NEWSOM, CRIGHTON DOWD. Behavioral Contrast and Decreasing Preference for a Multiple-Schedule Component with Reduced Response Rate. (1970) Directed by: Dr. Aaron J. Brownstein. pp. 48

When responding in one component of a multiple schedule of reinforcement is suppressed, behavioral contrast, indicated by an increase in response rate, may occur in an alternated, unchanged component. The present study attempted to determine whether the suppression of responding that produces contrast does so because it renders the component in which it occurs aversive relative to the unchanged component. Six pigeons were exposed to a multiple fixed-interval fixed-interval schedule of reinforcement with equal reinforcement rates in the two components, and, on alternate days, to a concurrent chain schedule having terminal links identical to the components of the multiple schedule. When responding was suppressed in one multiple-schedule component and in one terminal link, three subjects showed positive contrast in the unchanged multiple component and indicated decreased preference for the terminal link in which responding was suppressed. Two additional subjects showed no contrast in the multiple schedule and increased preference for the terminal link in which responding was suppressed. The conclusion that the increased aversiveness of the component in which responding was suppressed was sufficient to account for the occurrence of contrast in the multiple schedules is prevented by the performance of the last subject, who showed decreased preference for the manipulated component but did not show contrast. However, only those subjects who showed decreased preference for the terminal link where response rate was suppressed also showed contrast in the unchanged terminal link. This result suggests that establishing increased aversiveness in one terminal link may be both necessary and sufficient for the appearance of positive contrast in the unchanged terminal link of concurrent chain schedules of reinforcement.

An additional finding of the present study was a higher response rate in the FI components when they were the terminal links of concurrent chains than when they were the components of the multiple schedule. This contrast effect was interpreted as resulting from the absence of reinforcement just prior to the onset of the first fixed intervals in the terminal links.

BEHAVIORAL CONTRAST AND DECREASING PREFERENCE FOR A MULTIPLE-SCHEDULE COMPONENT WITH REDUCED RESPONSE RATE

by

Crighton Dowd Newsom

A Thesis Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Master of Arts

Greensboro
September, 1970

Approved by

Aaron J. Brownstein
Thesis Adviser

APPROVAL SHEET

This thesis has been approved by the following committee of the Faculty of the Graduate School at The University of North Carolina at Greensboro.

Thesis Adviser Aaron J. Brownstein

Oral Examination
Committee Members Aaron J. Brownstein
Richard L. Shull

Evalyn F. Segal

September 30, 1970
Date of Examination

ACKNOWLEDGMENTS

The author is grateful to Dr. Aaron J. Brownstein for suggesting this study and for his generous support with equipment and advice during its execution. He is further indebted to Dr. Richard Shull for many helpful suggestions which contributed substantially to the analysis of the results. The kind assistance of Drs. Evalyn F. Segal and Roger D. Bourdon in evaluating and completing this study is acknowledged with much appreciation.

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INTRODUCTION

A multiple schedule of reinforcement consists of at least two alternating schedules of reinforcement, each associated with a distinctive exteroceptive stimulus. The rate of responding in the presence of one of the stimulus conditions in a two-component multiple schedule can be altered by a change in the rate of reinforcement in the other component or by a change in the rate of responding in the other component. If the rates of responding in the two components change in opposite directions, the phenomenon known as behavioral contrast is said to occur (Reynolds, 1961a). Positive behavioral contrast is indicated by an increase in response rate in an unchanged component when some manipulation in the other component produces a decrease in response rate. When that manipulation is the elimination of reinforcement or a reduction in the rate of reinforcement, contrast reliably occurs in the unchanged component (e.g., Reynolds, 1961a). Contrast can also be produced in an unchanged component by the suppression of responding in the alternating component when rates of reinforcement are kept equal in both components (Brownstein & Hughes, 1970; Brownstein & Newsom, 1970; Terrace, 1968; Weisman, 1969, 1970). One current theoretical account of positive contrast may conveniently be designated the emotionality hypothesis. As recently explicated by Terrace (1966, 1968), this view holds that the suppression of responding in the presence of one of a pair of alternating stimuli is sufficient (1) to render the stimulus in the presence of which the reduction in response rate takes place an aversive one, and inhibitory, and (2) to cause a non-stimulus-specific excitatory state in the organism which occasions the increased response rate in the unchanged component indicative of contrast (Terrace, 1966, 1968). Other varieties of the emotionality hypothesis have been advanced from time to time. Amsel (1958) proposed that contrast was an effect of frustration due to the lack of or diminution in reinforcement in a situation where reinforcement was previously available. Bloomfield (1967a) also considered contrast to be a frustration effect, whereby frustration responses conditioned to the stimulus present when reinforcement was discontinued generalized to the stimulus associated with reinforcement. Finally, Premack (1969) has asserted that a necessary and sufficient condition for the occurrence of contrast is a change in the aversiveness associated with one of the components in a schedule.

The several varieties of the emotionality hypothesis have in common the characterization of the stimulus conditions in the manipulated component as aversive (relative to those in the unchanged component) and therefore having both inhibitory and excitatory effects. However, the main inhibitory and excitatory effects may be specified in purely behavioral terms as the decreased response rate in the manipulated component and the increased response rate in the unchanged component, respectively (cf Jenkins, 1965). To attribute these effects to a presumed aversiveness of the manipulated component is to insert an additional, and perhaps unnecessary, link in the causal chain. The legitimacy of considering the changed component aversive could be tested directly by incorporating a choice design into a procedure expected to generate contrast. It could reasonably be predicted that a component that is aversive relative to an alternated component would be nonpreferred relative to the alternated component. This follows from the definition of an aversive stimulus as "one that is effective as a negative reinforcer or as a punisher, or that suppresses positively reinforced operant behavior in the presence of a preceding stimulus [Catania, 1968, p. 328]."

A convenient procedure for the assessment of preference between two schedules of reinforcement is the concurrent chain design (Autor, 1969). Typically, a two-link chain schedule of reinforcement is programmed on each of two response keys. The initial links of the two chains are concurrently available, while the terminal links are mutually exclusive. First, both keys are illuminated and responding on the two keys is maintained by concurrent schedules of conditioned reinforcement. The conditioned reinforcement for responding on either of the two keys during the concurrent initial links is the appearance of the terminal link of the chain on that key, indicated by a change in the illuminated stimulus on the key. When one terminal link is entered, the other key becomes dark and ineffective. Further responding on the illuminated key is then reinforced according to some schedule of primary reinforcement. After one or two reinforcements are obtained in the terminal link, the concurrent initial links are reinstated. Preference for the contingencies of reinforcement in one terminal link relative to those in the other terminal link is indicated by a greater relative frequency of responses on one of the keys in the initial links. Relative frequency is calculated for either key by dividing the number of responses on the key by the total number of responses on both keys during the initial links.

The present concern lies with those contrast studies in which reinforcement rate is kept equal in the two components of a multiple schedule and responding is suppressed in one component. According to the emotionality hypothesis, the suppression of responding in one component renders that component aversive relative to the other component. Although this proposal was not directly tested until the present study was undertaken, there are some data from experiments employing the concurrent chain design which can be brought to bear on the relevant contrast studies.

For the case in which responding in one component is suppressed by electric shock punishment (Brethower & Reynolds, 1962; Terrace, 1968), there is sufficient independent evidence to support the assumption that shock is aversive in contexts similar to those of the contrast studies (Rachlin, 1967; Reynolds, 1963a).

Other procedures for producing contrast in an unchanged component while maintaining equal reinforcement rates have included differential reinforcement of low response rates (DRL) schedules (Terrace, 1968; Weisman, 1969), a differential reinforcement of behavior other than key-pecking (DRO) schedule (Weisman, 1970), a blackout-signalled reinforcement technique (Brownstein & Hughes, 1970), and a simple cueing of reinforcement availability in fixed-interval schedules (Brownstein & Newsom, 1970). In each of these studies it is not intuitively obvious that the component in which responding was suppressed was aversive relative to the unchanged component. Furthermore, the relevant concurrent chain schedule data are sparse and inconclusive.

Fantino (1968) attempted to measure preference between fixed-interval (FI) schedules and DRL schedules equated for reinforcement rate and inter-reinforcement duration. Only one subject consistently preferred the FI schedules. When reinforcement in the DRL schedule was contingent on no more than one response occurring during the 15-sec. interval, the relative rate of responding in the initial link of the FI key reached its maximum value of 63%. The applicability of Fantino's results to the contrast studies employing DRL schedules (Terrace, 1968; Weisman, 1969) is seriously limited for several reasons, primarily because the contrast studies cited alternated DRL schedules with variable-interval (VI) schedules rather than with FI schedules, and there were also differences in such parameters as inter-reinforcement duration and percentage of available reinforcements obtained. Fantino's results permit only a tentative conclusion that a component in which response rate is suppressed can be aversive relative to one in which response rate is free to vary.

Considering next the case of the DRO schedule, Killeen's (1968) experiment, which is fairly comparable in procedure to Weisman's (1969) contrast study, gives no support to a position holding that the reduction of response rate by this method is aversive. Killeen programmed VI 30-sec. schedules in the terminal links of a concurrent chain schedule. After preliminary training, a DRO 1.5-sec. requirement was added to the schedule in one terminal link (tand VI 30 sec. DRO 1.5 sec.), which reduced the response rate in that link almost to zero. This large obligatory reduction in response rate in one terminal link had little effect on choice responding in the initial links: four pigeons showed an average increase from baseline preference for the DRO terminal link of only 1%. Weisman (1969) found behavioral contrast in the unchanged component of a multiple VI 1-min. VI 1-min. schedule after the VI schedule in one component was changed to a DRO 32-sec. schedule, which kept reinforcement rates equal in the two components.

