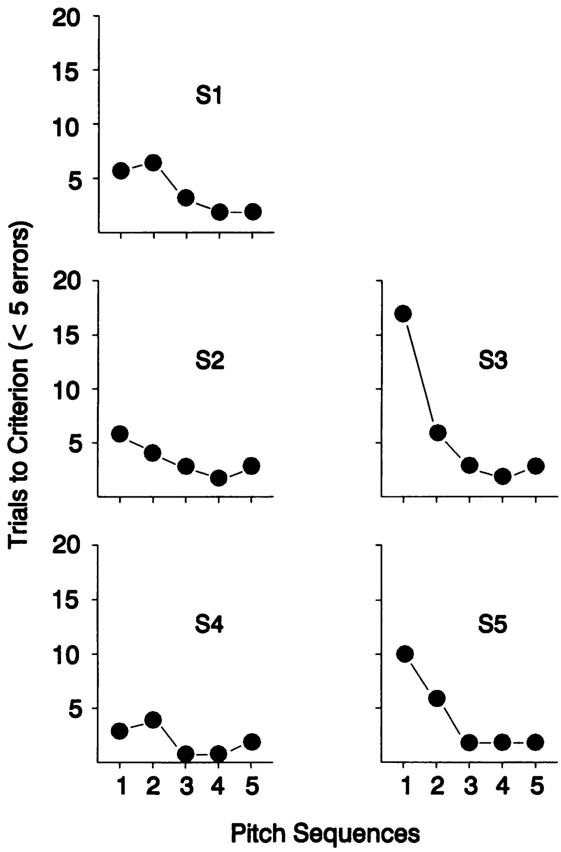


Fig. 5. Trials to criterion (less than five errors) for each pitch sequence in the keyboard playing test for Subjects 1 to 5 in the timing and placement training group.

these with the playing activity, may have constituted the development of larger and larger equivalence classes. If so, the improvement in the playing performances across pitch sequences may represent the sort of unreinforced acquisition effect that has been observed in the development of other, simpler equivalence relations (e.g., Devany, Hayes, & Nelson, 1986; L. J. Hayes, Tilley, & Hayes, 1988).

These processes are not the only possible explanations for the acquisition-like improvement during testing. Implicit feedback as to the adequacy of total performance on a specific score may have been provided by having to repeat the score versus having a new score

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Fig. 4. Individual training and testing data for Subjects 6 and 7 in the timing training only group and Subjects 8 and 9 in the placement training only group. Test data are presented as percentages of trials correct (vertical axis) across blocks of 10 trials (horizontal axis). Numbers of training trials are shown in vertical text.

