

*THE ESTABLISHMENT OF STIMULUS CONTROL BY  
INSTRUCTIONS AND BY DIFFERENTIAL REINFORCEMENT*

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A repeated acquisition design was used to study the effects of instructions and differential reinforcement on the performance of complex chains by undergraduates. The chains required responding on a series of keys that corresponded to characters that appeared on a monitor. Each day, subjects performed a new chain in a learning session and later relearned the same chain in a test session. Experiment 1 replicated previous research by showing that instructional stimuli paired with the correct responses in the learning sessions, combined with differential reinforcement in both learning and test sessions, resulted in stimulus control by the characters in each link. Experiment 2 separated the effects of instructional stimuli and differential reinforcement, and showed that stimulus control by the characters could be established solely by differential reinforcement during the test sessions. Experiment 3 showed that when a rule specified the relation between learning and test sessions, some subjects performed accurately in the test sessions without exposure to any differential consequences. This rule apparently altered the stimulus control properties of the characters much as did differential reinforcement during testing. However, compared to differential reinforcement, the rule established stimulus control more quickly.

*Key words:* rule-governed behavior, contingency-shaped behavior, stimulus control, repeated acquisition, key press, adults

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B. F. Skinner (1963) distinguished behavior affected by direct contact with contingencies and behavior affected by descriptions or rules about contingencies. He noted, "The efficiency may be the same, but the controlling variables are different and the behaviors are therefore different" (p. 513). This distinction has been referred to as the contingency-shaped versus rule-governed distinction (Skinner, 1966, 1969, 1974). Skinner has indicated, and others have concurred (Baron & Galizio, 1983; Zettle & Hayes, 1982), that rule following can be influenced by two sets of concurrent contingencies. One set of contingencies involves nonverbal antecedent stimuli and consequences in the

current context. The other set involves the verbal contingencies that are described in rules or instructions. Because much of human behavior involves rules, attempts have been made to distinguish these two sets of controlling variables when studying human behavior.

Recent research on rule-governed behavior has attempted to separate rule control from control by nonverbal contingencies by introducing rules that are inconsistent with the contingencies and comparing the results with those from conditions in which rules are either consistent with the contingencies or absent. Most of this research has suggested that rules evoke behavior that is especially resistant to change after contingencies are altered (Buskist, Bennett, & Miller, 1981; Kaufman, Baron, & Kopp, 1966; Matthews, Shimoff, Catania, & Sagvolden, 1977; Shimoff, Catania, & Matthews, 1981). Variables that influence such results include whether responding comes into contact with a stimulus change (Buskist & Miller, 1986; Galizio, 1979), the interaction between a history of rule-governed behavior that was reinforced and the programmed contingencies in the experiment (Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986), and whether subjects have had a history of one

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response pattern versus multiple response alternatives (LeFrancois, Chase, & Joyce, 1988).

Given that rules can influence control by nonverbal antecedent stimuli and consequences, one question is: Can we isolate variables that result in rules influencing the degree of control exerted by other stimuli? Much research has looked at how rules interfere with control by schedules of reinforcement. Measuring performance under schedules of reinforcement, however, makes it difficult to measure control because of issues concerning what is and what is not sensitive schedule performance (Hayes, Brownstein, Haas, & Greenway, 1986; Shimoff, Matthews, & Catania, 1986). In addition, schedule parameters represent only one type of environmental event that exists when people respond to rules. It would be prudent, therefore, to begin investigating other kinds of environmental conditions and their relations to rules and behavior.

Vaughan (1985) illustrated how the repeated acquisition design, as described by Boren and Devine (1968) with monkeys as subjects, could be used to analyze rule-governed behavior in humans. Repeated acquisition includes repeated exposures to novel chains of stimulus-response relations. Conditions are arranged so that a subject learns one chain of responses in a training session and then is tested later on the same chain of responses. Vaughan, and Boren and Devine, analyzed the role of instructional stimuli in the training sessions. The number of errors made in the test session permits inferences about controlling variables in the training sessions. Children in Vaughan's study made few errors on the test sessions, suggesting that the source of control in the training sessions was the nonverbal stimuli that made up each link of the chain. Monkey S in Boren and Devine's study made numerous testing errors, suggesting that the source of control in the training sessions was the instructional stimuli, not stimuli that made up each link of the chain. However, it is difficult to determine the specific variables controlling behavior because contingency-shaped and instructed conditions alternated throughout the study and because the two studies obtained different results.

The purpose of the current research, therefore, was to try to clarify the effects of rules and exposure to differential contingencies of reinforcement on the development of a complex chain. Experiment 1 replicated Vaughan

(1985), and Boren and Devine (1968), with college students and a computerized version of the repeated acquisition procedure. Experiments 2 and 3 separated the control exerted by verbal rules from control exerted by differential reinforcement such that stimulus control by rules could be analyzed in isolation from stimulus control by nonverbal programmed contingencies. The resulting function-altering effects illustrate the impact of contingencies and of rules citing those contingencies.

## EXPERIMENT 1

### METHOD

#### *Subjects*

Four undergraduate students, 2 females and 2 males, served as subjects. None had participated previously in a psychology experiment. They ranged in age from 18 to 21 years, and they received bonus points for psychology class credit contingent upon satisfactory attendance at research sessions.

#### *Apparatus and Materials*

Figure 1 presents the screen display and the keyboard of the Commodore 64<sup>®</sup> that was used to regulate the experiment. Four characters appeared on the screen. Each character was composed of a square border that had inside three of the following geometric shapes: a diamond, a large square, a vertical line, and a small solid square. The characters are labeled 1, 2, 3, and 4 to facilitate communication in this paper. These labels did not appear on the screen nor were they described to the subjects. The monitor also displayed a number in the top left corner of the screen (the counter).

The entire keyboard of the computer was covered except for the four function keys on the right and the pound key (£) on the top row. Blank adhesive tape was affixed over the numbers on the function keys. Each function key corresponded to one of the four positions of the characters. The pound key was used as an analogue of the consummatory response used in studies of nonhumans (cf. Matthews *et al.*, 1977).

#### *Setting*

The experiment took place in a 1.82-m by 2.22-m room. Subjects sat in front of the computer while experimenters observed through a

one-way mirror. Personal effects such as books and writing utensils were not allowed in the room with the subjects.

### Preliminary Training

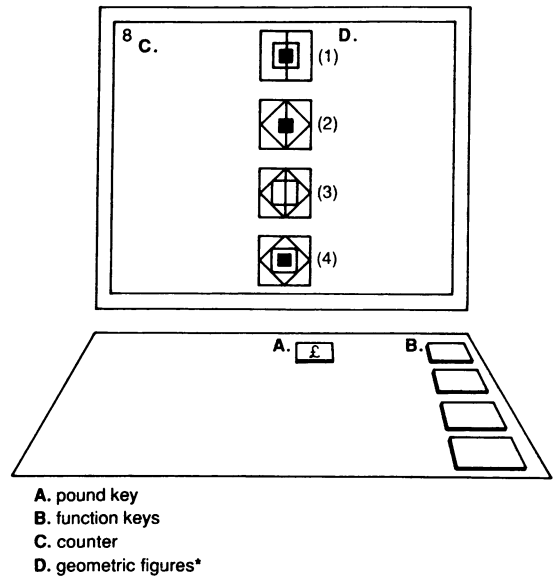
The purpose of preliminary training sessions was to train the subjects to press the function keys in a sequence or chain.

