JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1981, 36, 253-266 NUMBER 2 (SEPTEMBER)

PRECURRENT SELF-PROMPTING OPERANTS IN CHILDREN: "REMEMBERING"

JOSEPH A. PARSONS, DOUGLAS C. TAYLOR, AND TERESA M. JOYCE

UNIVERSITY OF NEW MEXICO

In Experiment I, one of three forms of collateral behavior was trained: Differential collateral behavior specific in form to one of two discriminative stimuli; Common collateral behavior of a single form regardless of the stimulus; or Nondifferential collateral behavior of either form regardless of the stimulus. Children were next given a short-delay matching-to-sample task in which the discriminative stimuli served as samples, and the children's previously trained collateral behavior terminated the delay and presented the comparison stimuli. Subjects engaging in sample-specific collateral behavior immediately acquired matching. Subjects engaging in sample-nonspecific collateral behavior failed to acquire matching or did so gradually. In Experiment II the minimal delay in the matching task was varied in a mixed sequence, first with collateral behavior required, and then with collateral behavior prohibited. When emitting collateral behavior Common and Nondifferential subjects showed delay-related decrements in matching while Differential subjects did not. When not emitting collateral behavior all subjects showed delay-related decrements in matching. Common and Nondifferential subjects matched more accurately when prohibited from emitting collateral behavior. Differential subjects matched more accurately when emitting collateral behavior. The results accord with Skinner's (1953, 1968) analysis of precurrent operants.

Key words: Precurrent behavior, delayed matching, collateral behavior, remembering, key press, children

---

The interaction of an organism with the environment constitutes a contingency of reinforcement, or operant, having three terms: (1) an antecedent discriminative event that sets the occasion for (2) a response that characteristically leads to (3) a consequent, reinforcing event. We distinguish between operants that directly involve reinforcement and operants that indirectly affect the environment through subsequent operants. Following Skinner's lead (1953, 1957, 1968, 1969) we refer to these two classes as *current* and *precurrent* operants, respectively. A current operant contingency is one that involves "effective behavior . . . a response which is likely to be reinforced," whereas a precurrent operant contingency is one that involves behavior that functions "mainly to make subsequent behavior more effective" (Skinner, 1968, pp. 120 and 124).

A precurrent operant can affect a current operant in at least three ways. First, a precurrent operant can alter the probability that the organism makes functional contact with the discriminative events controlling the current operant, as in "attending" (Bijou, 1976; Skinner, 1953). Second, a precurrent operant can alter the probability that another operant is reinforced, as in some types of autoclitics (Skinner, 1957). Finally, and most relevant to the present research, a precurrent operant can alter the probability that the current operant response falls within the functional limits of the response class, as in self-prompting and self-probing (Skinner, 1953).

Of major interest here is the relation between precurrent and current operants during initial conditioning and maintenance of a self-prompting interaction. The *maintenance* relationship has been characterized as one

This research was supported by a Research Allocations Grant from the University of New Mexico to Joseph A. Parsons. This reseach is based, in part, on the Senior Honors Thesis of Teresa M. Joyce, portions of which were presented at the 1979 Annual Meeting of the Association for Behavior Analysis, Dearborn, Michigan. We are indebted to the principal and teachers of St. Charles Borromero School for their cooperation and flexibility. Special thanks are due to Sam Leigland for helpful comments on the manuscript.

Send reprint requests to Joseph A. Parsons, Counselling Services, University Centre, University of Victoria, Victoria, B.C., V8W 2Y2, Canada.

of "mutual support"—the precurrent operant prompts a reinforcible instance of the current operant and reinforcement of the current operant maintains both the precurrent and current operants (Skinner, 1953, 1969). The *conditioning* relationship has been characterized differently. Although it is possible for a precurrent operant, if emitted, to be "automatically" reinforced by its effect upon the current operant contingency of reinforcement, such cases may be rare, and additional reinforcement, contingent upon the topography of the precurrent response, may be necessary for conditioning (Skinner, 1968).

Although much has been written on the role of precurrent operants, little empirical research has been directed to their experimental analysis. Studies that have investigated precurrent-current interactions have generally involved preparations in which the precurrent behavior influenced current behavior maintained by temporally-defined reinforcement contingencies. Wilson and Keller (1953) noted that rats developed stereotyped collateral behavior that seemed to function to "time" interresponse intervals of a current operant under an *interresponse-time-greater-than-t* (IRT >t) contingency. The collateral timing behavior led to more efficient current behavior in that reinforcement was more frequent when collateral behavior was emitted. Laties, Weiss, Clark, and Reynolds (1965) also noted stereotyped collateral behavior in a rat under an IRT>t contingency. The precurrent function of the collateral behavior was demonstrated by several manipulations. First, changing the current contingency from IRT>t to extinction decreased collateral behavior. Second, prevention of the current operant by removing the operandum also decreased collateral behavior. Third, disrupting collateral behavior decreased the frequency of the reinforced current operant. In a systematic replication, Laties, Weiss, and Weiss (1969) found that rats developed collateral behavior that increased the frequency of the reinforced current operant. Although some subjects developed precurrent behavior under the standard IRT>t contingency, others did not readily engage in effective collateral behavior until given access to stimuli that better set the occasion for stereotyped collateral behavior. As before, changing the current contingency to extinction decreased collateral behavior, and preventing collateral behavior decreased the frequency of the reinforced current operant. Collateral behavior that served a precurrent function in IRT>t paradigms has also been observed with pigeons (Schwartz & Williams, 1971), and humans (Bruner & Revusky, 1961). Similar "mediating" has been observed in response-alternation tasks (Hearst, 1962).

Another temporal task, delayed matching-to-sample, also seems to evoke the emission of precurrent operants on occasion. Blough (1959) noted that two pigeons responded with high matching-to-sample accuracy even when 5 or 10 seconds elapsed between sample offset and onset of the comparison stimuli. Other subjects did not display such high matching performance. Observations suggested that the difference was related to what subjects did during the delay intervals. High-accuracy subjects emitted topographically different collateral responses that were differential with respect to the sample stimuli that initiated trials. Low-accuracy subjects emitted a single repetitious pattern of collateral behavior during all delay intervals. Subsequent disruption or prohibition of sample-specific collateral behavior in high-accuracy subjects indicated that the collateral behavior was indeed precurrent, increasing the probability of delayed matching. When allowed to engage in sample-specific (differential) collateral behavior, matching was high and independent of the delay length, but when collateral behavior was disrupted or prohibited, accuracy was a decreasing function of delay length. Shimp and Moffitt (1977, Experiment III) replicated Blough's findings in a delayed-comparison task with pigeons. Subjects had to peck or not-peck (collateral behavior) during the delay depending on the stimulus that initiated the trial. Relative to conditions in which collateral behavior was not required (Experiments I and II), the frequency of the reinforced operant was higher at extended delays when differential collateral behavior was emitted.