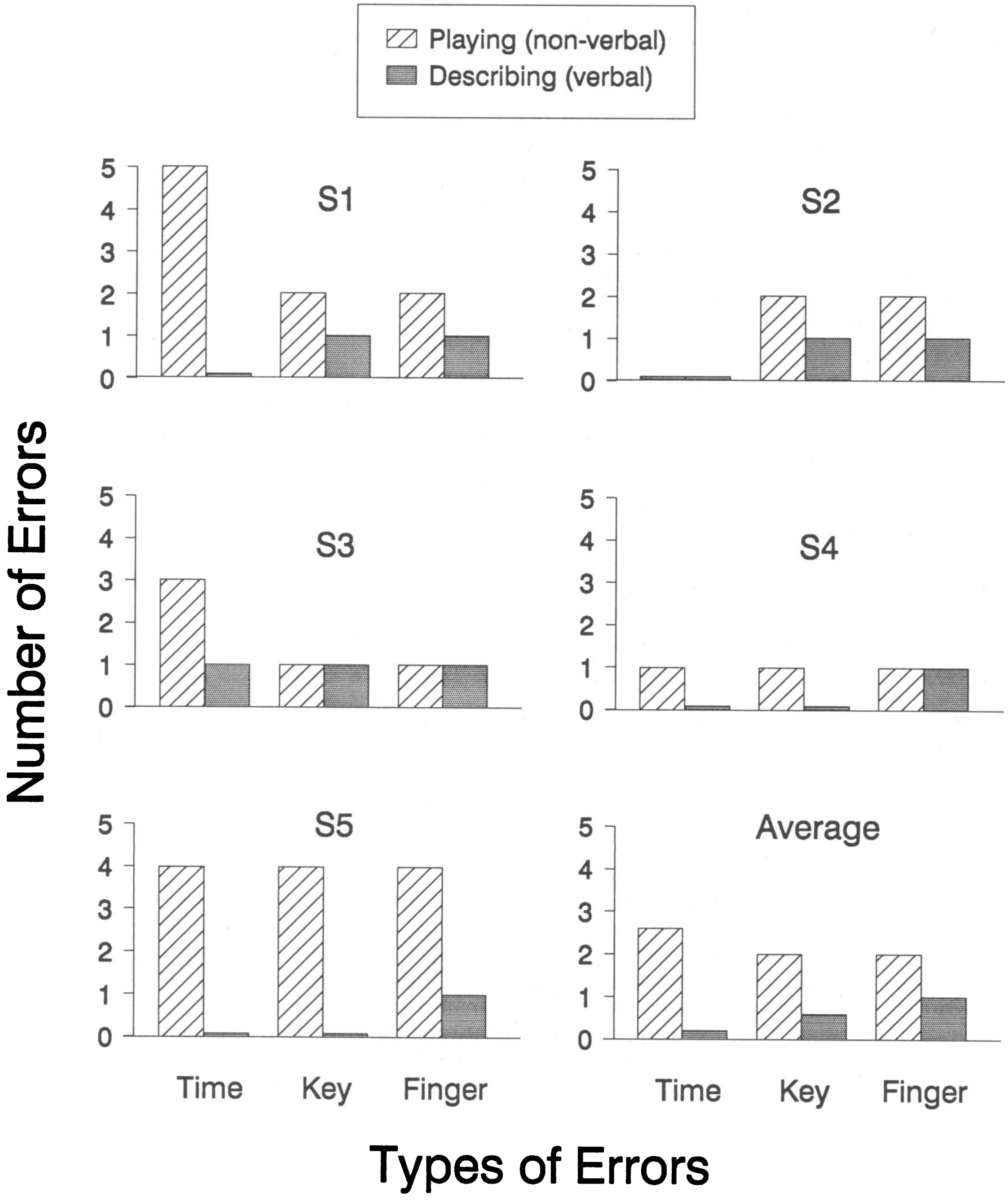


Fig. 6. Average number of verbal and nonverbal timing, key, and finger errors across all pitch sequences for Subjects 1 to 5 of the timing and placement training group.

introduced. Such an explanation seems unlikely because of the large number of alternative responses available. Assuming that responses were limited only to the keys (4), fingers (4), and timings (3) trained, each note in the 12-note score afforded 48 different response opportunities (4 × 4 × 3). Each score thus afforded 576 such opportunities (48 × 12), only 36 of which were correct. Because implicit feedback occurred upon completion of a score, it could apply to any or all of these performances. The timing and placement training subjects took an average of 4.1 trials to reach criterion on each score. Without the specification provided by the equivalence training, it seems unlikely that such feedback could shape successful keyboard playing given the number of response alternatives available. Shaping would be even more difficult for control subjects. For example, there would be no reason for subjects who did not receive timing training to limit their attempts to three specific timing alternatives.

Because the posttest was criterion based, the timing training only and placement training only subjects received fewer trials than did the timing and placement training group. It is possible that with more trials successful keyboard playing might emerge, but this too would seemingly require an effect for the global feedback provided by recyling during the test situation.

Verbal activities descriptive of relations among members of an established class appeared to enter that class more readily than did nonverbal activities demonstrative of those relations. Neither saying what to do nor doing it had been trained or required prior to the test; consequently, this difference in performance cannot be explained by appeal to differences in previous training experiences. Instead, it may point to a difference in the ease with which activities of different sorts may become incorporated into already established equivalence classes.