Finally, a study by Neuringer (1969) provides some data on the possible aversiveness of blackout relative to illumination of the chamber. An FI schedule of reinforcement was compared with a schedule of response-independent delayed reinforcement. Responding was eliminated in the delayed-reinforcement terminal link by total blackout of the chamber. The duration of the delay interval equaled the duration of the fixed interval as both varied from 2 to 60 sec. over the course of the experiment. Five subjects averaged a relative frequency of responses in the initial link of the FI key of 55%, indicating some preference for the FI terminal link. Control experiments indicated that the blackout in the delayed-reinforcement terminal link, rather than the absence of responding, was responsible for the preference for the FI schedule. These results could be used to argue that Brownstein and Hughes (1970) found contrast in an illuminated component of a multiple VI VI schedule because their subjects found it less aversive than an alternating blackout component. But the applicability of Neuringer's results are limited to some extent because Brownstein and Hughes employed a different schedule of reinforcement (variable interval) having a longer mean inter-reinforcement interval (2 min.).

The concurrent chain studies briefly reviewed above do not provide the basis for a definitive conclusion about the possible aversiveness of the methods used to suppress responding in behavioral contrast investigations, primarily because they used schedules with much shorter inter-reinforcement durations than are typically employed in contrast experiments. Insofar as they may be applied to the contrast studies, they indicate only that DRL schedules and blackout conditions can be somewhat aversive relative to FI schedules and conventional VI schedules, respectively, while DRO schedules can be shown not to be aversive relative to conventional VI schedules.

The present study was designed to avoid some of the hazards of analogizing the results of different experiments investigating different problems. A multiple schedule expected to produce positive contrast alternated on a daily basis with a concurrent chain schedule in which the terminal links were identical to the components of the multiple schedule. This allowed changes in preference to be measured nearly simultaneously with changes in responding indicative of contrast.

A secondary purpose of the present experiment was to evaluate the generality of Reynolds' (1963b) finding that interactions such as contrast will not occur in multiple schedules if responding in either component is maintained by a schedule providing more than 40 reinforcements per hour. The applicability of this finding to multiple schedules in which the rate of reinforcement remains constant in each component, instead of systematically varying in one component as in Reynolds' study, was tested by scheduling reinforcements for one group at a rate known to be low enough for contrast to appear and for a second group at a rate predicted by Reynolds' (1963b) results to be too great for contrast to appear.

METHOD

Subjects

Six adult pigeons were maintained at 80% of their free-feeding body weights during the course of the experiment. Four birds (C 1, C 9, C 11, C 12) were White Carneaux pigeons approximately two years old at the beginning of the study. Two birds (RH 1, RH 3) were Silver King pigeons approximately three years old when the study began. All were obtained from the Palmetto Pigeon Plant and were housed in individual cages with continuous access to water. Lighting conditions included a mixture of available natural light and artificial illumination from fluorescent bulbs which were always on. All of the subjects had been used in a series of experiments on behavioral contrast with multiple VI VI schedules of reinforcement which terminated about six months prior to the present study.

Apparatus

A standard operant conditioning chamber manufactured by Lehigh Valley Electronics was used. The chamber contained two translucent plastic response keys mounted behind 1-in. diameter holes in the front wall. The keys were 6.5 in. apart (center-to-center) and in a horizontal plane 10 in. above the floor. Stimulus projectors from Industrial Electrical Engineering Corporation were mounted behind the keys and allowed the presentation of different geometric figures in white against a dark gray background on each key. When either key was transilluminated with one of the figures, a force of at least 15 grams against the key broke an electrical contact which operated control and recording circuits and also produced a feedback click from a relay mounted behind the front wall. Reinforcement was a 3-sec. presentation of mixed grain accessible through a 2.25-in. by 2-in. opening located equidistant from the keys and 4 in. from the floor. When grain was presented the only illumination in the chamber was that of the feeder light. At all other times during a session a hooded 7-w. bulb located on the front wall equidistant from the response keys and near the ceiling provided general illumination. Extraneous sounds were masked by noise from a ventilating fan and white noise transmitted through a speaker mounted behind a 3-in. circular opening in the front wall to the left of and below the left response key. Electromechanical equipment located in the same room scheduled the experimental contingencies and recorded the data.

Procedure

Since all the subjects had experimental histories, the first session began with a two-component multiple schedule in effect. While the right key was dark and inoperative, a white, horizontal bar measuring 0.25 in. by 0.75 in. appeared on the left key and a fixed-ratio (FR) 1 schedule was in effect until two reinforcements were obtained. Then the left key became dark and inoperative and a white, vertical bar (0.25 in. by 0.75 in.) appeared on the right key. Pecks on the right key were also reinforced on an FR 1 schedule until two reinforcements were obtained. These stimuli and schedules alternated on the two keys until a total of 20 reinforcements had been presented. During the second session, subjects C 1, C 9, and C 11 (FI 120-sec. group) were placed on a multiple VI 60-sec. VI 60-sec. schedule of reinforcement and then on a multiple FI 60-sec. FI 60-sec. schedule the third and fourth days. In the fifth session a multiple FI 120-sec. FI 120-sec. schedule went into effect and remained in effect during the succeeding daily sessions of preliminary training. Subjects C 12, RH 1, and RH 3 (FI 30-sec. group) were exposed to a multiple FI 15-sec. FI 15-sec. schedule of reinforcement in the second and third sessions. During the fourth session a multiple FI 30-sec. FI 30-sec. schedule was instituted for these subjects and remained in effect during the remainder of the preliminary training sessions. On the eighteenth day the number of reinforcements during each session was increased to 30 for all subjects. The nineteenth and all subsequent sessions terminated after 40 reinforcements. For both groups of subjects the multiple-schedule components remained in effect until two reinforcements had been presented, and the left and right FI components were always correlated with a horizontal and a vertical bar, respectively. The left and right FI components alternated regularly during each session. Preliminary training on this multiple FI FI schedule lasted for 60 daily sessions, when responding appeared stable for all subjects.

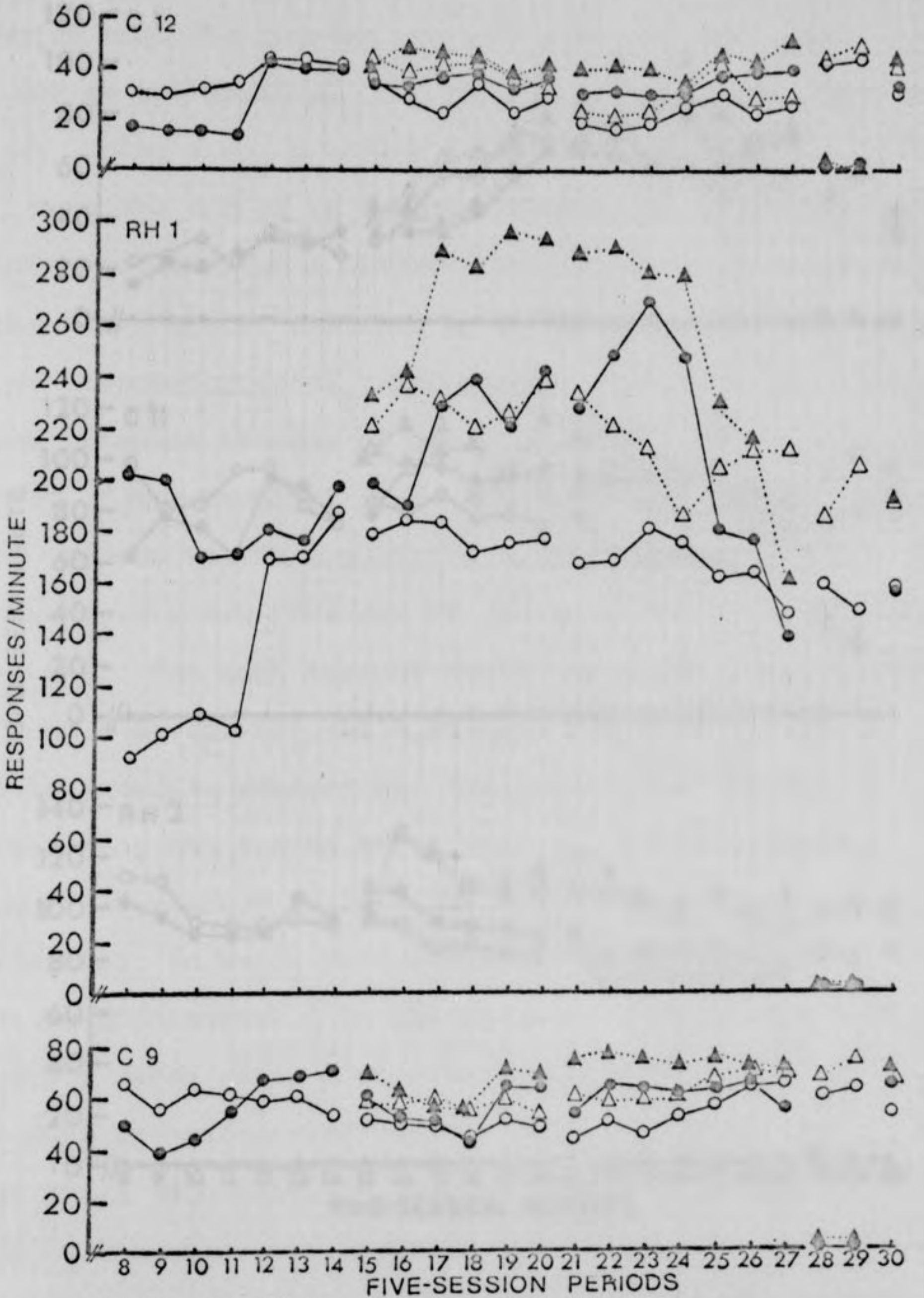
Beginning with the sixty-first session, a concurrent chain schedule was in effect in alternate sessions of the experiment. The initial links were indicated by 0.75-in. white squares projected on the keys simultaneously. For 27 concurrent chain sessions, entry into either terminal link required only one peck on the key for which an entry was programmed. For the remaining concurrent chain sessions, a single tape programmed entries on a VI schedule with an arithmetic mean interval of 30 sec., with the effect that each key separately was on a VI 60-sec. schedule of conditioned reinforcement during its initial link. The order of entries into the left and right terminal links was randomly ordered on a stepper switch under the restrictions that neither terminal link be entered more than three times successively and that both terminal links be entered an equal number of times (10) in each session. The terminal link on the left key, indicated by horizontal white bar, lasted until two fixed-interval reinforcements had been obtained. The duration of each fixed interval was 120 sec. for the FI 120-sec. group and 30 sec. for the FI 30-sec. group. The terminal link on the right key had the same schedule properties, but was indicated by a vertical white bar. Thus the left and right terminal links were identical to the left and right FI components of the multiple schedule in effect for each group on alternate days.