*Step 1.* Subjects were first trained to press function keys that corresponded to the location of one character. The following was read twice to each subject before the start of the first session:

You will be paid at the end of each session for the work you do in these research sessions. Your task includes pressing any one of the four keys on the right, one at a time. Four characters will appear on the screen in front of you. The top key will always correspond to whatever character is on top. The key next to the top will correspond to whatever character is next to the top. The key third from the top will correspond to the character third from the top and the bottom key will correspond to whatever character is on the bottom. Each time you make a correct response a beeper will sound. Then you press the pound key (experimenter pointed to the pound key). If the response was correct, two cents will be added to the total you receive at the session's end. If the response was wrong, one cent will be subtracted from this total. If you end up with negative earnings in a session, you will not owe the experimenter money, nor will money be subtracted from previous sessions' earnings. So your job is to figure out how to press the keys to earn the most money.

Except where noted, no further instructions were provided by the experimenter. If the subject asked questions, the experimenter repeated relevant portions of the instructions. If the subject did not respond or continued to ask questions the experimenter said, "It is up to you to figure out what to do."

After the instructions were read, the subjects were trained to respond to one character. Following a correct response on a function key, the beeper sounded. After the subjects pressed the pound key the beeper sounded twice, the characters disappeared, and a dollar sign (\$) appeared on the screen for 2 s. Then the characters reappeared and the subject began the second trial by pressing another function key,



\*the numbers did not appear on the screen nor were they described to the subjects

Fig. 1. The screen display and the keyboard of the computer that was used to regulate the experiments.

and so forth. After each response on the pound key the position of the characters changed. However, the correct character remained the same for 10 consecutive responses. Incorrect responses were followed by a blank screen and an inoperable keyboard for 5 s. Following this timeout, a correction procedure was arranged in which the characters reappeared in random positions and subjects continued to work until they made a correct response, with timeout after each incorrect response. Each session had a different correct character. Subjects were paid at the end of each session, but they were not told how many correct or incorrect responses they had made, because it was uncertain whether such instructional feedback would influence the number of correct and incorrect responses made.

*Step 2.* During Step 2, subjects began working with two-component chains. Additional instructions were read as follows:

You will now have to make a series of correct responses. After each correct response, the number on the top left of the screen (experimenter pointed to the counter) will advance by one number. This number tells you what section of the series you are on. After you make a series of correct responses the beeper will sound. Following a press on the

pound key, two cents will be added to your total for each correct response and one cent will be subtracted for each error, and then the number at the top left will be reset to 1.

An example of a two-component chain is as follows. At the beginning of the session, the four characters appeared on the screen and the counter displayed a 1. After the first correct response, the counter advanced to 2 and the characters changed positions randomly. After the second correct response, the beeper sounded. Following a press on the pound key, the dollar sign appeared and the beeper sounded twice. Then the characters reappeared in random position, the counter reset to 1, and the subject began again. If an incorrect response was made, the timeout procedure described earlier went into effect as soon as the wrong key was pressed. After 10 trials with a single two-component chain were completed, the screen read "end" and the session was terminated.

The length of subsequent chains was gradually increased whenever subjects made fewer than 33% of their errors in the last 7 of the 10 chains they completed each session. This criterion assured that subjects were able to learn the correct chain of responses within a session. Preliminary training continued until subjects met the criterion with eight-component chains.

#### *Procedure*

Three days a week, two 5- to 20-min sessions were conducted with each subject: a learning session and a test session. Each session consisted of 10 trials with a single nine-component chain. The order of correct characters was chosen from a random numbers list. To ensure that the chains were equivalent in difficulty (cf. Boren & Devine, 1968), the following qualifications were imposed on the random order. Every character appeared at least once in the chain and no character appeared more than three times. No character was correct more than twice in succession or appeared in two such pairs within the sequence (e.g., 4, 4, 3, 1, 4, 4, . . . was not selected). There were no sets of consecutive pairs of characters (e.g., 2, 2, 3, 3). Simple orders were avoided. For example, 1, 2, 3, 4, 1, 2, 3, 4, was not used. Finally, if a character was correct twice in a row, that sequence was not repeated in the same position within the chain the next day.

*Learning sessions.* During the instructed learning sessions, the differential reinforcement contingencies described above were arranged. However, a small dot also appeared on the screen adjacent to the correct character for each component of the chain. Boren and Devine (1968, p. 657) indicated that this procedure "was analogous to instructing a human subject exactly what to do." In addition, the dot could be said to function as an instructional stimulus because the data indicated that it already controlled the subject's responding even though the relation between the dot and pressing a key corresponding to a particular character had never been trained. Subjects completed the nine-component chains 10 times with the aid of this instructional stimulus.

On alternate days the contingency learning sessions required the subjects to complete the chains without the aid of any instructional stimuli; thus, the differential reinforcement contingencies shaped the correct chain of responses.

*Test sessions.* On each research day, a test session followed the learning session by about 4 hr. The correct response sequence was the same as programmed for that day's learning session. Instructional stimuli never appeared during test sessions, and subjects were not told that the response sequence learned during training was correct in the test sessions. If subjects missed one of the two sessions, the other session was still conducted even though the data were discarded. Subjects received payment in the form of 2 cents for each correct response minus 1 cent for each error at the end of each session.

Subject 1 began in the instructed learning condition, and Subjects 2 through 4 began in the contingency learning condition. Approximately halfway through the experiment, examination of the data revealed subjects were making few, if any, errors after the fifth chain in each session. Therefore, the number of chains the subject had to complete was reduced from 10 to 5 per session. This occurred following the fourth session for Subjects 1 and 4 and following the fifth session for Subjects 2 and 3.

#### RESULTS AND DISCUSSION

Figure 2 presents the number of errors per session for all 4 subjects during each phase of the experiment. During contingency learning sessions (the top left quadrant) subjects made