Eckerman (1970) investigated the function of topographically different sample-specific observing responses in pigeons' conditional-discrimination performance. The greater the difference between sample-specific observing topographies (loci of pecking), the more rapid the conditioning of the conditional discrimina-

tion. A test in which sample stimuli were not presented, but differential observing initiated the trial, demonstrated that performance was, in part, controlled by differential observing.

The present study was a systematic replication and extension of a preliminary study by Parsons and Ferraro (1977), who used a "mediated, delayed matching-to-sample" preparation suggested by Skinner (1969). In that study preschool children worked at an apparatus consisting of five keys arranged in a Greek Cross pattern (i.e., center, left, right, top, and bottom). Sample stimuli were presented on the center key. A single press at the sample darkened it and illuminated the top and bottom (collateral) keys with light of identical color. One group of children was required to emit sample-specific (differential) behavior to these keys in order to terminate the delay and present comparison stimuli on the left and right keys. Other children were required to emit the same (common) topographical response, regardless of sample. Children required to emit differential collateral behavior during the delay matched with near-perfect accuracy at delays exceeding 10 seconds. Children trained to emit a common collateral response during the delay interval, however, showed decreasing matching accuracy as a function of delay length. Subsequent prohibition of collateral behavior affected changes in matching performance that were consistent with the findings of Blough (1959). Differential-response children showed decreasing accuracy of matching as a function of delay length when collateral behavior was absent. Common-response children showed slight but systematic increases in matching performance, but still exhibited delay-related decrements, when collateral behavior was absent.

To extend Parsons and Ferraro's (1977) findings, the present study investigated .1-sec-delay matching acquisition and maintenance across 10-sec delays when subjects were required to (1) emit a sample-specific (differential) collateral response during the delay, (2) emit the same (common) collateral response during the delay regardless of sample, or (3) emit either (nondifferential) collateral response during the delay regardless of sample. Further to ascertain the precurrent function of collateral behavior, matching performance was assessed when collateral behavior was prohibited.

EXPERIMENT I

Method

Subjects

Twelve children in a local kindergarten served. Two children withdrew in the early sessions and were replaced with two other children. The final sample of six boys and six girls ranged in age from 61 months to 71 months and had no prior experimental history.

Setting and Apparatus

The laboratory was a mobile research trailer parked next to the kindergarten, containing a control room with programming equipment and a connecting experimental space with the subject's console, a movie projector, a table, and a small chair.

The subject's console was a dark blue box (31.6 by 46.2 by 28.5 cm) on the table. The front panel contained five circular keys (diameter 5.1 cm) in a Greek Cross pattern. The distal keys were 8.9 cm from the center key, center to center. Keys were translucent Plexiglas back-illuminated by three 7-W bulbs. Key miscroswitches were activated by approximately 2.5-N pressure.

The center key displayed either of two stimuli: simultaneous illumination of the three white bulbs through 16-ohm resistors (bright) or 140-ohm resistors (dim) [approximately 258 footlamberts (885 cd/m^2) and 1.7 footlamberts (5.7 cd/m^2), respectively]. The two vertical keys (top and bottom) could be simultaneously illuminated with a red hue and served as loci for collateral behavior. The two horizontal keys (left and right) displayed the comparison stimuli during the matching phase of the experiment. Left and right keys could be illuminated with bright and dim light identical to the center key. During matching sessions the comparison stimuli were presented in a mixed order with respect to position so that the matching stimulus appeared equally often on left and right keys.

Left of the console was a rear-screen, 8-mm movie projector (Fairchild, Seventy-07) for presenting consecutive 16-sec segments of Walt Disney sound cartoons as reinforcers. Subjects selected one of 12 cartoons before each session.

The console and movie projector were controlled by digital logic packages in the control

room. Response data cumulated on impulse counters so that the experimenter could record responses trial-by-trial.

Procedure

Experiment I had two phases: (1) conditioning of three types of collateral behavior to the collateral keys in separate subjects, and (2) conditioning of .1-sec-delay matching behavior in all subjects. The initial day for each subject was an adaptation period. Subjects were escorted individually to the trailer and allowed to explore the experimental space. The second session began Phase 1 of the study.

Phase 1. Each subject was escorted to the trailer, seated facing the console and movie projector, and given the following instructions:

> (Child's name), I want you to look carefully at these buttons, then press one of the buttons that is turned on. The buttons do not work when they are off. Please keep going until I tell you that you are finished. If you want to leave, let me know, and I will take you back to class. Now, go ahead and try the first one.

The experimenter remained in the room until the child received one 16-sec film reinforcer, then retired to the control room.

Each of 60 trials per session began with illumination of the center key with either the bright or dim sample. A single press on the sample key shut off the sample and immediately illuminated the top and bottom keys with the red hue.

Differential. Subjects randomly assigned to the Differential condition (S1, S2, S3, S4) received cartoon reinforcers contingent upon pressing the collateral keys depending on the sample. On bright-sample trials a single press on the top key resulted in key darkening and reinforcement, whereas a single press on the bottom key resulted in key darkening and a 16-sec timeout (all keys dark and no cartoon). On dim-sample trials film reinforcement was contingent upon a single press on the bottom key, whereas a single press on the top key produced timeout.

Common. Subjects randomly assigned to the Common condition (S5, S6, S7, S8) received cartoon reinforcement contingent upon pressing on the top collateral key, regardless of the sample. A single press on the top key resulted in key darkening and reinforcement, whereas a single press on the bottom key produced timeout.

Nondifferential. Subjects randomly assigned to the Nondifferential condition (S9, S10, S11, S12) received cartoon reinforcement contingent upon pressing either collateral key, regardless of the sample. A single press on either the top or the bottom key resulted in key darkening and reinforcement (i.e., all Phase-1 trials ended in reinforcement). Under this contingency subjects could emit differential or common collateral behavior.

Conditioning of collateral behavior continued until Differential subjects met an accuracy criterion of $\geqq 54$ trials ending in reinforcement (90% correct) for two consecutive sessions. Because the number of sessions needed for Differential subjects to attain criterion varied, whereas Common and Nondifferential subjects met criterion in the first two sessions, subjects in the other two conditions were "yoked" to Differential subjects on the number of sessions of exposure to the Phase-1 contingencies. All Differential subjects attained the criterion just before their interterm vacation. Following the vacation all children received one additional session of the Phase-1 contingencies before the change to Phase 2.