This ease with which verbal events enter into equivalence classes suggests that the formally verbal stimuli used in Experiment 1 might have contributed to successful keyboard playing. Subjects learned to respond to notes having different beats by pointing to the words "quarter," "half," and "whole" and to select the letters "F," "G," "A," or "B" conditionally upon particular positions on a musical staff. Because subjects were verbal adults, it is reasonable to suppose that they read these note and timing names as well as pointed to them. Some researchers have implicated names in the equivalence phenomenon (e.g., McIntire, Cleary, & Thompson, 1987). Experiment 2 was conducted to determine whether or not correct keyboard playing would occur if the equivalence classes on which it was based did not include formally verbal stimuli as members.

EXPERIMENT 2

METHOD

Subjects and Conditions

Nine right-handed undergraduates served as subjects in exchange for money at a rate of approximately minimum wage. Subjects had no previous training in music sight reading and no significant history of other musical performances. Subjects were assigned randomly to one of three conditions: no timing names ($n = 3$), no placement names ($n = 3$), and no names ($n = 3$).

Conditional Discrimination Training and Equivalence Testing

No timing names (S10–S12). Subjects in this group acquired both timing and placement classes as in the timing and placement training condition of Experiment 1; however, Stimulus Set C (i.e., "quarter," "half," and "whole") was not involved in training or testing.

No placement names (S13–S15). Subjects in this group acquired both timing and placement classes as in the timing and placement training condition of Experiment 1; however, Stimulus Set G (i.e., "F," "G," "A," and "B") was not involved in training or testing.

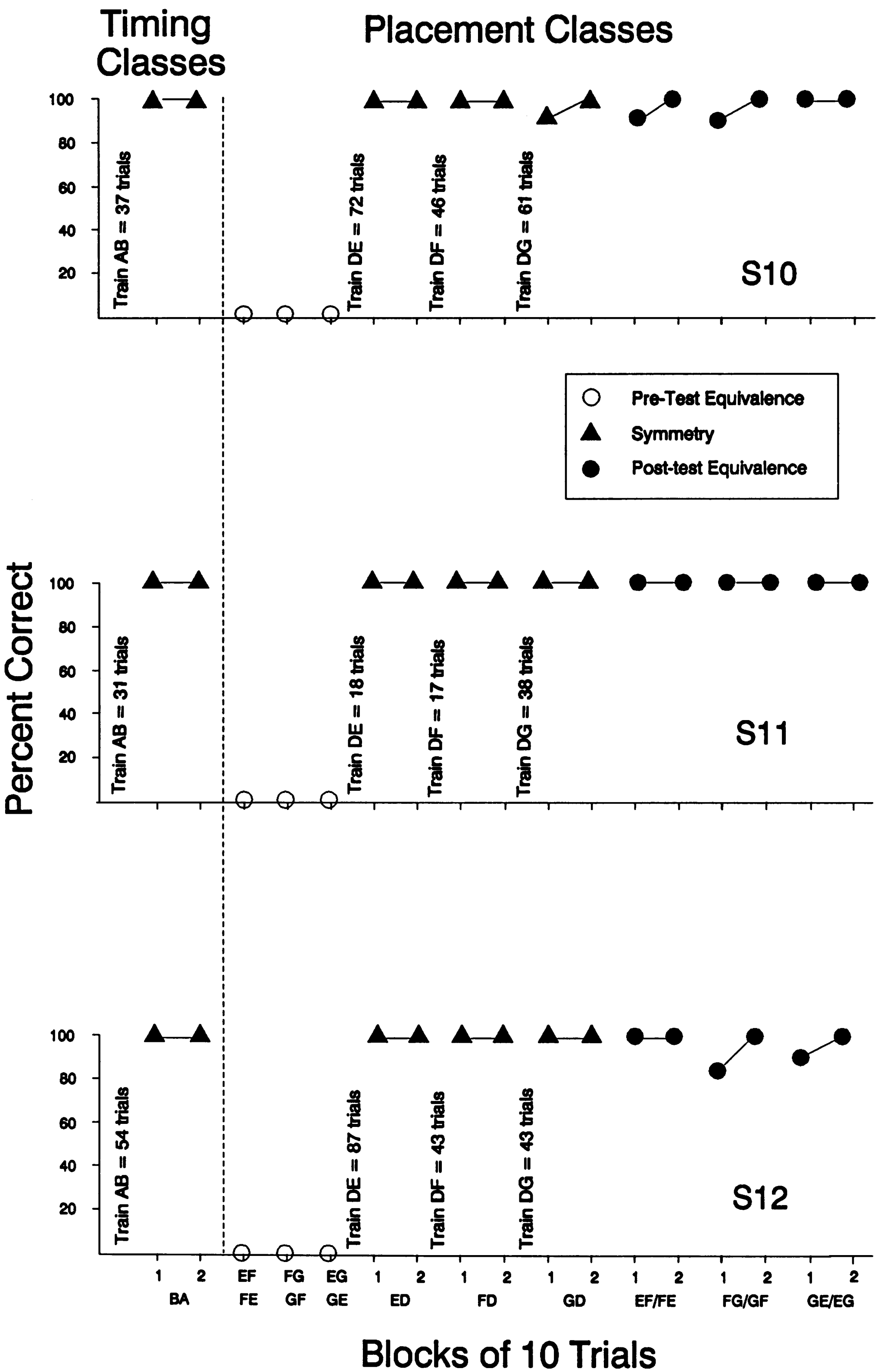
No names (S16–S18). Subjects in this group acquired both timing and placement classes as in the timing and placement training condition of Experiment 1; however, Stimulus Sets C and G were not involved in training or testing.