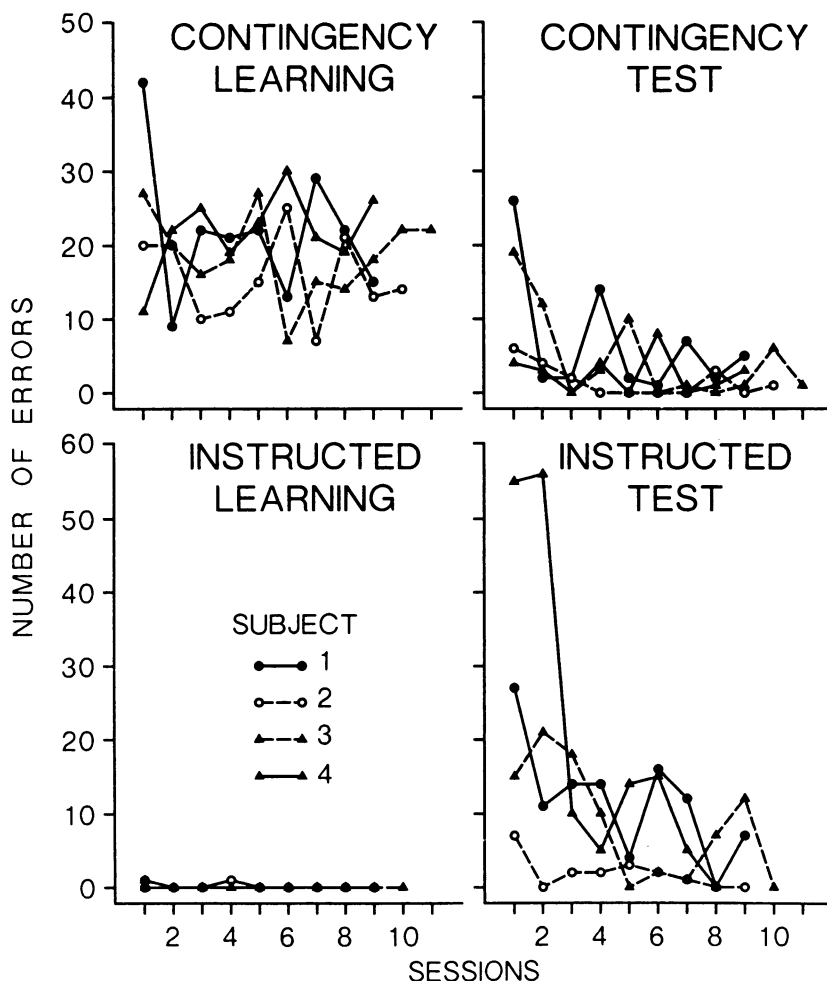


Fig. 2. Data from Experiment 1 showing the number of errors subjects made in each phase of the experiment. The top left quadrant shows errors from contingency learning sessions, and on the right are errors from the corresponding day's test sessions. The bottom left quadrant shows errors from instructed learning sessions, and in the bottom right are errors from the corresponding day's test sessions.

a high but relatively stable number of errors. Each subject showed fewer errors during contingency test sessions that followed.

During instructed learning, subjects made few or no errors. During instructed test sessions, the subjects had a moderate number of errors, similar to the number in the contingency test sessions. Subjects 1, 3, and 4 showed a somewhat more rapid and less variable decrease in errors in contingency testing than in instructed testing.

Each subject made fewer errors during instructed testing than during contingency learning, indicating that there was a carryover from the instructed learning sessions earlier in the

day. Subjects performed at a more efficient level after a session of instructed learning than would be expected during the first exposure to a chain. The implication is that the instructional stimulus assisted in the acquisition of stimulus control by the characters. Behavior was controlled by (a) the instructional stimuli, as shown by the low frequency of errors during instructed learning, and (b) the characters, as shown by the lower frequency of errors in both test conditions.

The results are similar to those reported by Vaughan (1985), illustrating empirical generalization of the results across subject populations (children vs. adults) and task complex-

ity (four-component chains vs. nine-component chains). The results contrast with those reported by Boren and Devine (1968), who demonstrated that when Monkey S's responding was controlled by the instructional stimulus, the monkey "transferred nothing about the response chain with the specific stimuli, since the error rate was the same as if it were acquiring the chain of lever presses for the first time" (p. 658).

It appears that two procedural manipulations may have been responsible for the stimulus control by the characters and the moderate rate of test errors after instructed learning. First, behavior was subject to differential reinforcement in contingency learning sessions on alternate days. Thus, any behavior (e.g., attending to the characters) strengthened during the contingency learning sessions that facilitated performance in the test sessions might have generalized to the learning conditions in which instructional stimuli were provided. Second, during testing conditions, the timeout/correction procedure followed errors, and the subjects received payment for correct responses at the end of each session. Over a number of sessions, their testing performance may have been contingency shaped by these differential consequences.

## EXPERIMENT 2

The purpose of Experiment 2 was to elucidate the role of differential reinforcement in the acquisition of stimulus control by the characters. One question addressed was whether instructed behavior would come under control of the characters, resulting in fewer instructed test errors, without exposure to differential reinforcement in either training or testing. In the absence of evidence for such control, would exposure to differential reinforcement during test sessions be sufficient to impart stimulus control properties to the characters during subsequent training sessions?

### METHOD

Five new subjects, 1 male and 4 female, were recruited from undergraduate psychology courses. The setting, and the apparatus and materials, remained largely unchanged.

#### *Preliminary Training*

Preliminary training followed the same general format as in Experiment 1, but there were

important changes. First, the word "correct" that was underlined in the instructions from Experiment 1 was eliminated and the counter advanced through successive links in the chain after both correct and incorrect responses. Second, the dot that appeared adjacent to the correct characters was replaced by the phrase, "This one is correct." Finally, subjects were paid at the end of the week, not at the end of the session. The purpose was to eliminate immediate differential consequences during preliminary training.

During the first training session, one character was programmed as correct, and the subject responded five times on the function keys while the phrase, "This one is correct," was adjacent to the proper character. After each response, correct or incorrect, the counter advanced one unit. After a subject responded to a character five times without an error, he or she worked on two-component chains until a chain was completed five consecutive times with no errors; then Phase A began.

An example of a two-component chain is as follows. The four characters appeared on the screen and the counter displayed a 1. After the first response, the counter advanced to 2 and the characters randomly changed position. After the second response, the beeper sounded. Following the consummatory response, the subject began again until the two-link chain was completed five times.

Once again, the timeout/correction procedure did not follow incorrect responses. Also, the counter advanced one unit after both correct and incorrect responses. Subjects did not receive daily feedback about their performance, but rather were paid at the end of the week.

#### *Procedure*

Table 1 shows the design of Experiment 2. An ABA design with a multiple baseline across subjects was used. Each session throughout the experiment consisted of 12-component chains that the subjects completed five times. Because the length of the chains was raised from nine to 12 links, the requirement that no character could appear in the chain more than three times was changed so that no character appeared in the chain more than four times. Subjects completed the learning sessions in the morning, and test sessions with the same correct response sequence were conducted ap-

Table 1  
Learning and test session format for Experiment 2.

	Learning sessions	Test sessions
A	New 12-component chain Instruction for correct response, "This one is correct" No differential consequences: 1. No timeout after errors, no correction procedure 2. Counter advanced following all responses	Same 12-component chain No instruction No differential consequences: 1. No timeout after errors, no correction procedure 2. Counter advanced following all responses
B	Same as above	Same 12-component chain No instruction Differential consequences: 1. Timeout after errors and the correction procedure 2. Counter advanced only after correct responses
A	Return to Phase A	

proximately 4 hr later. The correct sequence changed each day.

*Phase A: no differential consequences.* During the learning sessions, subjects were taught the chains with the aid of the instruction, "This one is correct," next to the correct character. After each response, correct or incorrect, the screen advanced to the next component. The timeout/correction procedure was not in effect. The test sessions were identical to the learning sessions except that the written phrase, "This one is correct," did not appear next to the correct character. Note that during preliminary training and both Phase A conditions, no immediate differential consequences occurred after correct or incorrect responses. Payment at the week's end constituted a molar consequence for performance. However, no consequence indicated that any single response was right or wrong.