Phase 2. In Phase 2 all subjects were transferred to a .1-sec delayed matching-to-sample task. Trials began as in Phase 1 with illumination of the center key with a sample. A single press on the sample key darkened it and illuminated the top and bottom keys with the red hue. The first appropriate (previously trained) collateral response after a fixed interval of .1 sec (FI .1 sec) simultaneously darkened the collateral keys and illuminated the left and right keys with the comparison stimuli, one bright and one dim. Inappropriate collateral responses (Differential and Common conditions only) had no programmed consequence—a change from the timeout of Phase 1 to extinction/correction in Phase 2. Once the comparison stimuli were illuminated, a single press to the comparison identical to the sample (matching) resulted in key darkening and cartoon reinforcement. A mismatching response resulted in key darkening and the 16-sec timeout.

Subjects were exposed to the Phase-2 contingencies until their matching performance exceeded a criterion of 90% correct for two consecutive sessions, or until eight sessions

were completed in case matching accuracy did not improve from 50%.

Results

Phase 1: Conditioning of Collateral Behavior

The proportions of reinforced collateral behavior for individual subjects in the three training conditions are shown in Figure 1, with Differential subjects' data appearing below their "yoked" Common and Nondifferential subjects' data.

Common. Subjects trained on Common collateral behavior quickly learned to press the top key on all trials. Only one subject (S8) ever pressed the bottom key during Phase 1.

Nondifferential. Nondifferential subjects received reinforcers on all Phase-1 trials. These children did not develop sample-specific patterns of responding to the collateral keys, but tended to press consistently on one key during a given session, although this "common response" tendency switched on occasion.

Differential. All Differential subjects responded predominantly to one of the two collateral keys during the initial session of Phase 1, yielding approximately 50% reinforcement. Subjects S1, S2, and S3 showed varied rates of learning differential collateral behavior, achieving the 90% reinforced criterion in nine or fewer sessions. Subject S4's differential collateral behavior was not conditioned under the standard contingency. Following ten sessions of 50% correct performance, a prompting procedure was instituted. At "A" in S4's record in Figure 1, the experimenter modeled appropriate differential behavior to the collateral keys for several trials at the beginning of the session. In addition, offset of the sample was postponed until a collateral response occurred, changing the task from a 0-delay conditional discrimination to a simultaneous discrimina-

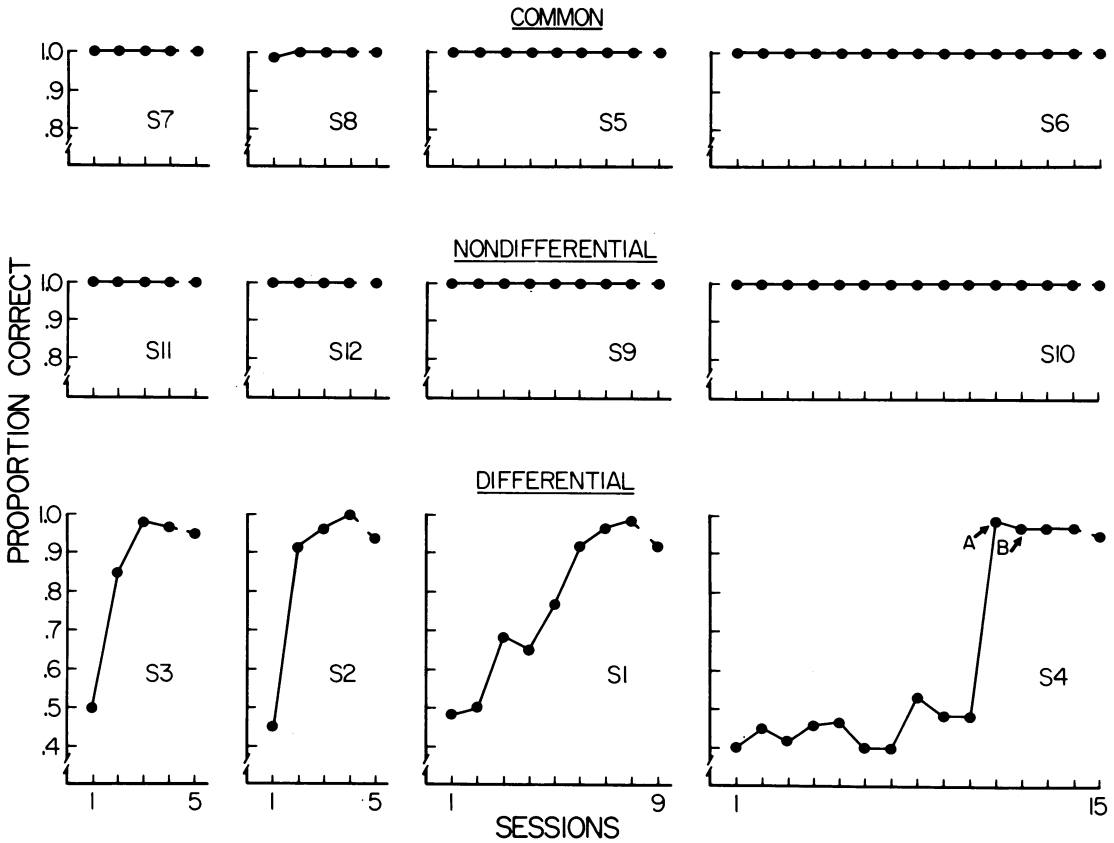

Fig. 1. Proportion of Phase-1 trials in which subjects emitted collateral behavior appropriate to their training. Subjects in the Common and Nondifferential conditions appear directly above the Differential subject with whom they were "yoked" for exposure to Phase-1 contingencies. The final unconnected points are the data obtained after the children's vacation.

tion. At "B" in S4's record the modeling procedure was omitted but the task remained simultaneous. The final three sessions of Phase 1 for S4 were the standard contingencies. Subject S4's differential collateral behavior quickly came under control of the sample stimuli at "A", and was maintained during the subsequent sessions of this phase.

Phase 2: Conditioning of Delayed Matching-to-Sample

Figure 2 shows data on the conditioning of FI .1-sec delayed matching for individual subjects. Plotted with the final criterion session above "N" on the abscissa, and prior sessions to the left (N-1, N-2, etc.), are the proportions of reinforced (matching) trials for consecutive sessions of Phase 2.