Playing the Keyboard

Pre- and posttesting conditions were identical to those of the timing and placement training condition of Experiment 1 for all subject groups.

Reliability

Test segments were videotaped and reliability was calculated as in Experiment 1. Reliability on keyboard playing performances was 96%.


Timing Classes
Placement Classes
Percent Correct
100
80
60
40
20
Train AB = 37 trials
Train DE = 72 trials
Train DF = 46 trials
Train DG = 61 trials
S10
Pre-Test Equivalence
Symmetry
Post-test Equivalence
Train AB = 31 trials
Train DE = 18 trials
Train DF = 17 trials
Train DG = 38 trials
S11
Train AB = 54 trials
Train DE = 87 trials
Train DF = 43 trials
Train DG = 43 trials
S12
1 2 BA
EF FE
FG GF
EG GE
1 2 ED
1 2 FD
1 2 GD
1 2 EF/FE
1 2 FG/GF
1 2 GE/EG
Blocks of 10 Trials

RESULTS

Acquisition of Equivalence Classes

No timing names. Results of equivalence training and testing for S10, S11, and S12 are shown in Figure 7. No subject showed evidence of the equivalence relations EF/FE, FG/GF, and EG/GE during the pretest. Symmetry of all trained relations emerged for all subjects, and all met a criterion of 80% correct on all equivalence posttests.

No placement names. Results of equivalence training and testing for S13, S14, and S15 are shown in Figure 8. Pretests of the equivalence relations BC/CB and EF/FE showed no evidence of preexistence for S13 and S15. S14 showed 70% accurate responding on the pretest of BC/CB. Symmetry of all trained relations was observed by the end of the second block of test trials for all subjects. The equivalence relations emerged in the posttests by the end of the second block of test trials for S14 and S15. The EF/FE relation did not emerge in the posttest for S13, with the result that the placement classes were retained. Symmetry and equivalence emerged on all relations for this subject following retraining.

No names. Results of equivalence training and testing for S16, S17, and S18 are shown in Figure 9. Pretests of the equivalence relation EF/FE showed no evidence of preexistence for S16 and S17. S18 scored 90% accurate on this pretest. Symmetry of all trained relations emerged for all subjects by the end of the second block of trials. Equivalence of the EF/FE relation emerged by the end of the second block of trials for all subjects. The accuracy of this relation declined from the first to the second block of trials for S18.