*Phase B: differential consequences in test sessions.* The learning sessions were identical to those in Phase A. During the test sessions the timeout/correction procedure was in effect. Incorrect responses were followed by an inoperable keyboard and a blank screen for 5 s, after which the characters reappeared in random order with the subject working on that link of the chain until a correct response was made. After a correct response, the counter advanced one unit. Following Phase B was a return to Phase A.

## RESULTS AND DISCUSSION

In all three phases, responding was controlled by the instructional stimulus in the morning, almost always resulting in zero learning errors. Figure 3 shows the total test errors made by each subject across all phases.

During Phase A there was a high number of errors, as if the subjects had no prior experience with the response sequence. The total number of errors remained around 45 per test session for all subjects, regardless of the length of the baseline. This number of errors per test session indicated a lack of stimulus control by the characters. Each test session had five 12-link chains for a total of 60 individual choices. Each individual link in the chain provided the subject with one correct choice out of the four characters, so there was a one in four chance of being correct if the subject guessed. Thus, guessing would result in one quarter of 60 responses being correct and three quarters of 60 responses being incorrect. This computes to 15 correct responses and 45 errors if the subjects simply guessed.

Test errors rose dramatically in the beginning of Phase B because the correction procedure required responding on the individual components of the chains until a correct response was made. Thus, there were more opportunities to make errors. Then test errors dropped steadily, with the terminal performance showing consistently fewer test errors than in the first Phase A. When subjects were returned to Phase A, the total number of test errors increased slightly but remained lower than the initial Phase A. This suggests that subjects had learned the relation between the response chains in the training and test sessions, and this knowledge, in turn, may have influenced their behavior.

Figure 4 shows the number of test errors made on the first response to each component during the first chain of the test sessions. These data were especially revealing because, as the first response in each component, they were

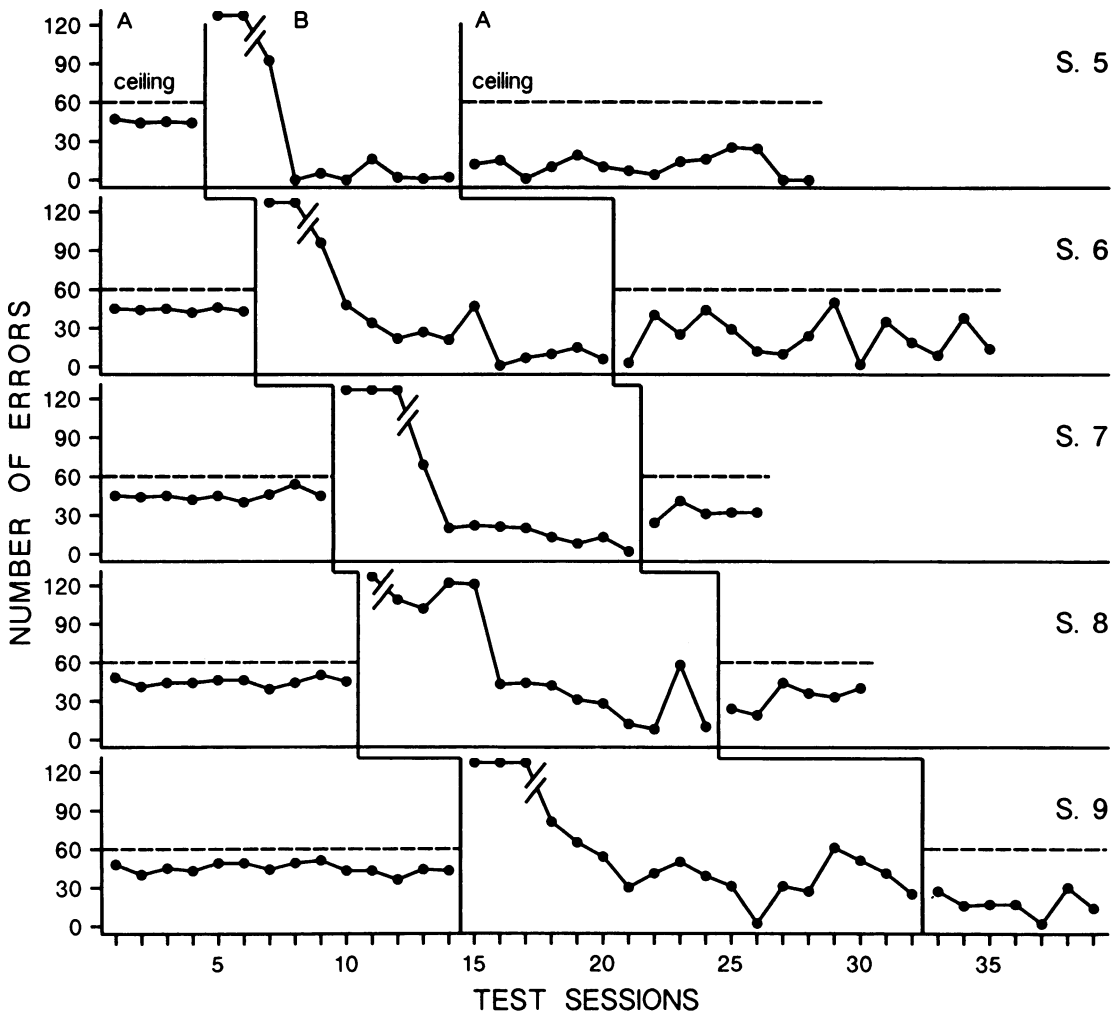


Fig. 3. The total number of test errors for each subject in Experiment 2. The maximum number of responses a subject could make in Phase A was 60.

emitted prior to any timeout/correction consequences. Thus, these data show test results isolated from any relearning influenced by differential consequences within Phase B test sessions. The maximum number of first-response errors a subject could make was 12 because the chains consisted of 12 links. In Phase A and the first few sessions of Phase B, the number of errors almost always ranged from 8 to 11. Guessing would average one quarter of 12 (3) responses being correct and three quarters of 12 (9) responses being incorrect. After a few days in Phase B with differential reinforcement in the test sessions, first-response errors dropped steadily and remained lower than in Phase A. Results from the return to A showed

that the first-response errors generally stayed within the same range as in Phase B, although there was an overall increase in errors. Thus, differential reinforcement in the early Phase B test sessions resulted in stimulus control by the characters in subsequent learning sessions.