Common. Only one subject (S7) in the Common condition learned to match. The percentage of matching responses for S7 rose gradually from approximately 50% during the first session until it surpassed the 90% criterion. After eight sessions S5, S6, and S8 were matching no more frequently than would be expected by chance. Subject S5 consistently chose the bright comparison. Subject S8 consistently chose the right comparison. Subject S6 showed no systematic response pattern. Because termination of the delay was contingent upon an appropriate collateral response, the obtained delays varied above the minimal programmed FI .1-sec delay. Individual subject's mean obtained delays ranged from .94 to 1.65 sec (group mean = 1.21 sec; SD = .31 sec), with the single learner (S7) having the lowest mean delay.

Nondifferential. Performance of Nondifferential subjects was like that of Common subjects. Three of the four subjects (S9, S11, S12) showed gradual increases in matching similar to Common Subject S7. One subject (S10) continued to match on approximately 50% of the trials throughout Phase 2, similar to Common Subjects S5, S6, and S8. This single nonlearner showed no consistent pattern of responding. Individual subject's mean obtained delays ranged from .79 to 1.51 sec (group mean = 1.32 sec; SD = .26 sec), with the single nonlearner having an intermediate mean delay.

Differential. Subjects in the Differential condition showed patterns of matching acquisition different from other conditions. Three subjects (S1, S2, and S4) began this phase with matching performances exceeding the 90% criterion. High accuracy was evident in the initial few trials of the first Phase-2 session. Not only was matching learned rapidly by these subjects, but they maintained differential collateral behavior throughout this phase. Subjects S1, S2, and S4 emitted appropriate collateral behavior on 81.7%, 98.3%, and 90.7% of all Phase-2 trials, respectively.

One subject (S3) performed as the nonlearners in the other two groups, matching at or below 50% for all eight sessions. Subject S3 developed a strong position bias to the right comparison key. This child's collateral behavior differed markedly from the other Differential subjects' behavior. During the initial few trials of the first matching session S3's collateral behavior became unsystematic with respect to the samples. Beginning in the first Phase-2 session S3's collateral behavior was appropriate to training on only 46.7% of the trials. The percentage of previously trained collateral behavior changed little during remaining sessions, yielding an overall performance of 49.8% appropriate differential behavior to the collateral keys. The predominant pattern that developed involved responding first to the top collateral key on all trials, and when this response had no consequence (dim-sample trials), switching to the bottom key. The strong relationship between collateral behavior and matching accuracy observed within this group was summarized by correlating matching accuracy and collateral-behavior accuracy using session means of individual subjects. Using data for Subjects S1, S2, and S4 only, the relation between matching and collateral accuracy is very small (r = .328); but with data for S3 included the relation is rather large (r = .964).

Individual Differential subjects' mean obtained delays ranged from 1.00 to 1.96 sec (group mean = 1.66 sec; SD = .45 sec), with the single nonlearner having the highest average delay, in part due to the form of his collateral behavior.

Discussion

The data on the conditioning of matching-to-sample behavior are consistent with Eckerman's (1970) findings with pigeons and Parsons and Ferraro's (1977) findings with children. Subjects who reliably engaged in sample-specific collateral behavior (S1, S2, S4) rapidly learned the conditional discrimination. Sub-

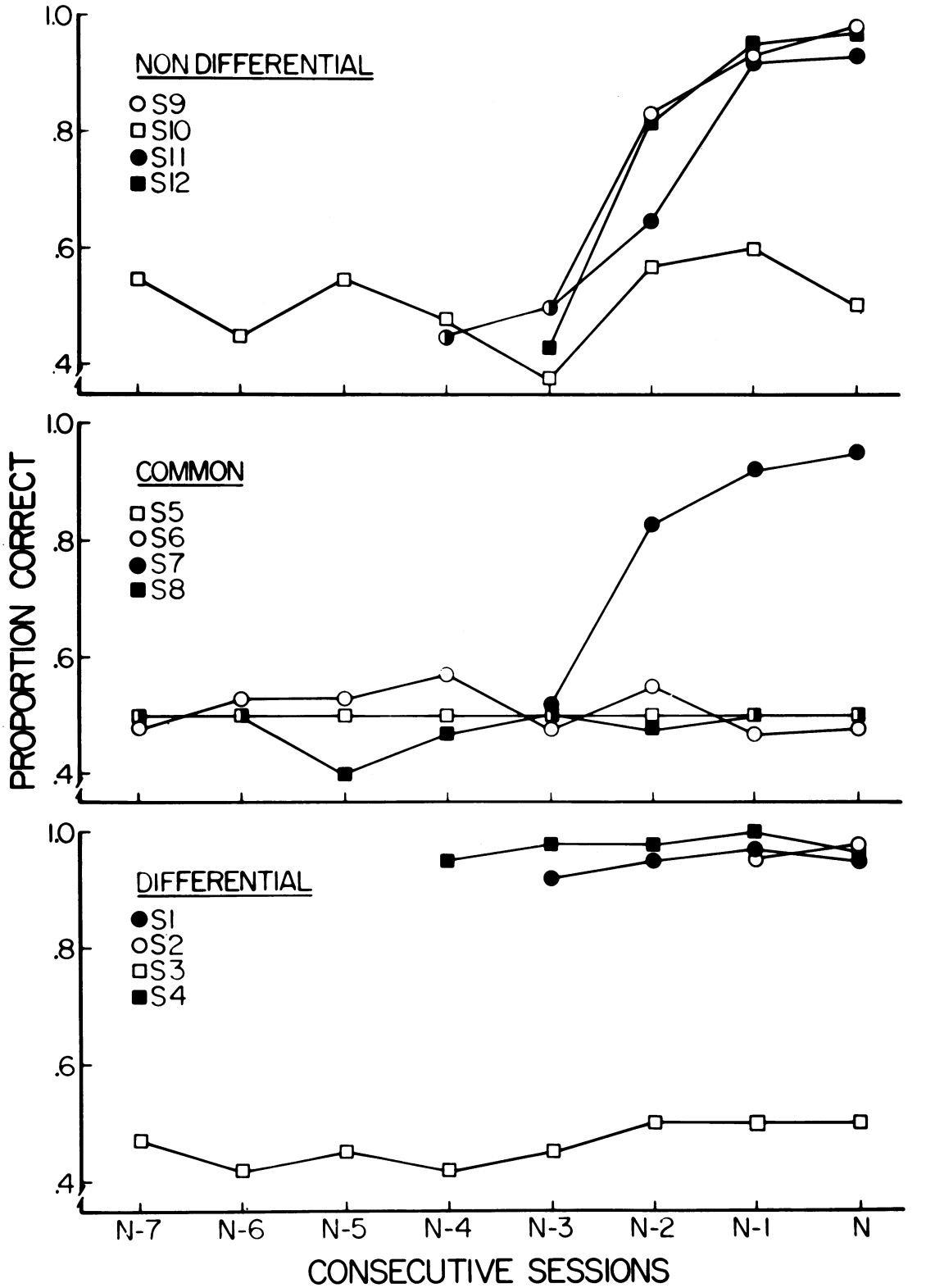

Fig. 2. Proportion of Phase-2 trials in which subjects matched. Data are plotted as "backward learning curves": Session "N" was their final Phase-2 session, Session "N-1" was their penultimate Phase-2 session, and so on.

jects who engaged in identical (S5, S6, S7, S8, S9) or nonspecific collateral behavior (S3, S10, S11, S12) either failed to acquire the discrimination or did so incrementally over a number of sessions.