The multiple schedule and the concurrent chain schedule alternated until each subject had experienced 37 multiple-schedule sessions and 38 concurrent chain sessions. Attempts to correct biases for either key by various ineffective procedures were ended just prior to this phase of the experiment in order to ensure stable responding during the main experimental phase. After the thirty-eighth concurrent chain session, the key bias of each subject was determined by examining the following three measures in the data of the previous 10 days: relative rates of responding in the terminal links and relative number of responses in the initial links of the concurrent chain schedule, and relative rates of responding in the components of the multiple schedule. For four birds these measures covaried and the key on which the higher percentages of responses were being emitted was designated the preferred key. For two birds (C 9, RH 1) these measures were not reliably in agreement; preference as indicated by the initial link percentages of responses was used to determine the preferred key, since this measure was much more consistent than either the terminal link or multiple-schedule component relative rates.

Beginning with the next session, in which the multiple schedule was in effect, the main experimental manipulation was introduced. In the FI component on the preferred key, no stimulus appeared on the key during each fixed interval. Pecks emitted on the dark key were counted, but produced no relay click. When each fixed interval had elapsed, the appropriate stimulus for that key was presented and a single peck would produce a relay click and reinforcement. The same contingencies were in force during both fixed intervals of the initially preferred FI component during multiple-schedule sessions, and during both fixed intervals of the initially preferred terminal link in concurrent chain sessions. The contingencies of reinforcement on the nonpreferred key remained unchanged. This procedure lasted for 26 sessions (the "dark-key" phase), ending after the thirteenth concurrent chain session. Then the baseline condition, in which the fixed intervals on both keys were illuminated with their respective stimuli, was reinstated for 10 recovery sessions.

RESULTS

The rates of responding in the FI components by individual subjects over the duration of the study appear in Fig. 1a, b. Each point is the median of five sessions; circles represent response rates in multiple-schedule sessions and triangles represent response rates in concurrent chain sessions. Responding on the preferred and nonpreferred keys are indicated by the filled and unfilled symbols, respectively. The introduction of the concurrent chain schedule in alternate sessions had no uniform effect on multiple schedule responding. In general, however, responding was maintained at a higher rate in the left and right terminal links than in the identical multiple-schedule components. This effect is seen most clearly in Bird RH 3 (Fig. 1b), but was reliably present in the other subjects as well. This increased response rate in the FI components when they were preceded by initial links is a case of positive behavioral contrast occurring in chained schedules of reinforcement. It was mediated by decreased pause times in the terminal links; when the FI components were the terminal links in concurrent chain sessions, pause duration per session was approximately half of what it was when the FI components were the components of the multiple schedule. Cumulative records and print-out counter records



Periods	Conditions
1-14	Mult only
15-20	Mult / Conc Chain (FR I Initial Links)
21-27	" " (VI 60-sec Initial Links)
28-29	Dark-key Phase
30	Recovery

Fig. 1a. Rate of responding in FI components.

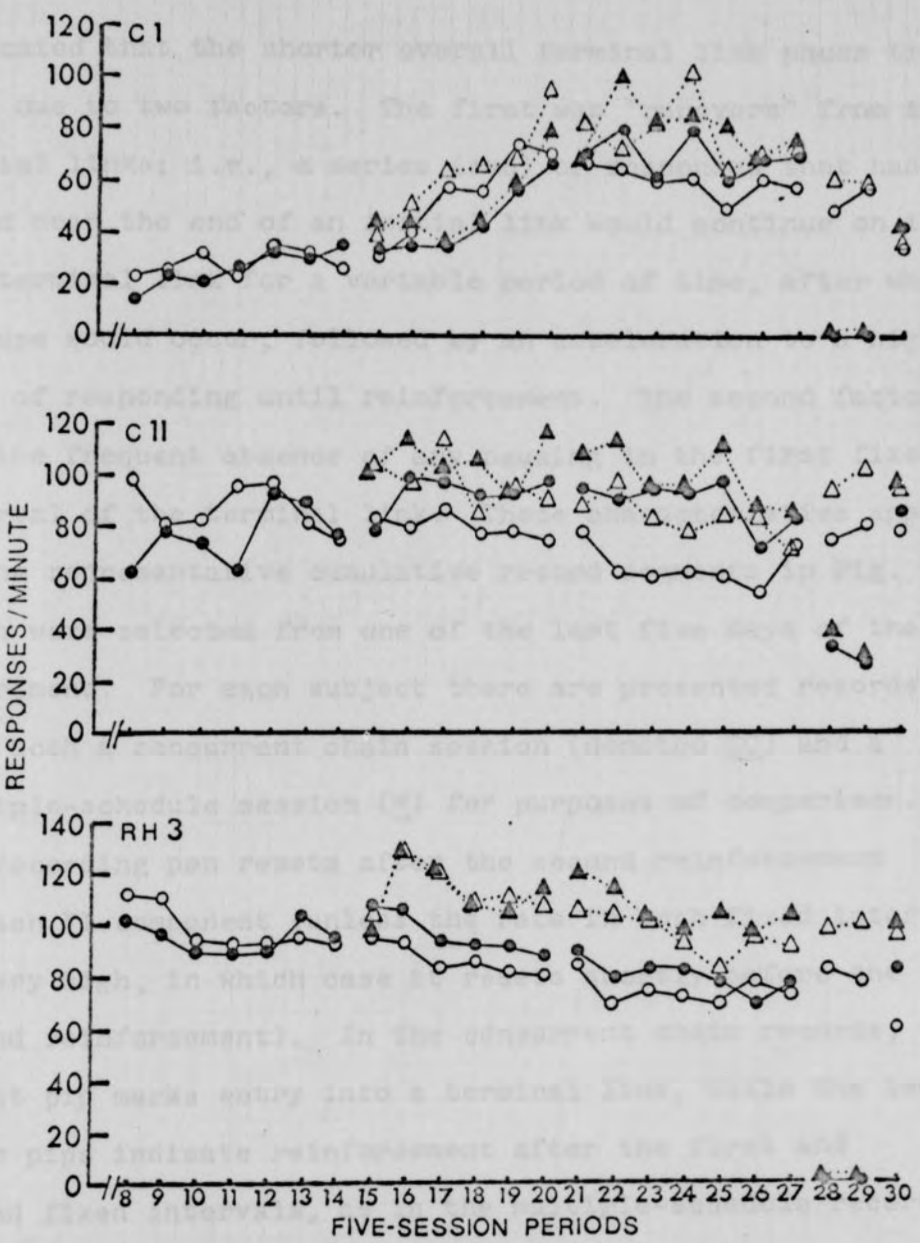


Fig. 1b. Rate of responding in FI components.

indicated that the shorter overall terminal link pause times were due to two factors. The first was "runovers" from the initial links; i.e., a series (run) of responses that had begun near the end of an initial link would continue on into the terminal link for a variable period of time, after which a pause would occur, followed by an acceleration to a high rate of responding until reinforcement. The second factor was the frequent absence of any pausing in the first fixed interval of the terminal link. These characteristics appear in the representative cumulative record segments in Fig. 2a, b, which were selected from one of the last five days of the experiment. For each subject there are presented records from both a concurrent chain session (denoted _CC_) and a multiple-schedule session (_M_) for purposes of comparison. The recording pen resets after the second reinforcement in each FI component (unless the rate in both fixed intervals is very high, in which case it resets shortly before the second reinforcement). In the concurrent chain records, the lowest pip marks entry into a terminal link, while the two upper pips indicate reinforcement after the first and second fixed intervals, as in the multiple-schedule records. Note that the rates are typically greater in the concurrent chain records, especially during the first fixed interval of each terminal link. A few examples of runovers are indicated by arrows. The frequent absence of pausing during the first fixed interval in the concurrent chain records of C 9,