To summarize, when no molecular consequences were programmed in Phase A, test responding was not accurate, suggesting that the characters were not controlling the behavior and that repeated exposure to learning and test sessions was not sufficient to bring about control by the characters. When subjects were exposed to a timeout/correction procedure during testing in Phase B, they began to show fewer test errors. The lower terminal error rate



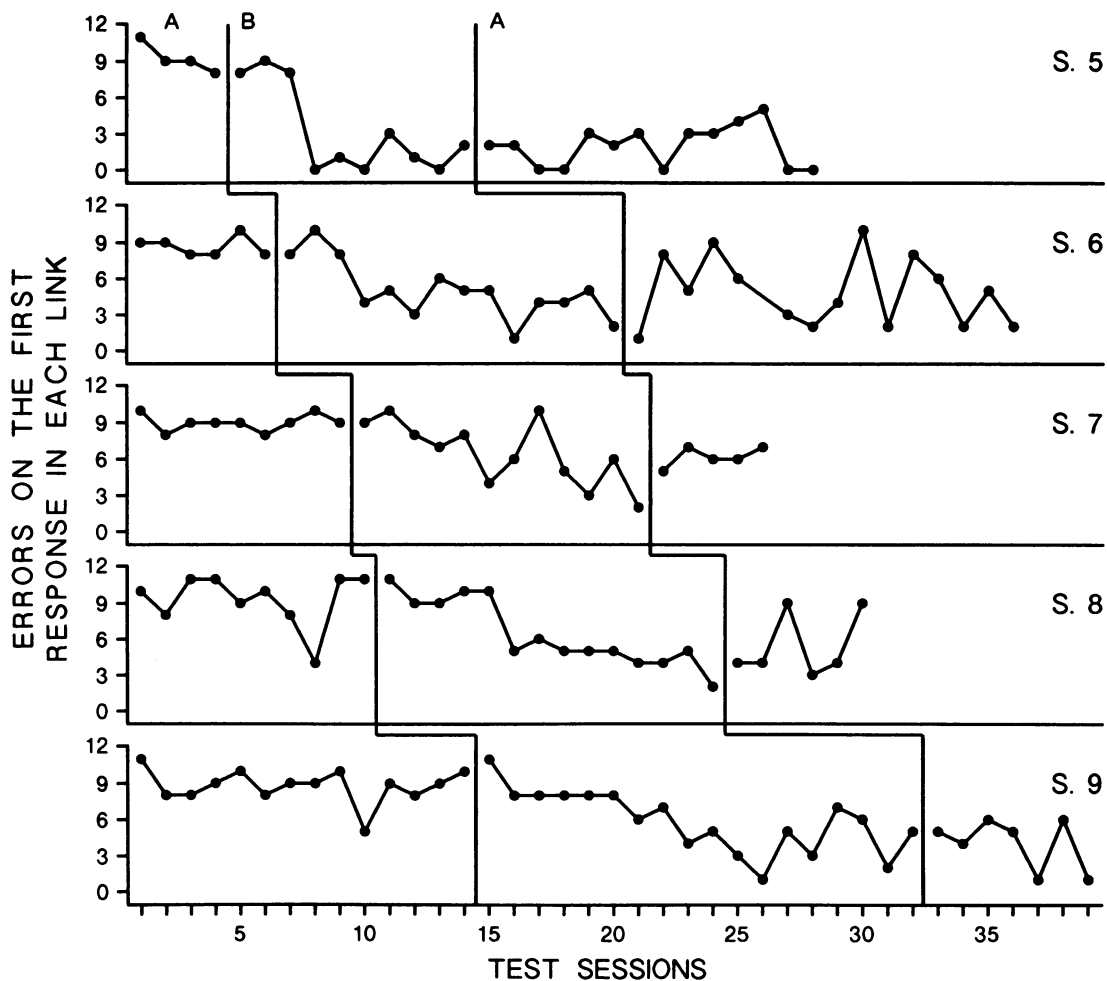


Fig. 4. Data from Experiment 2 showing the number of errors made on the first response to each link during the first chain in the test sessions. The maximum number of errors that could be made was 12 because each chain had 12 links.

suggests a conditioning effect and emerging dual stimulus control by the instruction stimulus and the characters. Instructional stimulus control is illustrated by trials with zero errors in the instructed learning sessions, and character control is shown by relatively accurate responses on the first chain of the test sessions.

The major inference to be drawn from these results is that differential reinforcement in the Phase B test sessions established the characters as discriminative stimuli in succeeding learning sessions. This may help explain Vaughan's (1985) data showing that there were fewer test errors following instructed learning compared to the frequency of errors during contingency learning. Subjects received differential conse-

quences during the test sessions, and this may have established the location of the "correct" manipulandum as a controlling stimulus event on subsequent sessions.

### EXPERIMENT 3

The question remained whether other kinds of instructions might facilitate control by the characters without exposure to explicit differential reinforcement. Specifically, would instructing the subjects that the learning and test sessions were the same be sufficient to produce accurate test responding?

In Experiments 1 and 2, the instructions described the behavior (pressing a designated

key, i.e., "This one is correct") and the potential consequences (2 cents for correct responses minus 1 cent for errors). A more detailed instruction could also tact all the appropriate occasions upon which to make these responses. Thus, in Experiment 3 subjects were told that the correct responses were identical in both the learning and test sessions. As a result, the complete set of instructions specified (a) what the correct responses were, (b) that these responses were correct in the morning and afternoon, and (c) the monetary consequences. The question asked was whether such a rule, in isolation from concurrent differential reinforcement, could strengthen the stimulus control properties of the characters and result in accurate test responses.

#### METHOD

Five new subjects, 1 female and 4 male, were recruited from undergraduate psychology courses. The setting, apparatus, materials, and preliminary training were the same as in Experiment 2. Two changes were made in the instructions read to the subjects. First, in order to decrease the likelihood of differential consequences influencing their behavior, subjects were told they would be paid at the end of the semester, not at the end of the week (as subjects in Experiment 2 were told). Second, to ensure attendance, the following phrase was added:

Following your last session each week, you will be paid 50 cents for each session attended that week. This sum will be drawn from the total earnings that you are to receive at the semester's end. To receive the remainder of your earnings you must complete the experiment.

#### *Procedure*

The general procedure was similar to that of the first two experiments. Two sessions were conducted each day: a morning learning session and an afternoon test session. Subjects completed five chains per session. The correct response chain was the same for both learning and test sessions, but the correct response sequence changed each research day. Subjects did not receive feedback about their performance, but they were paid for attendance at the end of the week.

An ABCB design with a multiple baseline across subjects was used. Table 2 shows the outline of this study. A second rule was added

for analysis in Experiment 3. Thus, to avoid confusion, the phrase, "This one is correct," will hereafter be referred to as Rule 1.

*Phase A: baseline.* This phase was identical to Phase A from Experiment 2. Subjects who averaged approximately 45 errors per test session, similar to subjects in Experiment 2, remained in Phase A for three sessions. Subject 10 remained in Phase A for six sessions because this subject's test errors initially showed a downward trend.

Note that during preliminary training and Phase A, no immediate differential consequences occurred after correct or incorrect responses. Payment at the week's end constituted a molar consequence for attendance. However, no differential consequence indicated that any single response was right or wrong.

*Phase B: instructions.* Before the first learning and first test sessions in Phase B, the subjects were required to read the following sentence aloud in the presence of the experimenter: "The characters that are correct in the morning are the same characters that are correct in the afternoon" (Rule 2).

Immediately prior to each of the remaining sessions in Phase B, Rule 2 appeared on the screen while the subjects were seated before the computer. Subjects were told to "hit the space bar to begin," after which Rule 2 disappeared and the characters for the first component appeared. This was the only difference between Phase A and Phase B.