Two interpretations of this finding are possible. One could argue that the conditioning of matching behavior was a function of the different contingencies correlated with the two sample stimuli during Phase 1 of the experiment. Children in the Differential condition developed discriminated operants under the control of the two sample stimuli. Children in the Common and Nondifferential conditions, however, developed an operant that was reinforced independently of the sample stimuli. This mode of interpretation may be found in the literature concerning "stimulus predifferentiation" (e.g., Tighe & Tighe, 1968) or "acquired distinctiveness of cues" (e.g., Norcross & Spiker, 1957). This interpretation alone would have some difficulty accounting for the absence of matching in Subject S3 as well as some additional data to be presented in Experiment II.

An extended interpretation which we favor is in line with Skinner's (1969) analysis. Under Phase-1 contingencies Differential subjects developed two discriminated chains of behavior: respond to bright sample, respond to top collateral key; respond to dim sample, respond to bottom collateral key. Common and Nondifferential subjects, on the other hand, developed a single chain of behavior that was emitted regardless of the sample. When the matching contingency was added in Phase 2, control over matching operants could be mediated by the collateral behavior in Differential subjects, but not in Common or Nondifferential subjects. The chaining interpretation suggests that collateral behavior functioned to prompt matching for subjects engaging in sample-specific responses. This interpretation has no difficulty accounting for the absence of matching in Subject S3, considering the lack of maintenance of differential collateral behavior.

Both positions would predict that Common-Phase-1 contingencies would interfere with the conditioning of matching behavior. The first position would assert that learning a common response to both samples would make the stimuli more alike ("acquired equivalence of cues," Norcross & Spiker, 1957) hence less likely to control the discriminated matching operant. The chaining interpretation would assert that a single chain of behavior conditioned in the Common condition would provide a single discriminative event on both types of matching trials, prompting undiscriminated behavior, if anything. Although it is tempting to say that the difference in the number of learners in the Common and Nondifferential groups reflects the retardation of matching acquisition by Common Phase-1 training, such a conclusion is limited by the fact that Nondifferential subjects were likely to behave in a "common" manner. It was true, however, that Nondifferential subjects switched the locus of their collateral response between sessions and sometimes within a session.

There was a weak relation between the number of sessions of exposure to the Phase-1 contingencies and matching performance in Phase 2. In the Common group, subjects who failed to learn the matching operant received 5, 9, and 15 sessions of Phase 1 training whereas the single Common subject who learned the matching operant spent five sessions in Phase 1. In the Nondifferential group the subject who failed to learn the matching operant had 15 sessions of Phase-1 training whereas the three Nondifferential subjects who learned the matching operant had 5, 5, and 9 sessions of Phase-1 training. Thus, within these two groups subjects with more Phase-1 experience appear to have more difficulty with the matching contingency. In the Differential group the opposite pattern emerged. The single subject who failed to learn the matching operant received five sessions of Phase-1 training whereas those subjects who did maintain sample-specific collateral behavior and learned the matching operant received 5, 9, and 15 sessions of Phase-1 training. These speculations regarding a relationship between extent of collateral training and conditioning of the current operant require further empirical support.

All children except Differential Subject S3 maintained trained collateral behavior through the introduction of the current matching contingency. Why S3 did not maintain sample-specific collateral behavior is not apparent, but the change in the contingencies for collateral behavior from Phase 1 to Phase 2 deserves mention. Recall that during Phase

1 of the study, appropriate collateral behavior resulted in reinforcement and inappropriate collateral behavior resulted in timeout. In Phase 2 this contingency was changed so that inappropriate collateral behavior did not result in a timeout. Rather, the contingency simply required that the last collateral response be appropriate to the sample that had initiated the trial. This correction procedure and/or lack of a timeout contingency for errors may have resulted in the loss of discriminative control by the sample of S3's collateral behavior. Other experiments on matching-to-sample have reported parallel findings on the reinforced operant with similar correction procedures (Ginsburg, 1957) and timeouts (Ferster & Appel, 1961).

EXPERIMENT II

Experiment II continued the analysis of the function of trained collateral behavior in the performance of the matching-to-sample task. The experiment was conducted in two phases. In Phase 1, subjects who had achieved a criterion level of matching in Experiment I were given three probe sessions in which the minimal delay between offset of the sample and collateral response-contingent presentation of the comparisons was varied within each session. The purpose of Phase 1 was to ascertain the function of collateral behavior in a "short-term-memory" task—to determine if collateral behavior would function as a precurrent operant that facilitated "remembering." In Phase 2 subjects were given the same variable-delay matching task but were prohibited from pressing the collateral keys. The purpose of Phase 2 was to analyze further the function of collateral behavior.

METHOD

Subjects

The seven children who achieved the 90% matching criterion in Experiment I served. Three subjects had histories of reinforcement for Differential collateral behavior (S1, S2, S4), three for Nondifferential collateral behavior (S9, S11, S12), and one for Common collateral behavior (S7).

Setting and Apparatus

The setting and apparatus were as in Experiment I.

Procedure

Phase 1: Variable-delay matching with collateral behavior. Variable-delay probe sessions were identical to matching sessions in Experiment I except that the minimal delay between the offset of the sample and the collateral response-contingent presentation of the comparisons was varied within each session. Three sessions were conducted in which 36 of the 60 trials per session remained as in the matching phase of Experiment I, with a minimal delay of .1 sec before a previously-trained collateral response could produce the comparison stimuli (FI .1-sec). In 12 trials per session, a minimal delay of 4.9 sec elapsed before a previously trained collateral response could produce the comparisons (FI 4.9-sec). The remaining 12 trials were similarly arranged with a minimal delay of 9.9 sec (FI 9.9-sec). The ordering of FI delays within a session was mixed within blocks of 20 trials. A different mixed order was constructed for each session.