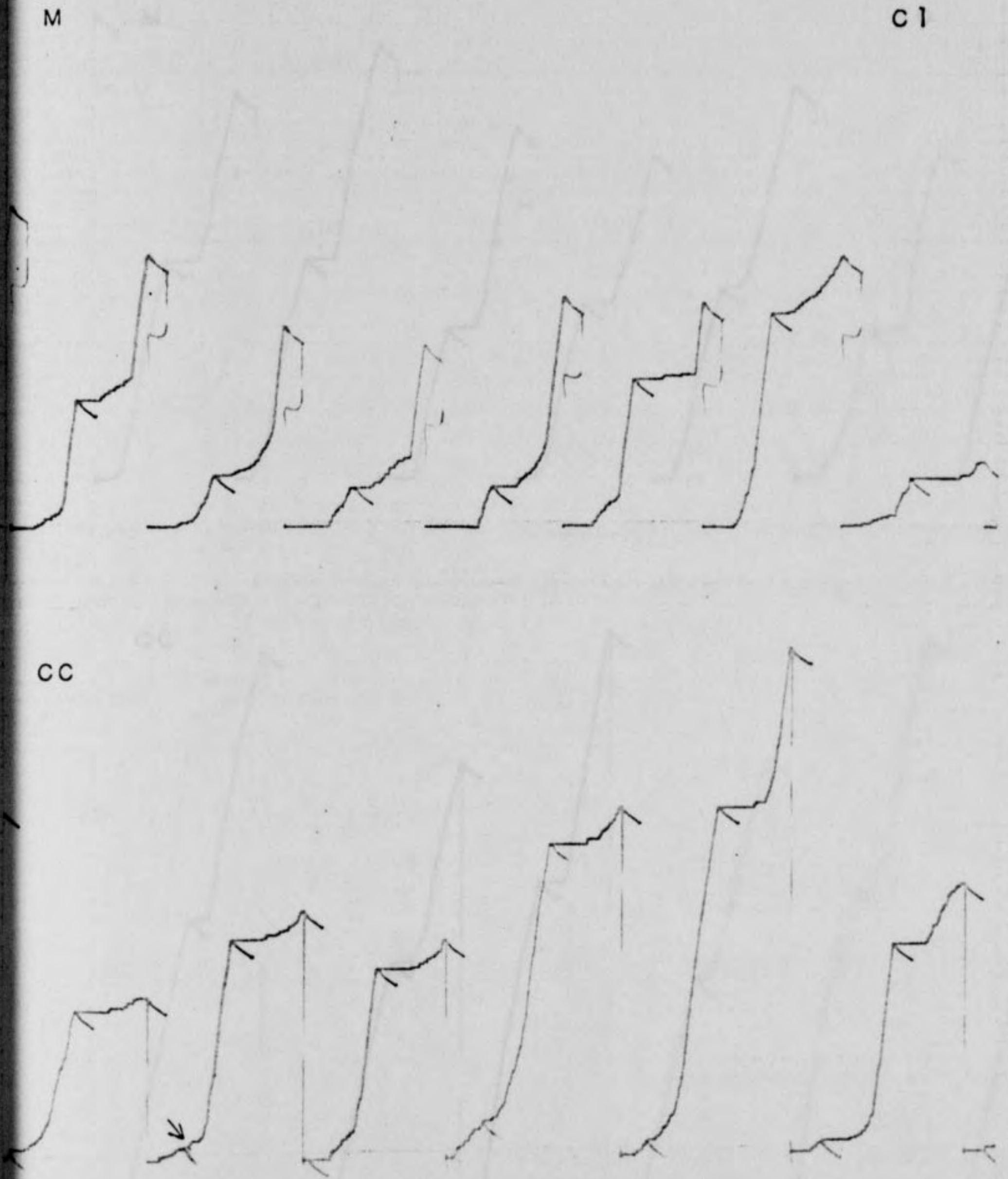


Fig. 2 a. Cumulative records, FI 120-sec. group.

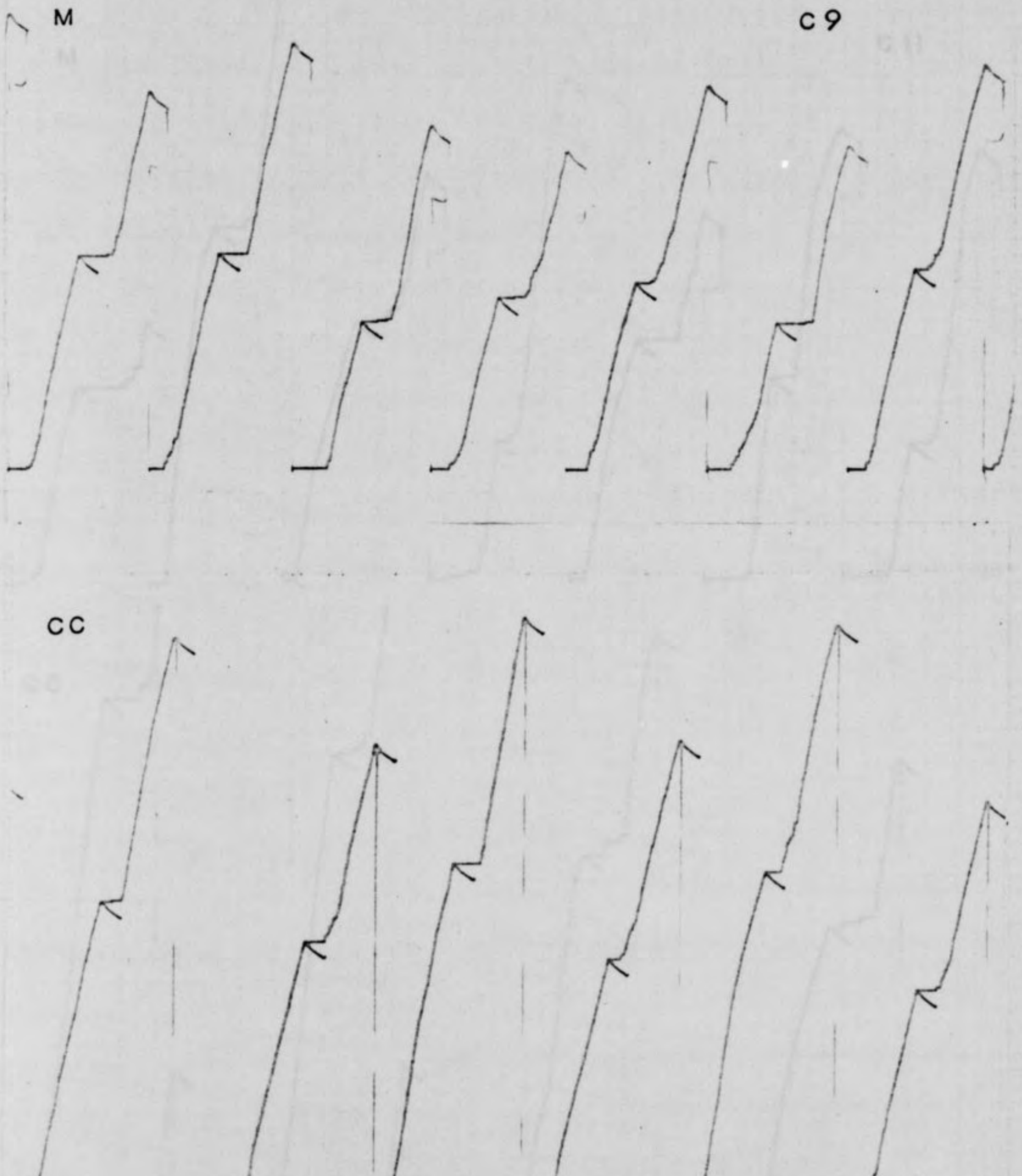


Fig. 2a (cont'd).

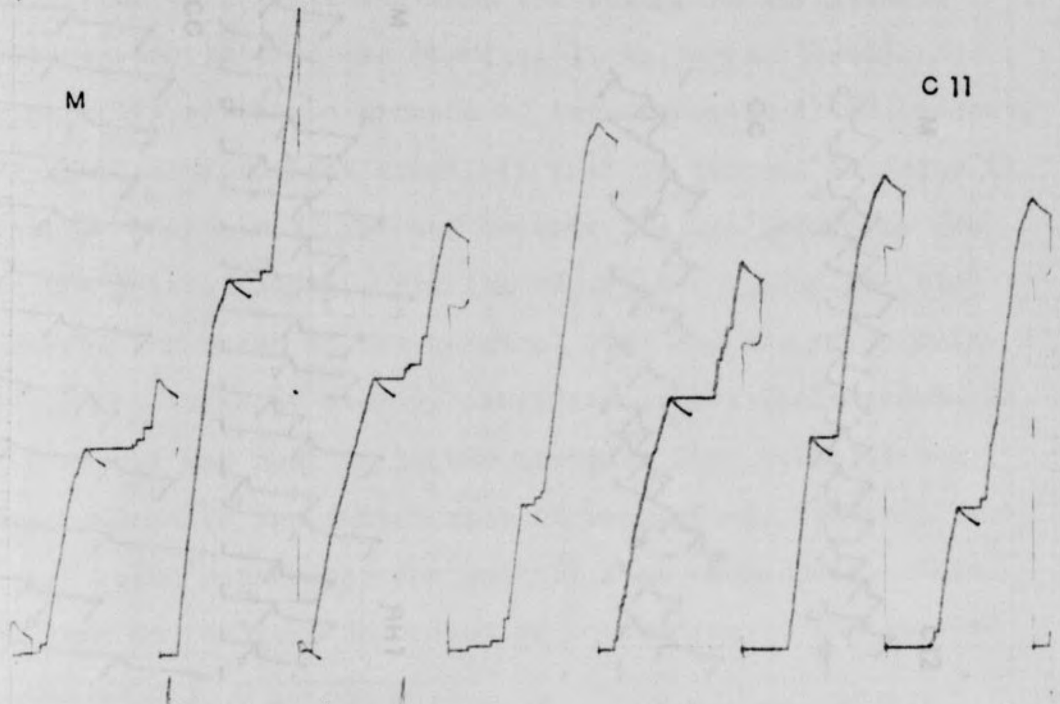


Fig. 2 a (cont'd).