Subjects 10, 11, and 12 advanced to Phase C after responding in the Phase B test sessions was stable or errors were increasing. A split middle stability criterion based on the trend of the test errors determined whether the last 5 days of data points indicated a flat trend or increasing errors. Subjects 13 and 14 remained in Phase B to observe the effects of longer exposure to this condition after responding stabilized.

*Phase C: differential reinforcement.* Phase C was conducted to determine whether exposure to differential reinforcement during training would consistently reduce the frequency of test errors made by subjects who had already received instructions indicating that the learning and test sessions were the same. If Rule 2 did not establish the characters as controlling stimuli, then perhaps differential reinforcement in learning sessions would do so.

During the morning learning sessions in Phase C, the timeout/correction procedure was

Table 2  
Learning and test session formats for Experiment 3.

	Learning sessions	Test sessions
A	New 12-component chain Instruction for correct response, Rule 1, "This one is correct" No differential consequences: 1. No timeout after errors, no correction procedure 2. Counter advanced following all responses	Same 12-component chain No instruction No differential consequences: 1. No timeout after errors, no correction procedure 2. Counter advanced following all responses
B	Rule 2: "The characters that are correct in the morning are the same characters that are correct in the afternoon," presented prior to both learning and test sessions Same as above	Same as above Same as above
C	Rule 2: "The characters that are correct in the morning are the same characters that are correct in the afternoon," presented prior to both learning and test sessions New 12-component chain No Rule 1 Differential consequences: 1. Timeout after errors and the correction procedure 2. Counter advanced only after correct responses	Same as above Same as above
B	Return to Phase B	

in effect and Rule 1 did not appear. After correct responses, the counter advanced one unit. At the completion of a chain, the beeper sounded and the consummatory response was followed by two beeps, just as in earlier phases. Incorrect responses were followed by a blank screen and an inoperable keyboard for 5 s. Following this timeout, the correction procedure was arranged wherein the counter did not advance. Instead, the characters reappeared in random position and subjects continued to work on that link of the chain until they made a correct response. As in previous phases, subjects completed five chains per session. The afternoon test sessions remained unchanged.

*Return to Phase B.* During this phase, the program was identical to that in the first Phase B for Subjects 10 and 11.

#### RESULTS AND DISCUSSION

Figure 5 shows the total errors during the learning sessions for each subject. In Phase A, baseline, few errors were made. Subject 12 was the only subject who made more than one error, and the number of errors decreased from 14 in the first session to zero in the third session. During Phase B, instructions, subjects continued to respond correctly on almost every trial.

Phase C, differential reinforcement, resulted in a considerable number of learning errors compared to the other phases. This was a result of the differential reinforcement pro-

cedure that eliminated Rule 1 ("This one is correct") and required responding on each link of the chain until a correct response was made. Subjects 10 and 11 made a large number of errors at the beginning of Phase C with a steady decrease as the phase continued. Subject 12 had a relatively consistent number of learning errors ranging from eight to 46. Subjects 10 and 11 returned to Phase B and once again made very few learning errors.

Figure 6 shows the total errors during the test sessions for each subject. In Phase A, baseline, subjects made about 45 test errors per session. The only exception to this was Subject 10, who had three test sessions with errors ranging from 28 to 35. In each of these sessions correct responses were made primarily to character 1. In Test Sessions 5 and 6, Subject 10 ceased responding in this manner, making 44 errors in each of these two sessions.

Phase B test sessions indicated a general reduction in errors for most subjects. Subject 10, however, had errors ranging from 26 to 40, with the majority of correct responses being accounted for by accurate responding to Character 1. Subjects 11 and 12 showed a definite decline in errors after one session in Phase B, but variability was evident. For example, Subject 11 had zero errors in the seventh test session, 34 in the eighth test session, and zero again in the ninth. Subject 12 had one or zero errors in Test Sessions 7, 10, 11, and 14 and more than 20 errors in Test Sessions 9 and 12. Subjects 13 and 14 showed a steadier de-

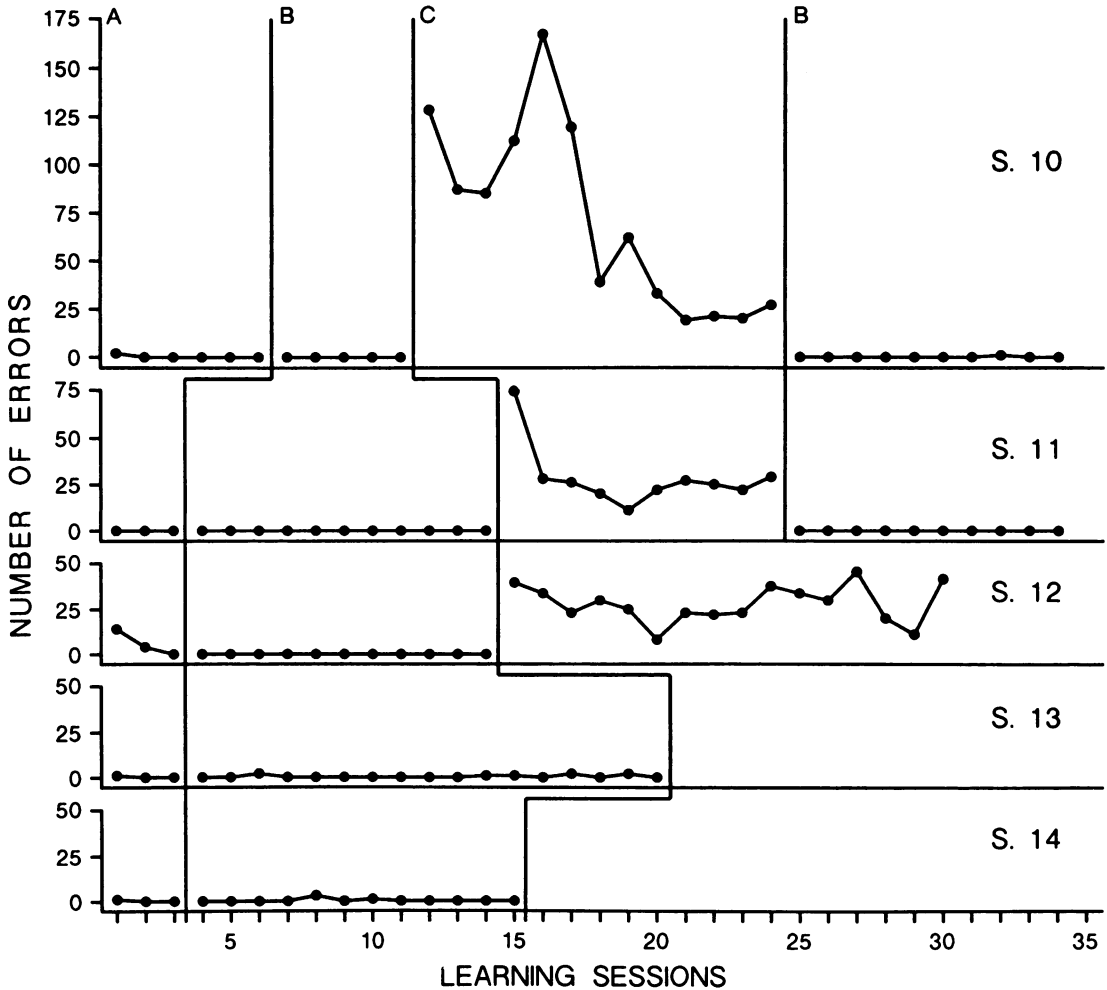


Fig. 5. The total number of errors made by each subject during the learning sessions of Experiment 3.

cline in errors from Phase A until both had sessions in which they made zero errors. Across Subjects 11 through 14, it appears that the decrease in errors occurred because of repeated exposure to Phase B conditions.