Playing the Keyboard

Pretest. No subject showed correct timing, key selection, or fingering on any score during the pretest of keyboard playing.

Posttest. All subjects showed a pattern of decreasing numbers of practice trials to criterion across pitch sequences, as shown in Figure 10. For the no timing names group, S10 began with eight trials on the first sequence, decreasing to two by the final sequence; S11 began with four trials, ended with one, and S12 began with six, ended with two. For the no placement names group, S13 began with 12 trials on the first sequence, decreasing to five by the final sequence; S14 began with six trials, ended with four, and S15 began with four, ended with three. For the no names group, S16 began with 17 trials, ended with three; S17 began with 19, ended with five; and S18 began with seven, ended with four.

DISCUSSION

Experiment 2 was conducted to determine whether or not keyboard playing would occur if experimenter-provided names were eliminated from the equivalence classes on which the playing was based. All subjects were able to play the keyboard despite the elimination of one or the other or both sets of names. It is quite possible that subjects generated their own names for this purpose. That possibility was not tested in this experiment.

Whether or not experimenter-provided names facilitated keyboard playing is unclear. On average, subjects in the no placement names and no names groups required greater numbers of trials to reach criterion on the pitch sequences than did the no timing names subjects and those in the timing and placement training group of Experiment 1. These results might suggest that names did facilitate the playing performances, but that only the placement names were relevant to those performances. Within-group variability is high, however, so these differences could reflect individual and not experimental differences.

GENERAL DISCUSSION

The purpose of these experiments was to examine whether (a) a novel combination of equivalence class members (b) each with functions either directly trained or derived through equivalence (c) would produce a novel performance by the combination of these functions (d) in settings participating in the underlying equivalence classes. The data indicate that novel performances can be established in this

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Fig. 7. Individual training and testing data for Subjects 10 to 12 of the no timing names group. Test data are presented as percentages of trials correct (vertical axis) across blocks of 10 trials (horizontal axis). Numbers of training trials are shown in vertical text.