As in Experiment I, inappropriate collateral behavior (Differential and Common only) was without effect. The last collateral press was always appropriate to the subject's training history and produced the comparison stimuli. The reinforcement contingencies were as in Experiment I: cartoon reinforcers were contingent upon a press to the comparison that matched the sample; mismatching presses resulted in timeout.

Phase 2: Variable-delay matching without collateral behavior. A final session was conducted with variable-delay procedures in which subjects were instructed not to perform collateral presses. Prior to the first trial, subjects were told that the apparatus no longer required them to "press the red buttons," and that they should not press the collateral keys even though they would be illuminated as usual. In the event that a child pressed the collateral keys, the experimenter entered the room and told the child not to press them.

During prohibition sessions the apparatus was programmed to present the comparisons according to a mixed sequence of fixed-time schedules so that the delays approximated the mean obtained delays for the subject in the prior phase. Reinforcement contingencies for matching were as in the prior phase.

Results

Phase 1

Matching-to-sample. Data for the three sessions were pooled for individual subjects and are presented in Figure 3 as solid lines. Matching data from the single Common subject and the three Nondifferential subjects were similar. On trials when the FI delay was as in Experiment I, FI .1-sec, matching performance was

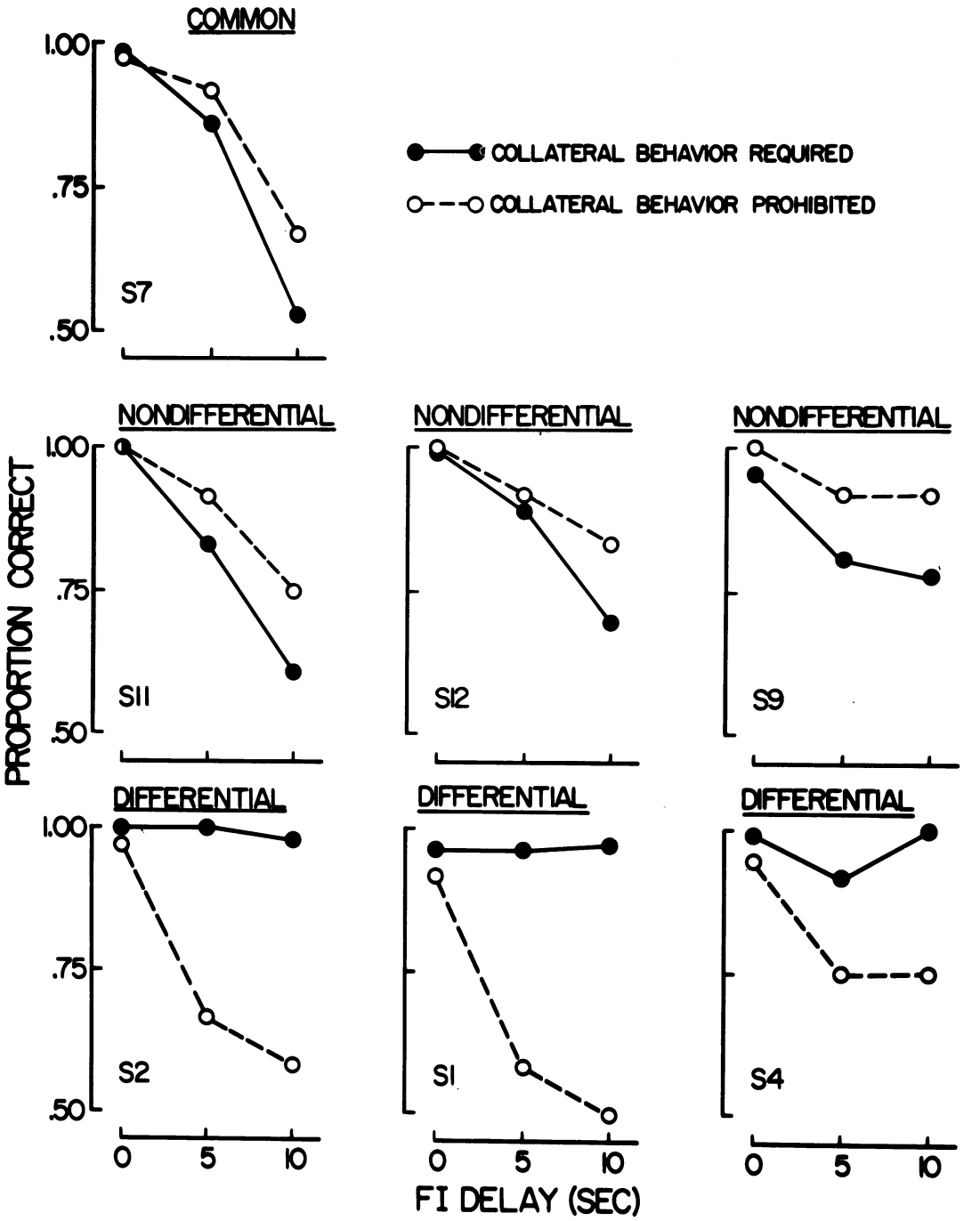

Fig. 3. Proportion of trials in which subjects matched at the three levels of FI delay. Solid lines represent Phase 1, dashed lines represent Phase 2.

high for all subjects (range 95.3 to 100%). When the FI delay was set at 4.9 sec, Common and Nondifferential subjects showed decrements in matching (range 80.6 to 88.9%). When the minimum delay was 9.9 sec, further decrements in matching were evident (range 52.8 to 77.8%). Individual Common and Nondifferential subjects had monotonic, decreasing matching accuracy as a function of delay. Because presentation of the comparisons was contingent on an appropriate collateral press, obtained delays exceeded programmed delays. Common Subject S7 had obtained delays averaging 1.05, 6.33, and 12.19 sec, respectively, for the three FIs. The three Nondifferential subjects had similar obtained delays ranging between 1.02 and 1.18, 5.10 and 6.50, and 10.18 and 12.16 sec.

Differential subjects showed variable-delay matching performance that differed markedly from Common and Nondifferential subjects. All Differential subjects showed high matching accuracy regardless of the length of delay. On FI .1-sec trials individual subjects matched on almost every trial (range 98.1 to 100%). On FI 4.9-sec trials performance remained high (range 91.7 to 100%), as it did on FI 9.9-sec trials (range 94.5 to 100%). Mean obtained delays for Differential subjects were generally longer than for the other subjects, in part due to occasional switching between the collateral keys, ranging between 1.70 and 2.48, 5.29 and 7.22, and 10.19 and 13.86 sec.