Subjects 10, 11, and 12 were subsequently exposed to the differential reinforcement of Phase C to see whether a more consistent number of test errors would occur. Subject 10's errors ranged from 23 to 37 in the first five sessions of Phase C, with responses still being controlled by Character 1. Later sessions, however, showed a steady decrease until zero test errors occurred. This decrease coincided with Subject 10's decrease in learning errors in Phase C (see Figure 5). In Phase C, Subject 11 had a consistently lower number of errors. Eight

of 10 sessions showed one or zero errors. The variability of Subject 12's errors in Phase C was similar to the trend seen in Phase B. On two occasions, sessions with one or zero errors were followed by sessions with 30 or more errors. In the return to Phase B, Subjects 10's and 11's test errors were generally the same as those made at the end of Phase C. This suggests that for these two subjects the differential reinforcement procedure in Phase C learning sessions further strengthened the stimulus control properties of the figures.

Figure 7 shows the number of errors that subjects made during the first chain of the afternoon test sessions. The maximum number of errors a subject could make was 12. In Phase A each subject averaged approximately nine

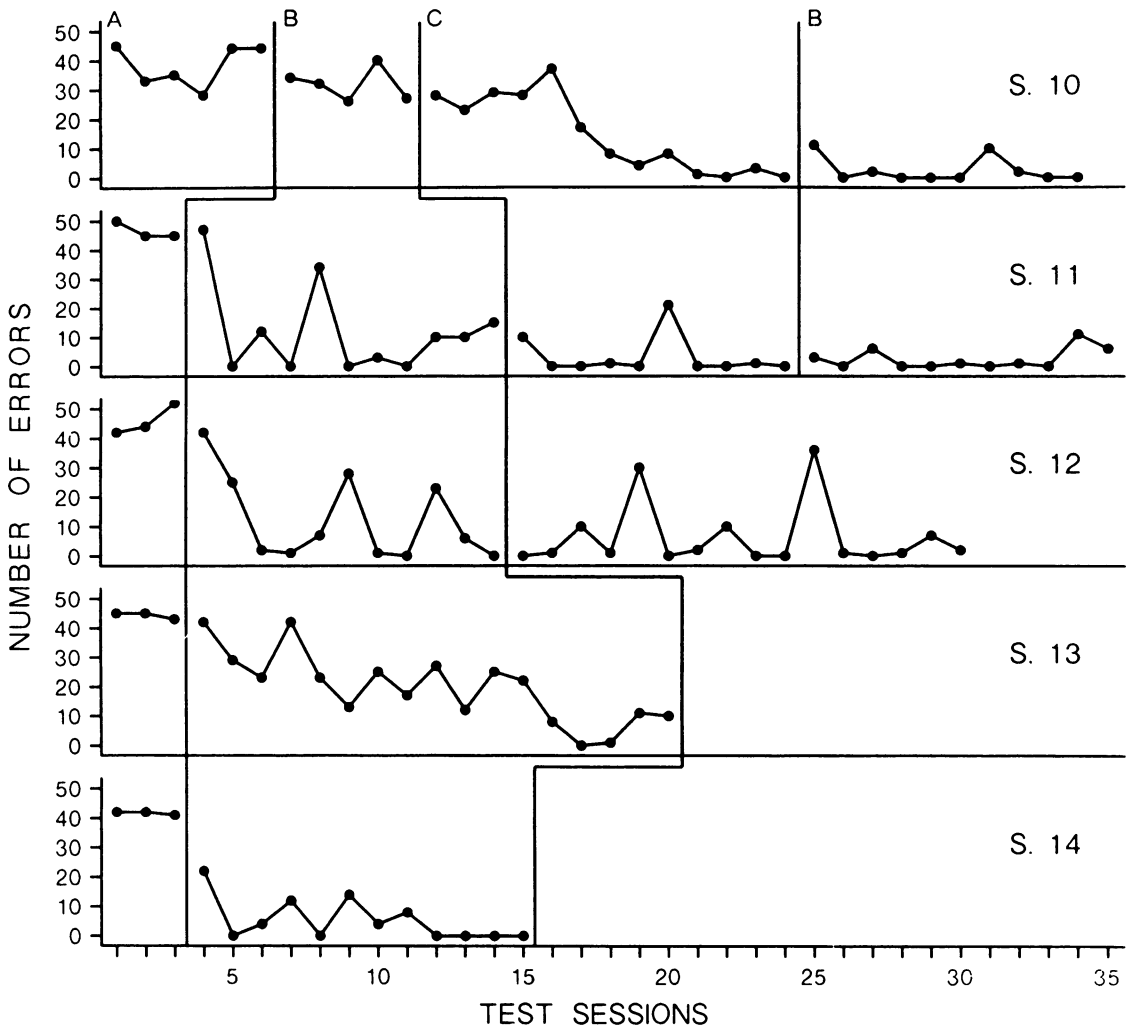


Fig. 6. The total number of errors made by each subject during the test sessions of Experiment 3.

errors per chain. During Phase B all subjects showed a decrease in first-chain errors. Subjects 11 through 14 showed immediate declines and had a number of chains with zero errors. In Phase C Subject 10's errors remained steady for five sessions and then gradually decreased to zero, and Subjects 11 and 12 maintained a low number of errors. In the return to Phase B, the number of errors made by Subjects 10 and 11 was similar to the number made in the preceding Phase C.

The results suggest that in Phase B, Rule 2 acted to establish the stimulus control properties of the characters. Prior to the introduction of Rule 2, the many errors made during the test sessions when the characters were presented alone illustrated the lack of control by

the characters. After Rule 2 was presented, the subjects began to make fewer errors in the test sessions. Thus, after Rule 2 was presented, responding appeared to be under discriminative control of the characters.