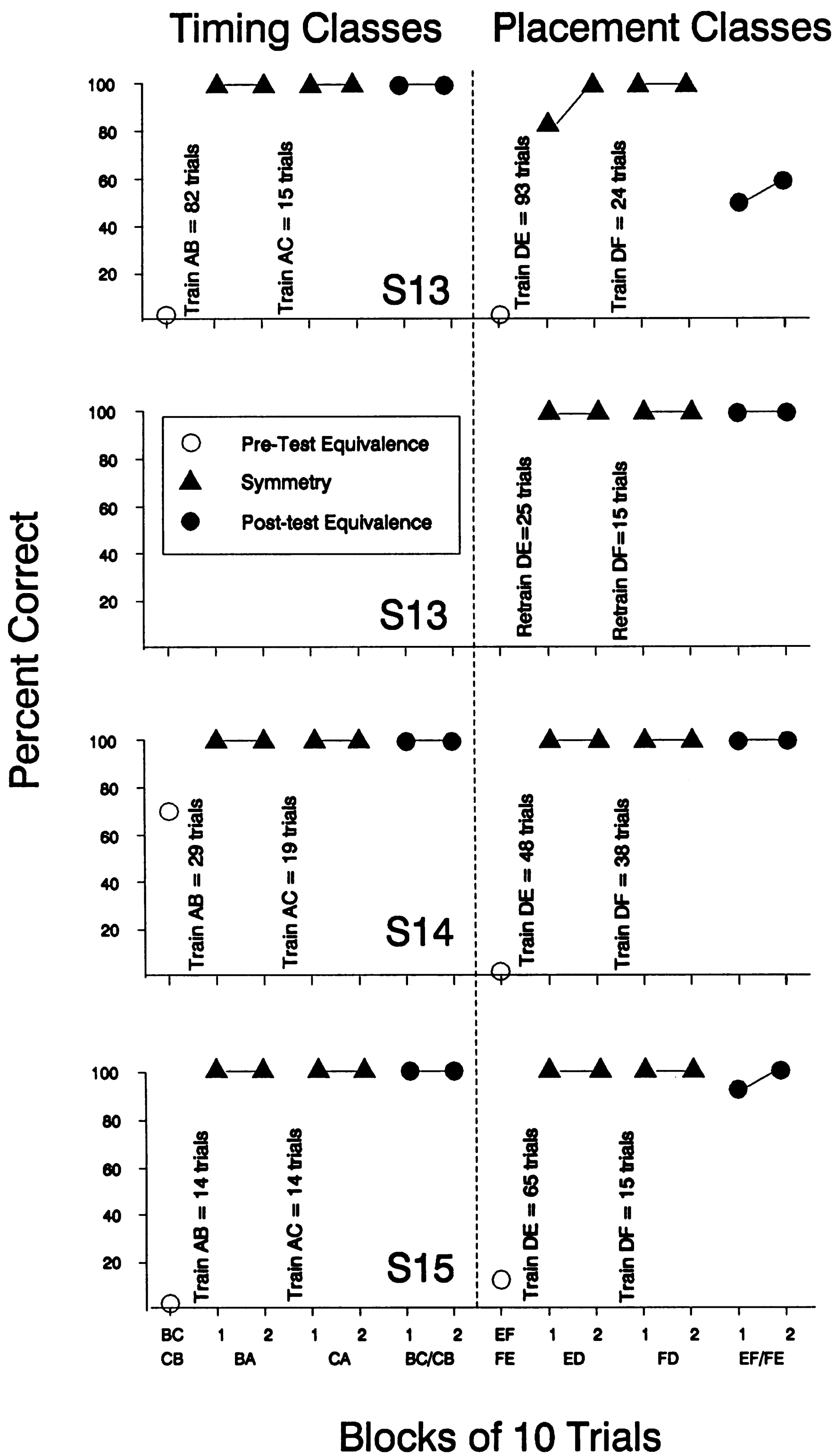

Fig. 8. Individual training and testing data for Subjects 13 to 15 of the no placement names group. Test data are presented as percentages of trials correct (vertical axis) across blocks of 10 trials (horizontal axis). Numbers of training trials are shown in vertical text.

manner. We will first consider whether each of the above elements was satisfied in the present experiments.

Novel Combination of Equivalence Class Members

The novel stimulus patterns in the keyboard-playing test were compound stimuli in the form of musical scores (i.e., 12 notes on a staff). Each compound included elements from both the timing and placement equivalence classes. However, many of the elements from the original stimulus classes were missing, and those that were present appeared in altered form. The original placement class element (i.e., a staff with a position marked by an X) was missing the original marker. The timing class element was also altered. No more than four notes had appeared together prior to the test, and never on a musical staff. The auditory stimuli involved in the original timing class were not present except as they occurred as products of responding. Likewise, the note type (e.g., quarter, half, whole) and letter names for notes (e.g., F, G, A, B) were not present physically in the keyboard-playing situation. Thus, the overall configuration of stimulus elements in this test situation was novel.

Functions Derived Through Equivalence or Directly Trained

The terminal performance of keyboard playing depended on both direct and indirect functions of stimuli previously organized in equivalence classes. The proper timing of the notes produced in the test required a transfer of functions indirectly via equivalence. In the timing class, the sample was experimenter-produced auditory beats, and the comparisons were note symbols in one case and note type names in another. A correct response in the keyboard-playing test depended on the emergence of symmetry, in that it required subjects to produce notes for the proper number of beats given note symbols. In the verbal test, equivalence was shown, as subjects produced the note type names given the note symbols.

The placement elements were also arranged in equivalence classes. In this case, however, the terminal playing performance depended on more direct transfers of stimulus functions. During training, the position mark on the staff was the sample, and finger and key alternatives were the comparisons. In the test, subjects saw an altered sample and had now actually to use the proper fingers to play the proper keys. The functions actualized in the test were thereby novel, but they involved the same sorts of relations among the same sources of stimulation as were involved in training.