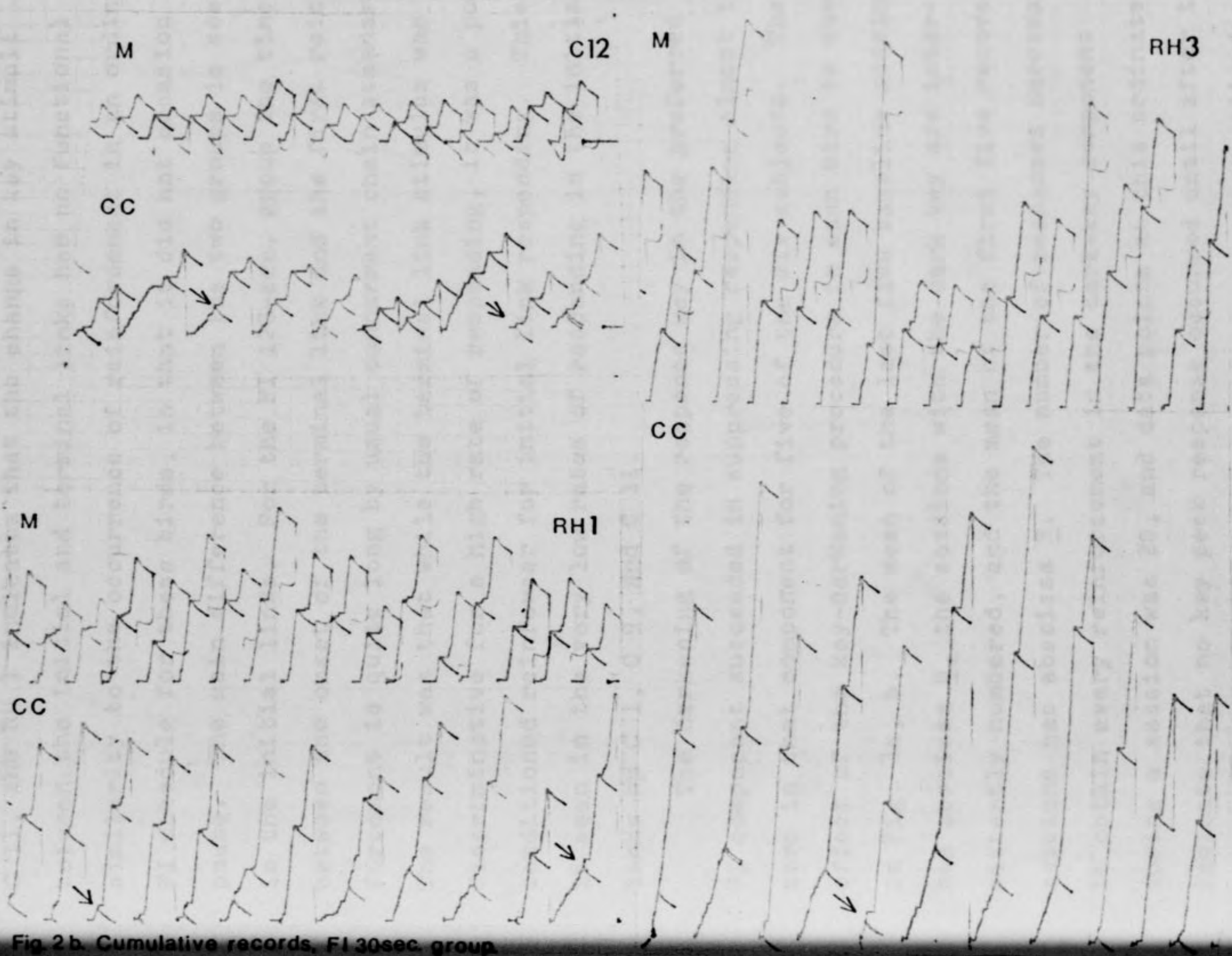


Fig. 2 b. Cumulative records, FI 30sec. group.

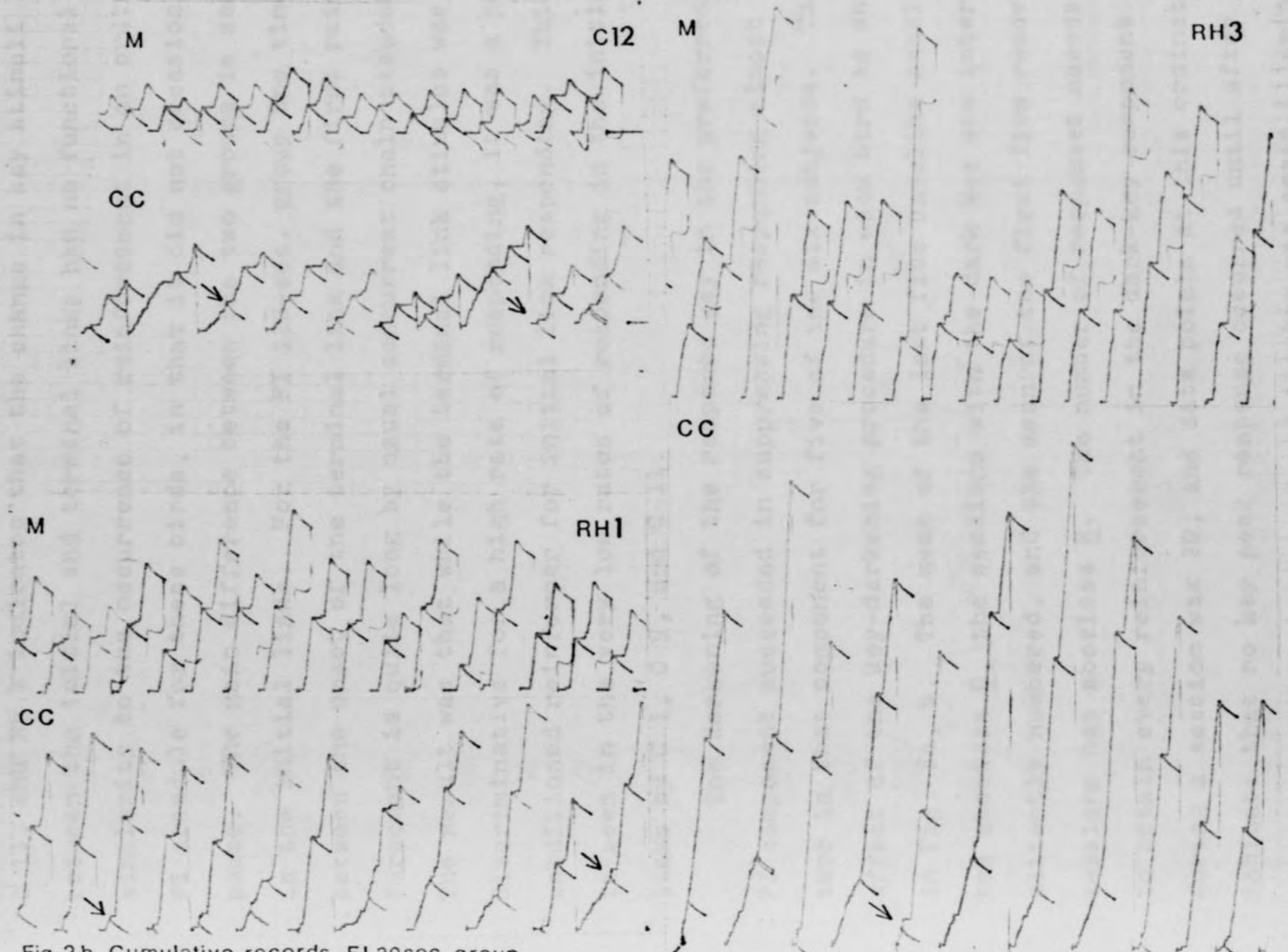


Fig. 2 b. Cumulative records, FI 30-sec. group.

C 11, and RH 1 indicates that the change in key stimuli between the initial and terminal links had no functional similarity to the occurrence of reinforcement in an ordinary FI schedule for these birds, in that it did not occasion a pause. The main difference between the two groups is seen in the initial links. For the FI 120-sec. group the time between the onset of the terminal link and the first reinforcement is quite long by usual concurrent chain standards. The result was that while the terminal link stimulus was discriminative for a high rate of responding, it was a poor conditioned reinforcer for initial link responding. This is seen in the very low rates of responding in the initial links by C 1, C 9, and C 11.

The darkening of the response key in the preferred FI component succeeded in suppressing responding almost to zero in that component for five of the six subjects. The effect of the key-darkening procedure in each bird is shown in Fig. 3a, b. The mean of the last five baseline sessions has abscissa B, the sessions with the dark key are intermittently numbered, and the mean of the first five recovery sessions has abscissa R. The number of responses necessary to obtain every reinforcement in the dark-key component during a session was 20, and data points at this ordinate indicate that no key peck response occurred until after the fixed interval had elapsed and the key was again illuminated. This was typically the case during the multiple-schedule

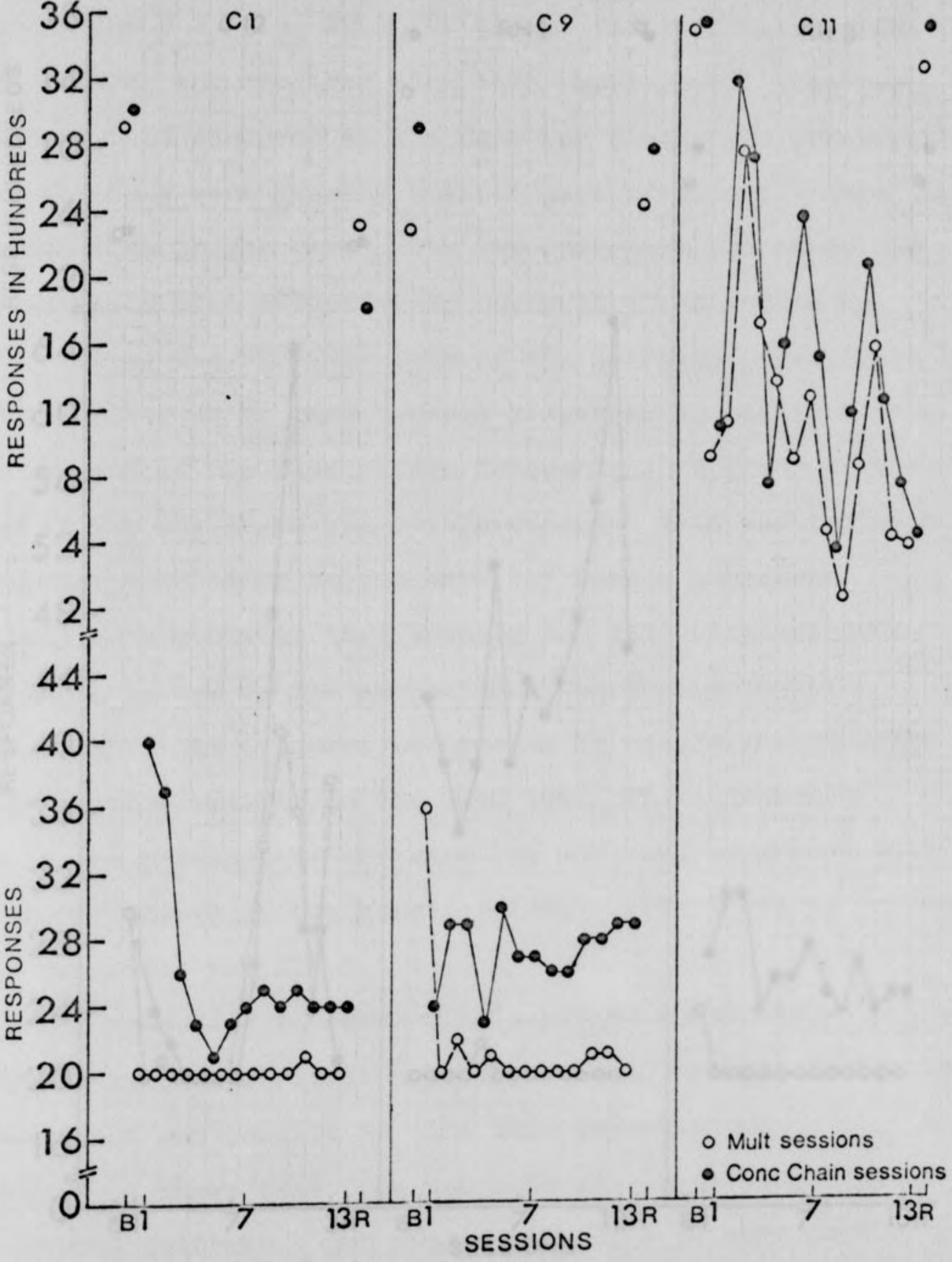


Fig. 3a. Effect of key-darkening procedure. FI 120-sec. group.