The logic of this analysis is consistent with that used by Reynolds (1961). In that study, responding by pigeons was conditioned in the presence of a compound discriminative stimulus, a geometric figure and a background color. When the stimuli were later presented separately, responding occurred in the presence of only one of them, illustrating that only one element of the compound stimulus was functioning as a discriminative stimulus. During Phase A of the current study, the subjects were presented with a similar compound stimulus,

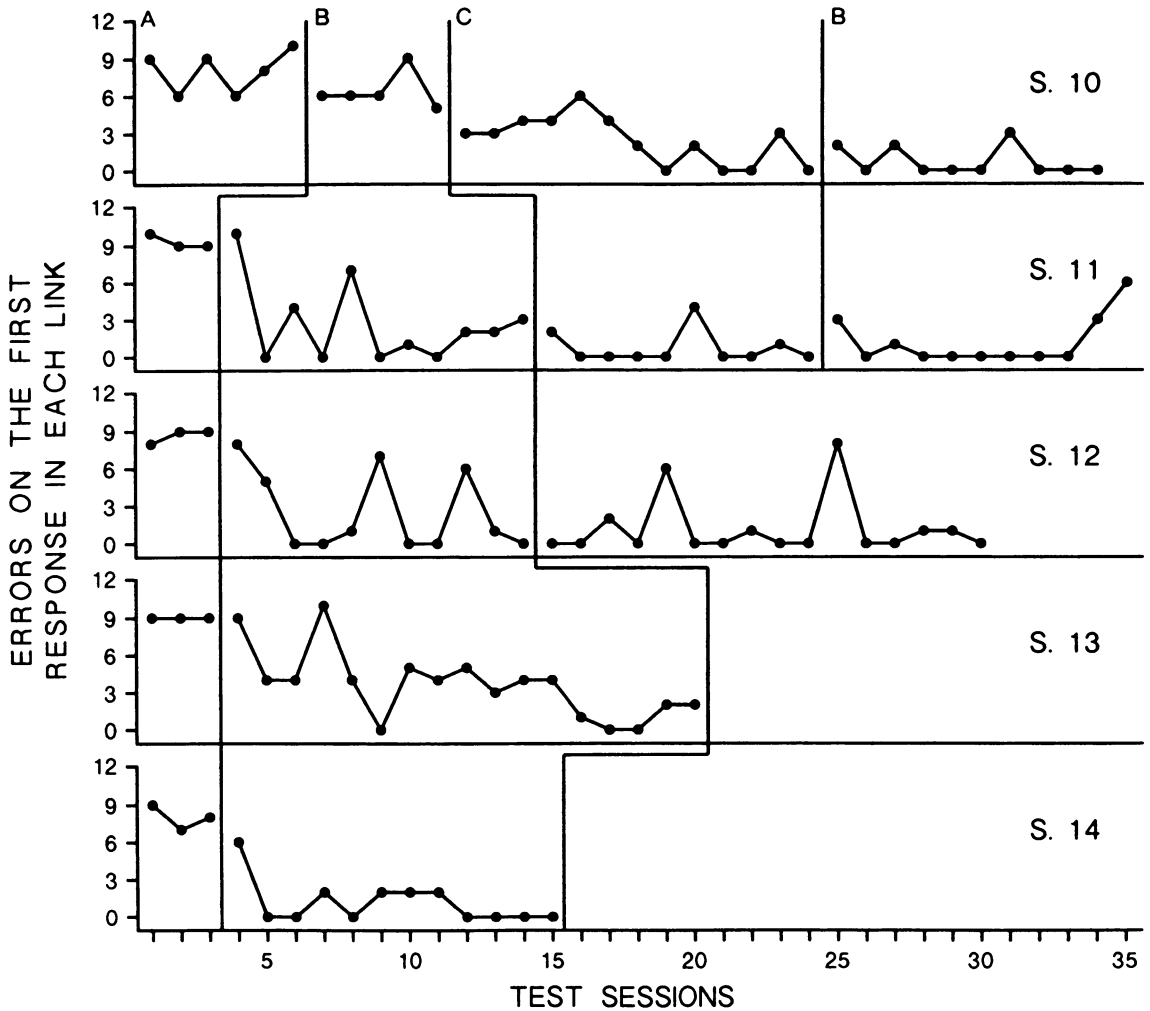


Fig. 7. The number of errors during the first chain of the test sessions in Experiment 3.

Rule 1 and the characters, and only the rule seemed to control responding. However, in Phase B, Rule 2 appeared to enhance the stimulus control properties of the characters.

One process discussed in previous research that might account for the alteration in discriminative control suggests that Rule 2 increased the strength of observing behavior. Examples of such behavior include looking directly at the characters, verbalizing (tacting) a name for the characters, or writing the characters down between sessions and studying them. Stimuli correlated with reinforcement evoke behavior necessary to observe those stimuli, which in turn increases the stimulus control properties of the relevant stimuli (Dinsmoor, 1985). Although explicit correlations

between characters and money were not provided in this experiment, such a correlation was implied by Rule 2.

### GENERAL DISCUSSION

Experiment 1 illustrated that the instructional stimulus influenced the stimulus control of the characters. However, the procedure made it difficult to separate the effects of the instructional stimuli from the effects of differential reinforcement. Experiment 2 illustrated that the instructional stimulus alone was not sufficient to establish stimulus control by the characters, but exposure to nonverbal differential reinforcement altered the function of the previously neutral characters. Experiment 3 in-

licated that the establishment of stimulus control by the characters could emerge following exposure to Rule 2, which described the relationship between learning and test sessions. This resulted in a declining test error trend that paralleled the trend in Experiment 2 (compare Figures 3 and 6, Phase B, and Figures 4 and 7, Phase B) suggesting that both the differential reinforcement in Experiment 2 and Rule 2 in Experiment 3 altered the stimulus control properties of the characters. However, Rule 2 and differential reinforcement during testing apparently were not functionally equivalent. In general, test errors declined gradually across sessions when there was differential feedback during tests (Figure 4), but test errors for 3 subjects (11, 12, and 14) dropped sharply when Rule 2 was presented without differential feedback (Figure 7). This is consistent with early research on rule-governed behavior that demonstrated how accurate instructions could quickly evoke effective, efficient behavior (Ayllon & Azrin, 1964; Baron, Kaufman, & Stauber, 1969; Weiner, 1970).

Recently, Schlinger and Blakely (1987) discussed a number of function-altering characteristics of rules. Their analysis of operant relations contrasted previous descriptions of rules as discriminative stimuli with a conceptualization suggesting that rules can alter the function of stimuli by "bringing a response under the discriminative control of a previously neutral stimulus or by altering (either strengthening or weakening) an existing discriminative relation" (p. 42). They concluded their analysis by suggesting that researchers study the function of stimuli described by rules. The current study exemplifies such research by illustrating how behavior was brought under control of the previously neutral characters.

The stimulus control issues involved in the procedure used in this experiment are complex. In the instructed learning conditions, the subject's responding was at least under the control of the instructional stimulus, because it was always paired with advancement through the sequence. During the test conditions, a subject's response in one component of the chain may have been controlled by the character responded to in the previous component, indicating sequential control of a chain of responses. An alternative explanation suggests that responding may have been jointly under

control of the counter numbers and the correct character in each trial. For example, subjects may have learned that if a specific counter number was displayed, then a specific character was the one to respond to, indicating the possibility of interpreting the performance as a series of conditional discriminations. Using the current repeated acquisition design, it would be interesting to probe subjects with a series of trials in which the components are reordered. If the frequency of errors was maintained at the same level, it might be concluded that the performances involved conditional discriminations in which the counter served as the sample and the characters served as comparisons. The issue of sequential control versus conditional discrimination was addressed in a study by Snodgrass and McMillan (1989). Their results suggested that the behavior of pigeons under a repeated acquisition procedure was controlled primarily by the discriminative stimulus paired with each link in the sequence, not the stimuli generated by the occurrence of the previous response.

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