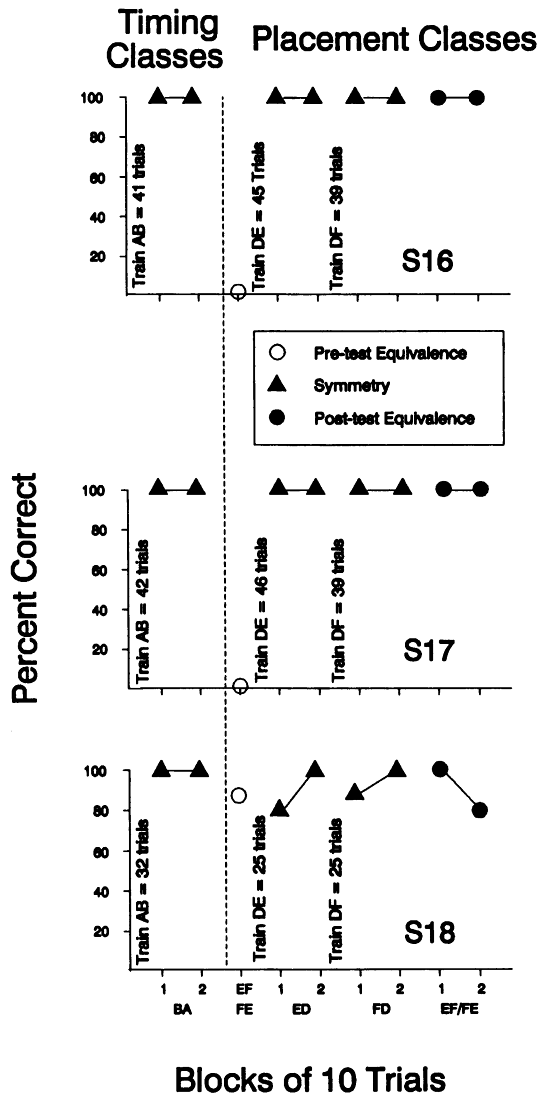

Fig. 9. Individual training and testing data for Subjects 16 to 18 of the no names group. Test data are presented as percentages of trials correct (vertical axis) across blocks of 10 trials (horizontal axis). Numbers of training trials are shown in vertical text.

Novel Performances

A correct response in the keyboard-playing situation was unlike any previously established response. A correct response in the test involved playing particular keys with particular