Collateral behavior. Rates of collateral behavior during the delays are shown in Figure 4 separately for each subject. The figure shows rates of collateral behavior to the top (solid lines) and bottom (dashed lines) keys separately for trials with bright sample (unfilled circles) and dim sample (filled circles). Each point indicates mean rate of pressing per trial over the three delay probe sessions. The single Common subject, S7, responded almost always to the top key, with little difference in rates on bright and dim trials. With longer delays there was a slight trend toward decreasing rates of collateral behavior. This pattern of decreasing rates with increasing delays was also evident in Nondifferential Subject S12. Subject S12 had a higher rate of responding to the bottom key at the shortest delay value, but as the delay was extended, and as rates of collateral behavior decreased, key preference disappeared. Nondifferential Subjects S9 and S11 also showed a strong preference for the bottom key on both bright and dim trials, but as the delay was extended these subjects showed slight increases in rates of collateral behavior, although these changes were not systematic. What is clear from the collateral behavior of Common and Nondifferential subjects is the absence of a systematic relationship between rates of top and bottom key responding and the type of trial, bright or dim. In general, these subjects emitted stereotyped collateral behavior that was similar on both trial types.

Data on the collateral behavior of Differential subjects (S1, S2, and S4) reveal the degree of maintenance of sample-specific collateral behavior across lengthening delays. Subject S2 showed strong maintenance of trained collateral behavior with rates of appropriate and inappropriate collateral behavior diverging as the delay was extended. This divergence was due to increases in appropriate collateral behavior. Subjects S1 and S4 also showed higher rates of appropriate than inappropriate collateral behavior across the range of delays, but their rates are more parallel and do not show higher rates of collateral behavior at the longer delays.

Phase 2

Data describing the relation between matching performance and delay length for the session in which subjects were prohibited from emitting collateral behavior are presented in Figure 3 as dashed lines. Comparison of matching data from the two phases reveals several systematic features. Common and Nondifferential subjects matched more accurately when prohibited from engaging in collateral behavior. Even though all of these subjects decreased in matching accuracy as delay lengthened, matching was more accurate than in the previous phase on FI 4.9 and FI 9.9-sec trials.

Differential subjects showed another pattern. When prohibited from emitting collateral behavior, these subjects showed marked decrements in matching on FI 4.9 and FI 9.9-sec trials. In fact, they performed more poorly than Common and Nondifferential subjects.

DISCUSSION

The delay probe data collected in Experiment II are consistent with previous research

(Blough, 1959; Laties et al., 1965; Laties et al., 1969; Parsons & Ferraro, 1977). Performance of sample-specific collateral behavior functioned to increase the probability of the reinforced operant, and prohibition of differential collateral behavior functioned to decrease the fre-

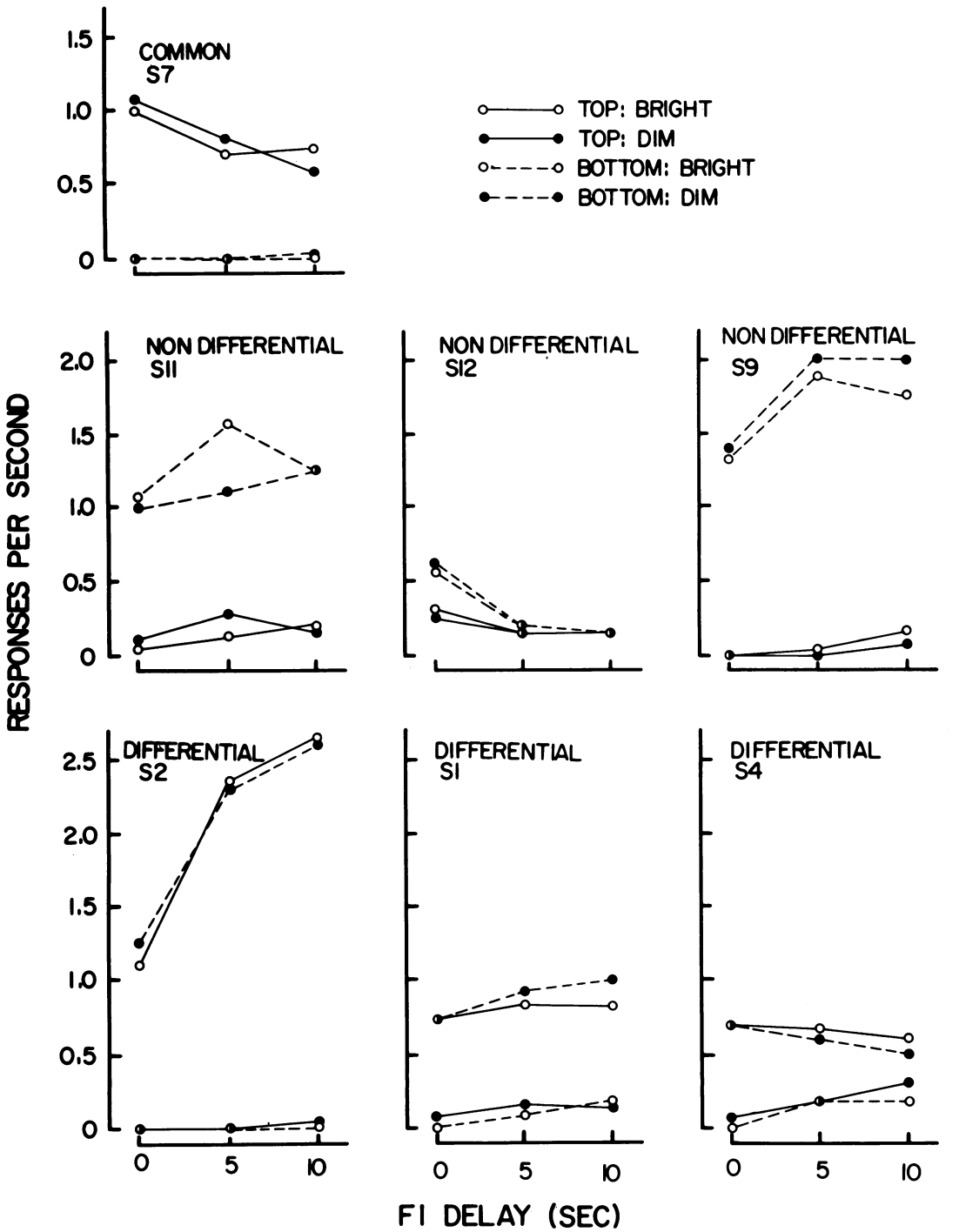

Fig. 4. Rates of top and bottom collateral behavior by subjects on bright-sample and dim-sample trials plotted as a function of FI delay. Each point depicts mean rate per trial over the three Phase-1 sessions.

quency of the reinforced operant. Previous findings were extended in the current study by inclusion of the Common and Nondifferential conditions. Under both Common and Nondifferential contingencies subjects matched less well as the delays were extended, both when collateral behavior was required and when it was prohibited. At the longer delays Common and Nondifferential subjects matched more accurately when prohibited from emitting stereotyped collateral behavior during the delays.