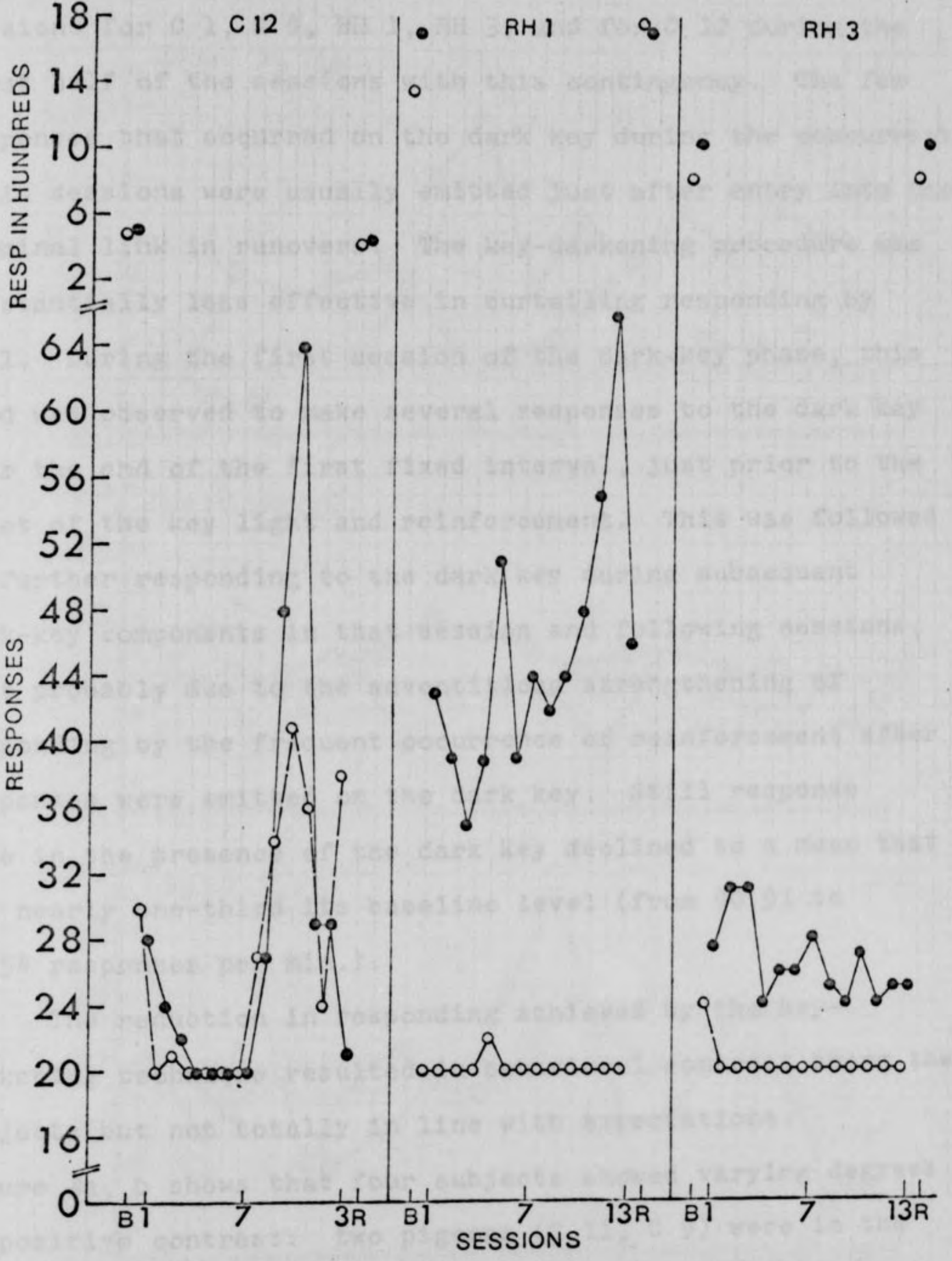


Fig. 3b. Effect of key-darkening procedure, FI 30-sec. group.

sessions for C 1, C 9, RH 1, RH 3, and for C 12 during the first half of the sessions with this contingency. The few responses that occurred on the dark key during the concurrent chain sessions were usually emitted just after entry into the terminal link in runovers. The key-darkening procedure was substantially less effective in curtailing responding by C 11. During the first session of the dark-key phase, this bird was observed to make several responses to the dark key near the end of the first fixed interval, just prior to the onset of the key light and reinforcement. This was followed by further responding to the dark key during subsequent dark-key components in that session and following sessions, most probably due to the adventitious strengthening of responding by the frequent occurrence of reinforcement after responses were emitted on the dark key. Still response rate in the presence of the dark key declined to a mean that was nearly one-third its baseline level (from 90.91 to 32.54 responses per min.).

The reduction in responding achieved by the key-darkening technique resulted in behavioral contrast among the subjects but not totally in line with expectations. Figure 4a, b shows that four subjects showed varying degrees of positive contrast: two pigeons (C 11, C 9) were in the FI 120-sec. group, all of whose subjects were predicted to show contrast, while the other two birds (C 12, RH 3) were in the FI 30-sec. group, all of whose subjects were predicted

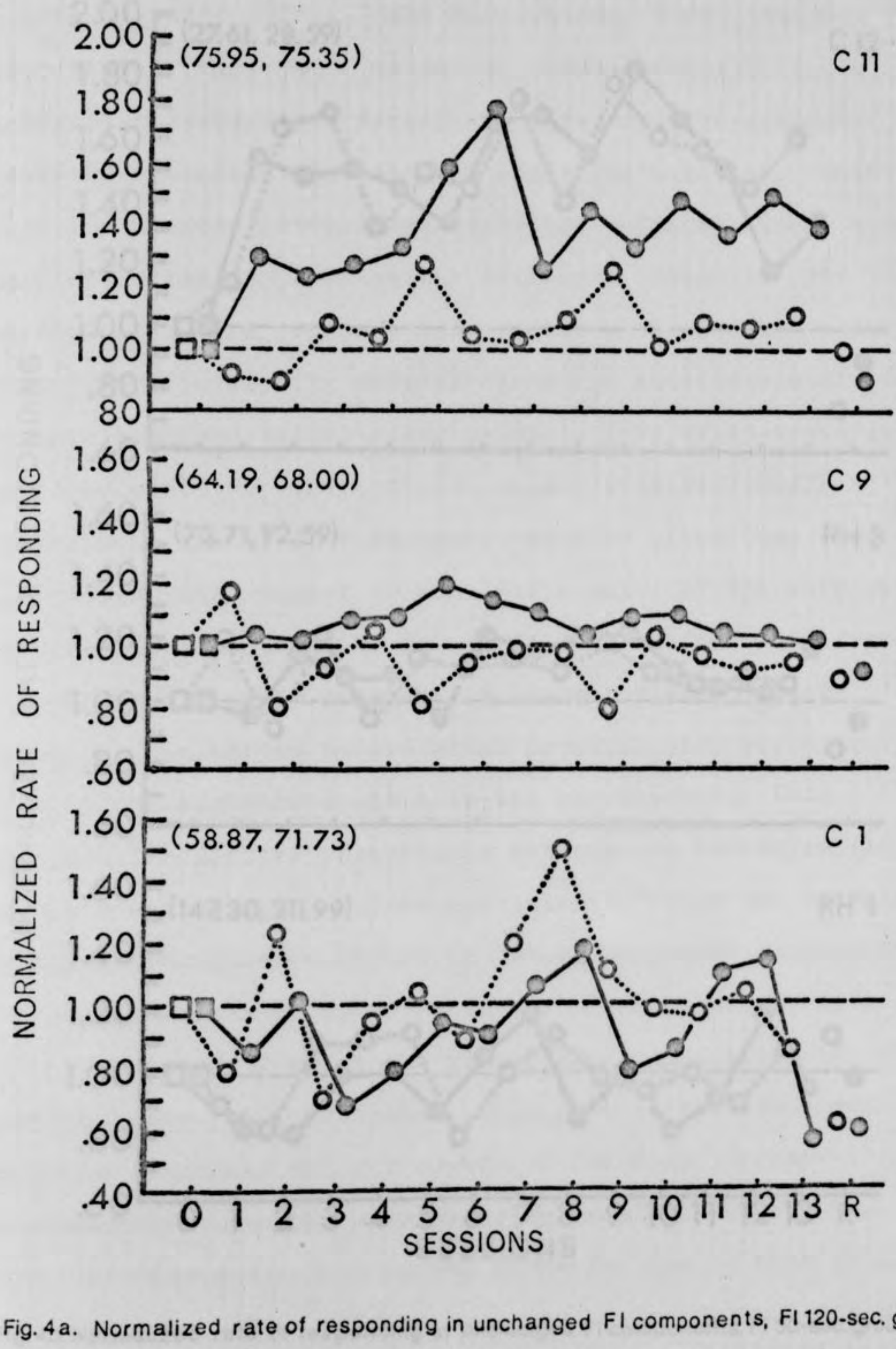


Fig. 4a. Normalized rate of responding in unchanged FI components, FI 120-sec. group.