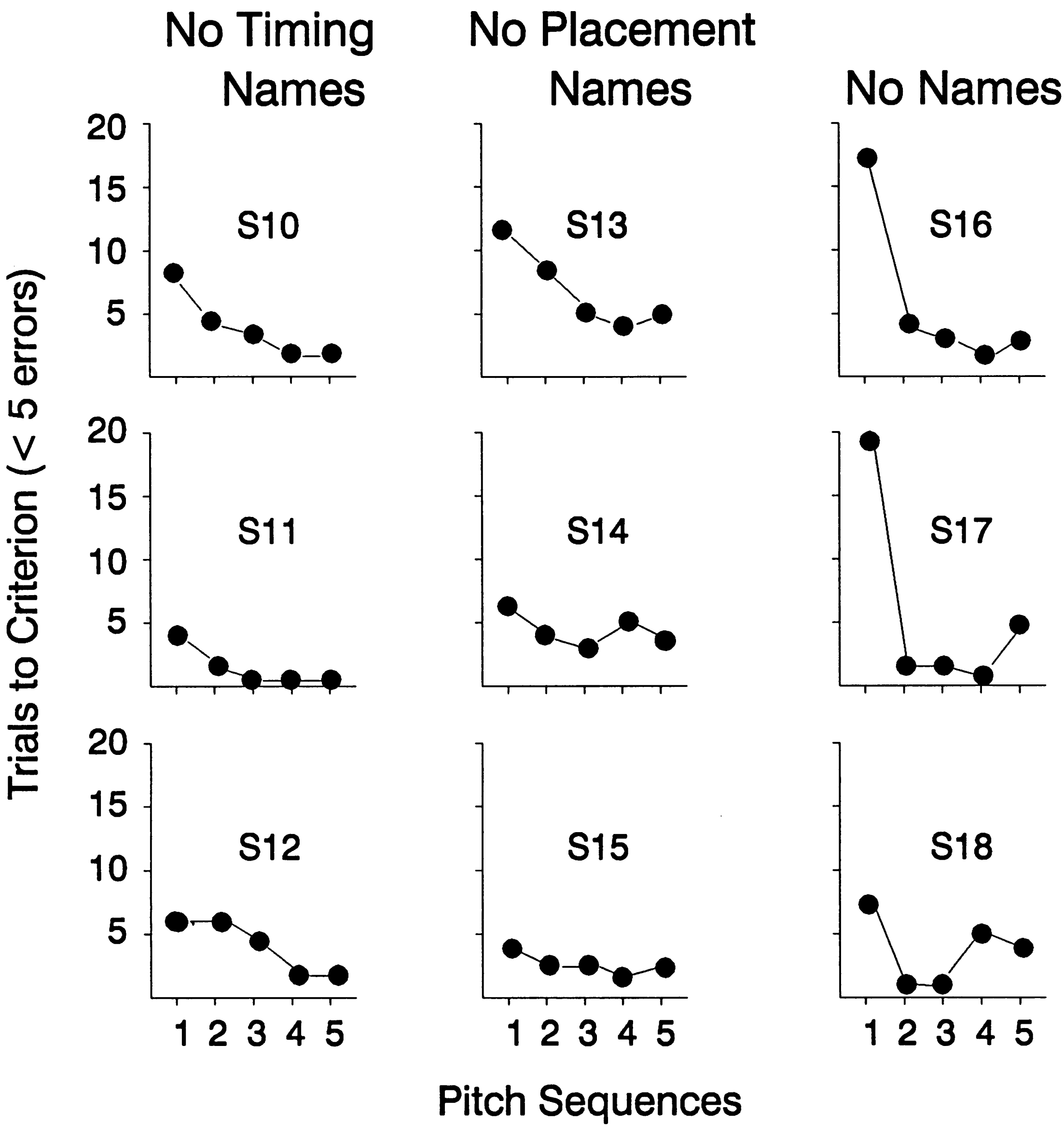

Fig. 10. Trials to criterion (less than five errors) for each pitch sequence in the keyboard playing test for Subjects 10 to 18 in the no timing names, no placement names, and no names groups.

fingers for particular numbers of beats. Prior to this test, responses consisted of pointing to a comparison stimulus, given a sample. In addition, correct responding involved acts having these parameters arranged in different sequences. Thus, the terminal performance may be considered novel.

Settings Participating in the Underlying Equivalence Classes

The pitch sequences specified that particular fingers and particular keys be used, via the participation of the staff placement, fingers, and keys in the same equivalence class. Among the factors subsequently present in the keyboard-playing situation were the keyboard and the subject's right hand. Thus, aspects of the testing situation and elements of the rule shared class membership.

Stimulus Equivalence and Rule Following

The configuration of stimuli used in the final test situation thus may be conceptualized as a rule, in terms of the analysis developed earlier. Keyboard playing may be conceptualized as rule following. Subjects who were not given training that would lead to the necessary underlying equivalence classes (Experiment 1) in essence were presented with an incomplete rule and thus were unable to follow it.

Rule governance occupies a special place in behavior analysis: It provides a link between humans' verbal and nonverbal repertoires. A great deal of research, over several decades, has shaped our understanding of nonverbal behavior. Recent empirical research and conceptual work on rule governance have advanced our understanding of rule following, but not its source. A more analytic interpretation of rule governance is needed that both articulates the relation between verbal and nonverbal behavior and delineates a method for its investigation. The present experiments demonstrate one such approach.

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