The interpretation favored in Experiment I deals equally well with the results of Experiment II. Subjects in the Differential condition developed two chains of behavior that involved sample-specific collateral behavior. When the delay was lengthened, control of the matching operant continued to be mediated by the emission of sample-specific collateral behavior. When collateral behavior to the keys was absent during prohibition, control of matching was restricted to the recently vanished sample stimulus. On FI .1-sec trials, performance was little affected. As the interval between the offset of the sample and the onset of the comparisons increased, however, control of matching by the sample deteriorated. Common and Nondifferential subjects, on the other hand, emitted one stereotyped behavior chain regardless of the sample. When the delay was at its minimum, control by the sample was apparently sufficient to maintain high matching accuracy. When the delay was extended these subjects' matching accuracy decreased as a function of delay both when stereotyped behavior was emitted and when it was prohibited. It is possible that stereotyped collateral behavior during the delay functioned to decrease sample control over matching. This is suggested by the fact that matching was more accurate in these subjects when sample-nonspecific collateral behavior was prohibited.

One of the major extensions to the literature on precurrent behavior offered by this study was the direct measurement of collateral behavior. One question posed by this research was whether precurrent collateral behavior would be maintained when reinforcement was made contingent upon a subsequent current operant. With the exception of the loss of stimulus control over S3's behavior, collateral behavior of all subjects was maintained through the transition from direct reinforcement (Experiment I, Phase 1) to indirect reinforcement (Experiment I, Phase 2). As the FI contingency was varied in Experiment II, previously reinforced patterns of collateral behavior were maintained in all subjects. The collateral behavior served two functions. For all subjects, it functioned to produce the comparison stimuli. For Differential subjects it also served a precurrent function, increasing the likelihood of the reinforced operant. For Common and Nondifferential subjects collateral behavior served to decrease the likelihood of the reinforced operant. Skinner (1968) has suggested that a precurrent operant may require explicit conditioning, but that its maintenance will depend upon its effect on the current operant. Extending this argument to the present task one could predict that Differential subjects would continue to emit sample-specific collateral behavior appropriate to their histories when this behavior was not required but not prohibited, but that Common and Nondifferential subjects would not. A preliminary study (Note 1) has indicated maintenance of Differential collateral behavior under these conditions, but data have yet to be collected concerning the maintenance of Common and Nondifferential collateral behavior.

REFERENCE NOTE

1. Parsons, J. A., Goehring, M., and Waugh, M. A pilot study of the maintenance of precurrent self-prompting behavior. Unpublished research, 1979. Abstract available from Joseph A. Parsons (see footnote).

REFERENCES

Bijou, S. W. *Child development: The basic stage of early childhood.* Englewood Cliffs, N.J.: Prentice-Hall, 1976.

Blough, D. S. Delayed matching in the pigeon. *Journal of the Experimental Analysis of Behavior,* 1959, **2,** 151-160.

Bruner, A., & Revusky, S. H. Collateral behavior in humans. *Journal of the Experimental Analysis of Behavior,* 1961, **4,** 349-350.

Eckerman, D. A. Generalization and response mediation of a conditional discrimination. *Journal of the Experimental Analysis of Behavior,* 1970, **13,** 301-316.

Ferster, C. B., & Appel, J. B. Punishment of S^{Δ} responding in matching to sample by time out from positive reinforcement. *Journal of the Experimental Analysis of Behavior,* 1961, **4,** 45-56.

Ginsburg, N. Matching in pigeons. *Journal of Comparative and Physiological Psychology,* 1957, **50,** 261-263.

Hearst, E. Delayed alternation in the pigeon. *Journal of the Experimental Analysis of Behavior,* 1962, **5,** 225-228.

Laties, V. G., Weiss, B., Clark, R. L., & Reynolds, M. D. Overt "mediating" behavior during temporally spaced responding. *Journal of the Experimental Analysis of Behavior,* 1965, **8,** 107-116.

Laties, V. G., Weiss, B., & Weiss, A. B. Further observations of overt "mediating" behavior and the discrimination of time. *Journal of the Experimental Analysis of Behavior,* 1969, **12,** 43-57.

Norcross, K. J., & Spiker, C. C. The effects of type of stimulus pretraining on discrimination performance in preschool children. *Child Development,* 1957, **28,** 79-84.

Parsons, J. A., & Ferraro, D. P. Complex interactions: A functional approach. In B. C. Etzel, J. M. LeBlanc, & D. M. Baer (Eds.), *New developments in behavioral research: Theory, method, and application. In honor of Sidney W. Bijou.* Hillsdale, N.J.: Lawrence Erlbaum Associates, 1977.

Schwartz, B., & Williams, D. R. Discrete-trials spaced responding in the pigeon: The dependence of efficient performance on the availability of a stimulus for collateral pecking. *Journal of the Experimental Analysis of Behavior,* 1971, **16,** 155-160.

Shimp, C. P., & Moffitt, M. Short-term memory in the pigeon: Delayed-pair-comparison procedures and some results. *Journal of the Experimental Analysis of Behavior,* 1977, **28,** 13-25.

Skinner, B. F. *Science and human behavior.* New York: The Free Press, 1953.

Skinner, B. F. *Verbal behavior.* New York: Appleton-Century-Crofts, 1957.

Skinner, B. F. *The technology of teaching.* New York: Appleton-Century-Crofts, 1968.

Skinner, B. F. *Contingencies of reinforcement: A theoretical analysis.* Englewood Cliffs, N.J.: Prentice-Hall, 1969.

Tighe, T. J., & Tighe, L. S. Perceptual learning in the discrimination processes of children: An analysis of five variables in perceptual pretraining. *Journal of Experimental Psychology,* 1968, **77,** 125-134.

Wilson, M. P., & Keller, F. S. On the selective reinforcement of spaced responses. *Journal of Comparative and Physiological Psychology,* 1953, **46,** 190-193.

Received April 21, 1980
Final acceptance March 24, 1981