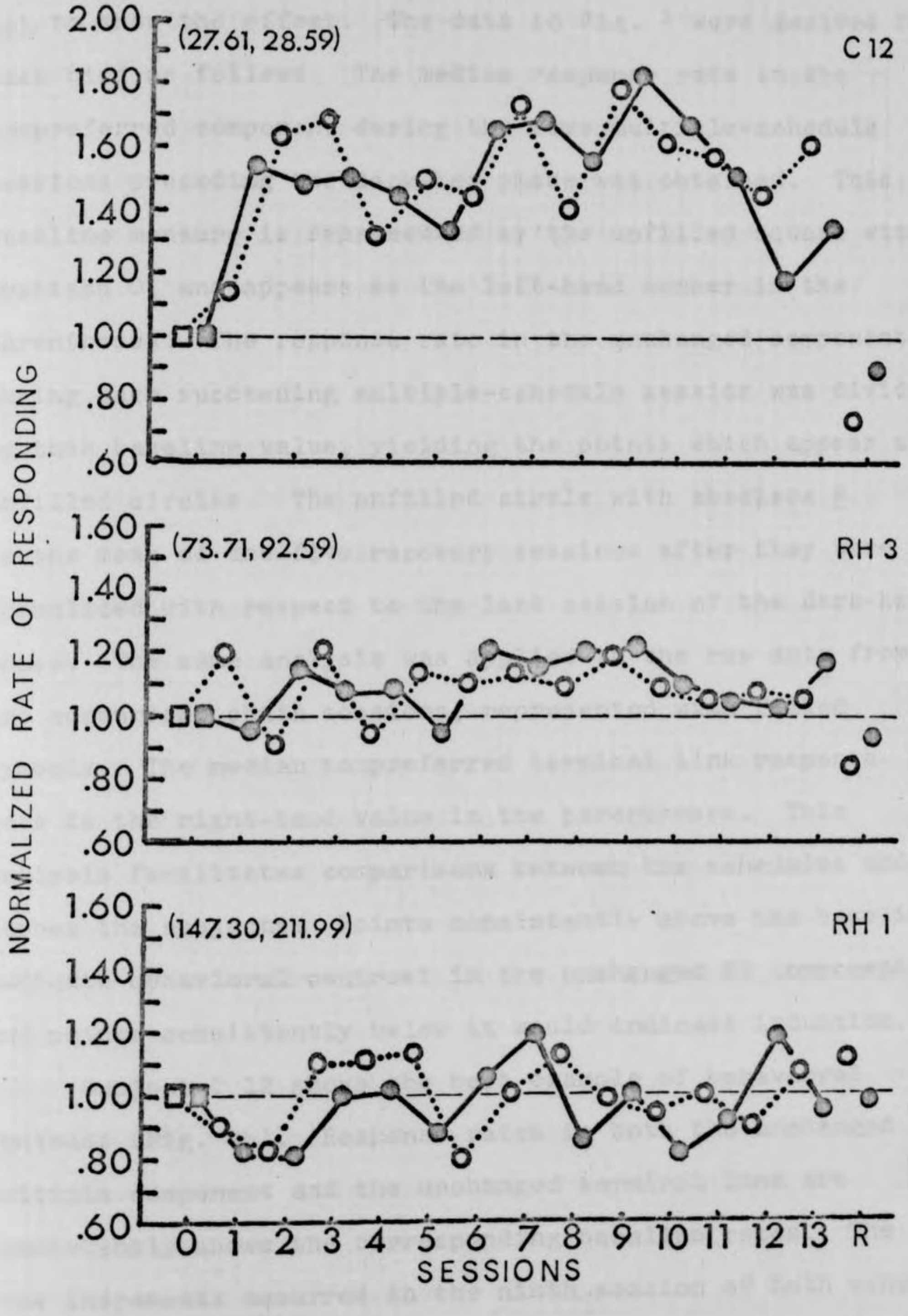


Fig. 4b. Normalized rate of responding in unchanged FI components, FI 30-sec. group.

not to show the effect. The data in Fig. 4 were derived for each bird as follows. The median response rate in the nonpreferred component during the five multiple-schedule sessions preceding the dark-key phase was obtained. This baseline measure is represented by the unfilled square with abscissa 0, and appears as the left-hand number in the parentheses. The response rate in the unchanged component during each succeeding multiple-schedule session was divided by this baseline value, yielding the points which appear as unfilled circles. The unfilled circle with abscissa R is the mean of the five recovery sessions after they were normalized with respect to the last session of the dark-key phase. The same analysis was applied to the raw data from the concurrent chain sessions, represented with filled symbols. The median nonpreferred terminal link response rate is the right-hand value in the parentheses. This analysis facilitates comparisons between the schedules and across the subjects. Points consistently above the baseline indicate behavioral contrast in the unchanged FI component and points consistently below it would indicate induction.

Subject C 12 shows the best example of behavioral contrast (Fig. 4b). Response rates in both the unchanged multiple component and the unchanged terminal link are consistently above the corresponding baseline rates. The peak increments occurred in the ninth session of both schedules and were 78% and 83% above baseline in the multiple and concurrent chain schedules, respectively. The increased response rates during the dark-key phase were mediated by increased running rates and decreased post-reinforcement pause times in the FI components of both schedules. Pigeon C 11 shows clearly sustained contrast during the concurrent chain sessions and the effect to a lesser degree in the multiple sessions after the first two sessions (Fig. 4a). This subject's running rate increased in both schedules, with the concurrent chain schedule maintaining the greater increment. Post-reinforcement pause time also increased slightly in both schedules, but was much longer during baseline and increased over baseline to a greater degree in the multiple schedule.

Two additional subjects show some contrast. With the exception of two multiple and two concurrent chain sessions, RH 3 shows increased response rates in both schedules. The increase in rate in the multiple schedule was mediated by a decrease in post-reinforcement pause time while that in the concurrent chain schedule was due to an increased running rate. Subject C 9 shows a reliable contrast effect in the concurrent chain schedule but not in the multiple schedule. The increased terminal link rates were the effect of decreased post-reinforcement pause time with the running rate remaining essentially unchanged. The other two subjects, C 1 and RH 1, showed no consistent behavioral contrast.

Of major interest in the present study is the comparison between the contrast data and measure of preference based on responding in the initial links of the concurrent chain schedule. Figure 5 shows the mean relative frequency of responses on the initial link key leading to the preferred key during various phases of the experiment. The open circle with abscissa B represents the mean relative frequency during the last five sessions of the baseline condition. The filled circles with abscissas 1 and 2 represent the means of the first and last five sessions, respectively, during the experimental phase in which the key was darkened in one terminal link. The free, filled circle with abscissa D represents the mean relative frequency for the entire 13 concurrent chain sessions of the dark-key phase. The same denotations apply to the triangles and squares representing group means. The number below each curve is the difference between the baseline mean and the total dark-key condition mean. The comparison of interest is that between each baseline relative frequency (B) and its associated total dark-key condition relative frequency (D), joined by the dotted line. No subject completely shifted preference to the unchanged key, as shown by the failure of the total dark-key condition means to fall below the line through ordinate 0.50. However, each subject showing positive contrast in the unchanged terminal link (C 9, C 11, C 12, RH 3; Fig. 4) showed a decrease in relative frequency on the

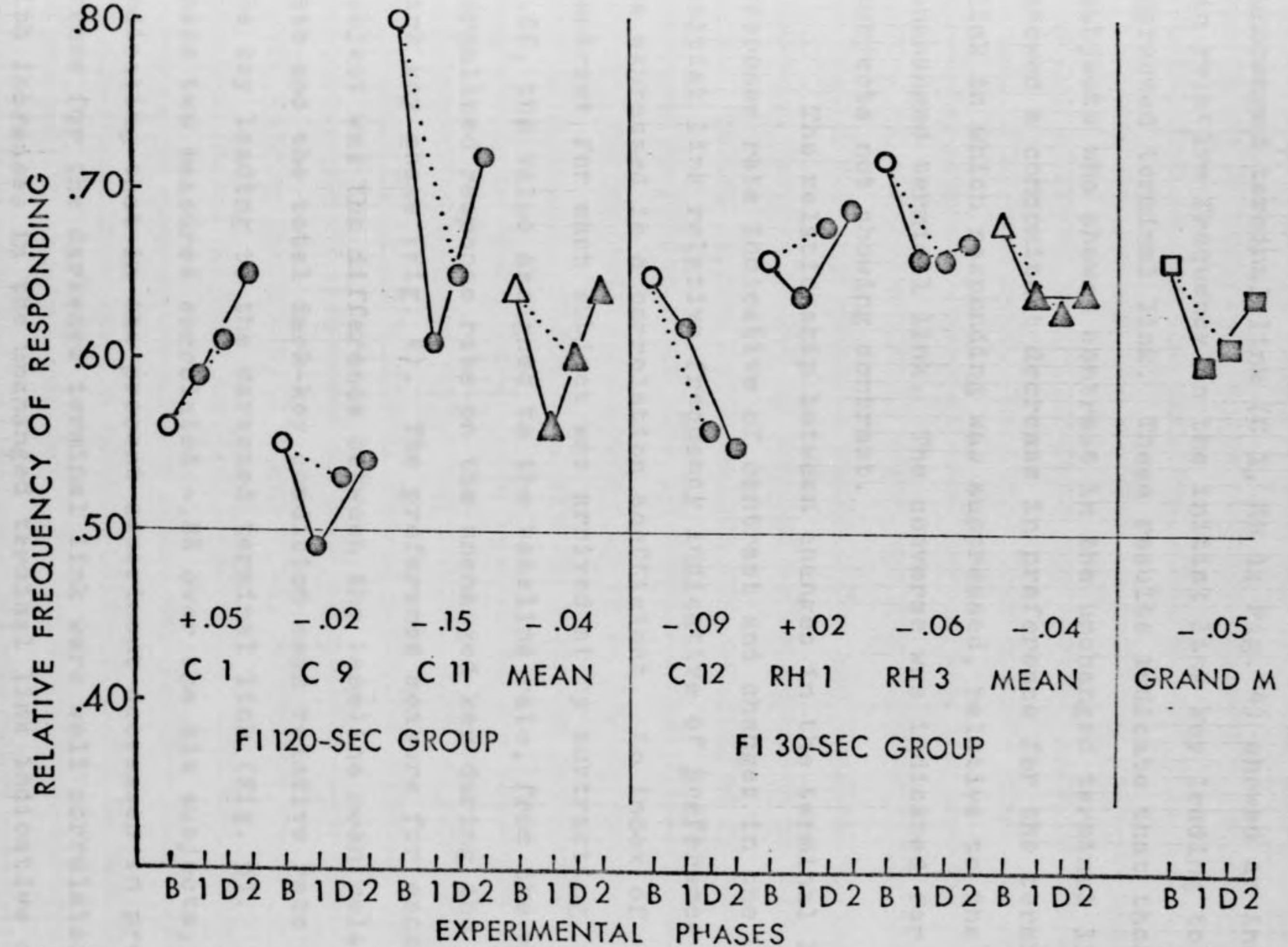


Fig. 5. Mean relative frequency of responding in initial link of chain with reduced response rate in the terminal link.

initial link key leading to the darkened terminal link. Conversely, the two subjects not showing contrast in the unchanged terminal link (C 1, RH 1; Fig. 4) showed an increase in relative frequency on the initial link key leading to the darkened terminal link. These results indicate that those subjects who showed contrast in the unchanged terminal link showed a concomitant decrease in preference for the terminal link in which responding was suppressed, relative to the unchanged terminal link. The converse was indicated for those subjects not showing contrast.

The relationship between changes in the terminal link response rate indicative of contrast and changes in the initial link relative frequency indicative of preference may be expressed in a correlation coefficient. An index of contrast for each subject was arrived at by subtracting 1.00, the value assigned to the baseline rate, from the mean normalized response rate on the unchanged key during the dark key phase (Fig. 4). The preference measure for each subject was the difference between the baseline mean relative rate and the total dark-key condition mean relative rate on the key leading to the darkened terminal link (Fig. 5). These two measures correlated -.88 over the six subjects, indicating that in the present experiment decreases in preference for the darkened terminal link were well correlated with increases in the unchanged terminal link indicative of positive contrast. However, no generality beyond the present data of this finding is warranted, for the measure of preference from the concurrent chain sessions correlated with the index of contrast in the multiple-schedule components (calculated as for the terminal links above) only -.34.

Table 1 shows how changes in response rate on each initial link key contributed to the initial link relative rates. For each bird, the first four columns show the mean absolute response rates on each key during the indicated phases of the experiment, which are the same as those used in Fig. 5 for the relative rates. The key leading to the darkened terminal link is denoted by an asterisk in each case. Values in the fifth column are the ratios of total dark-key condition mean rate to baseline mean rate. Values above 1.00 indicate an increase in rate; values below 1.00 show a decrease. Birds C 12 and RH 3 showed decreased responding in the initial link leading to the darkened key and increased responding in the initial link on the unchanged key. Both of these subjects showed positive contrast in the unchanged FI component of both schedules. The other two birds showing contrast, C 9 and C 11, increased their response rates on both initial link keys. The very large increase in mean rates on the right key for the first five dark-key sessions and the total condition for C 11 are due to one highly unusual session. In the third concurrent chain session with the key darkened in the right terminal link, C 11 emitted 1308 responses in the right initial link,

Table 1

Mean Absolute Response Rates in Initial Links

			Baseline	First 5 Days	Last 5 Days	Total Condition	Total Condition / Baseline
FI 120-sec. Group	C 1	L*	6.56	11.63	4.10	6.70	1.02
		R	5.23	7.47	2.29	4.24	.81
	C 9	L	1.04	1.79	1.40	1.52	1.46
		R*	1.34	1.71	1.78	1.76	1.32
	C 11	L	.45	1.56	.69	1.10	2.44
		R*	1.99	9.65(2.11)	3.07	5.26(2.41)	2.64(1.21)
FI 30-sec. Group	C 12	L	9.56	11.78	12.24	12.31	1.28
		R*	18.20	20.73	15.18	16.34	.90
	RH 1	L*	36.59	29.48	36.00	34.71	.94
		R	19.15	17.42	16.33	16.82	.87
	RH 3	L	8.24	9.64	9.63	9.14	1.09
		R*	21.36	19.00	19.10	18.76	.88

well above his baseline mean of 67 per session on that key. If that remarkable (and unexplained) performance is disregarded, the more representative means in parentheses are obtained and it can be seen that the mean rate on the unchanged left key shows a greater increase relative to baseline than does the rate on the manipulated key. This subject showed contrast in the FI component of both schedules. Subject C 9 showed a greater relative increase on the unchanged key, and showed contrast in the unchanged terminal link. The two subjects which did not show contrast (C 1, RH 1) showed decreased initial link rates on the unchanged key.

DISCUSSION

The emotionality hypothesis assumes that the multiple-schedule component in which responding is suppressed becomes more aversive than it was formerly and this increased aversiveness is necessary for positive behavioral contrast to occur in the unchanged component. The present experiment supports this minimal assumption. Three pigeons showing positive contrast in one component of a multiple schedule were found to decrease their relative frequencies of responding in an initial link leading to a component where responding was suppressed when both components were programmed in a choice design (C 11, C 12, RH 3). Of three birds not showing consistent positive contrast in the multiple schedule, two (C 1, RH 1) showed an increased relative response frequency in the initial link leading to the component where responding was suppressed when both components appeared in a choice design. The third subject not showing contrast in the multiple schedule (C 9) had a slightly decreased relative response frequency in the initial link leading to the manipulated component. These results indicate that the suppression of responding in one component does not necessarily render that component aversive relative to an unchanged component. Furthermore, the performance of C 9 indicates that even if response suppression does render one component less preferred than it was initially, contrast may not occur in the unchanged component. This argues against those formulations of the emotionality hypothesis asserting that a manipulation which makes one component of a multiple schedule more aversive is a sufficient condition for contrast to occur in an alternated component (Premack, 1969; Terrace, 1966, 1968). With regard to the concurrent chain schedule, however, the present study indicated that the establishment of decreasing preference for one terminal link was both necessary and sufficient for the occurrence of contrast in the unchanged terminal link. Each subject indicating decreased preference for the terminal link in which responding was suppressed also showed contrast in the unchanged terminal link (C 9, C 11, C 12, RH 3). No subject failing to decrease preference for the terminal link in which responding was suppressed showed contrast in the unchanged terminal link (C 1, RH 1).

The first finding of the present study, that a higher rate of responding occurred in the FI components when they were preceded by initial links in concurrent chains than when they alternated regularly as the components of a multiple schedule, has a single-key chain analog. In one experiment, Wilton and Gay (1969) first trained pigeons on a mixed VI 60-sec. VI 60-sec. schedule of reinforcement with both components associated with a red key. This schedule was transformed into a chain VI 60-sec.

VI 60-sec. schedule by substituting a green key for the red one in the first component and eliminating primary reinforcement in the presence of green; now pecks in green produced the red component, which remained unchanged. The rate of responding in red increased over its rate in the mixed schedule, indicating positive contrast. Finally, the two links were programmed as the two components of a multiple schedule, and the rate in red declined. In the present experiment it was noted that the increased rates in FI components preceded by an initial link were due to higher rates in the first fixed interval than in the second, mediated by runovers and by complete failures to pause after entry into the first fixed interval. Kendall (1967) has reported the same findings for a single-key chain (VI)(FI FI) schedule when the first fixed interval was either shorter than or equal to the second fixed interval in the terminal link.

The occurrence of positive contrast in chained schedules might be due to an effect similar to that found by Staddon and Innis (1969). When a blackout was substituted for reinforcement at the end of 25% of the intervals on an FI 2-min. schedule, pause times in the immediately following fixed intervals were greatly reduced, approaching zero as blackout duration approached zero. The authors explained this result as being due to the failure of a brief blackout to control pausing to the same degree that reinforcement does in FI schedules. Insofar as the intermittently occurring initial link ending with only a change in key stimuli in the present concurrent chain schedule may be compared with an intermittently occurring fixed interval ending in a brief blackout in the Staddon and Innis experiment, the present results may be explained in a parallel way. The change from initial link stimuli to terminal link stimuli had, predictably, even less influence on pausing than brief blackouts; only rarely was the change in key stimuli followed immediately by a pause. Each subject's behavior came under good FI schedule control during preliminary training, but this pattern was disrupted in the first fixed interval of each component when, on alternate days, a variable-interval initial link not ending in reinforcement preceded each FI component. Instead of always being bounded by two reinforcements, the first fixed interval was now occasionally bounded by a relatively less well discriminated key-stimulus change and a reinforcement. The increased response rates that resulted in the first fixed interval of both terminal links very probably contributed to the failure of substantial contrast to develop in the unchanged terminal link for four of the subjects during the dark key phase of the experiment and to an attenuation of contrast in the two subjects who did show the effect clearly (C 11, C 12).

This interpretation does not, however, provide any help in accounting for the relatively small degree of contrast shown in the multiple schedules by all the subjects except C 12. Responding in both fixed intervals of each component was under appropriate FI schedule control, and behavioral contrast could reasonably have been expected to occur during the dark-key phase of the experiment.

Finally, the fact that positive contrast occurred in the FI 30-sec. group (which included C 12, the bird showing the best contrast in both schedules) may limit the generality of Reynolds' (1963b) finding that contrast does not occur in an unchanged component of a multiple schedule when responding in that component is maintained by 38 or more reinforcements per hour. In the present experiment, responding in each multiple-schedule component was maintained by a rate of reinforcement equivalent to 120 per hour for the FI 30-sec. group, and positive contrast did occur in two of the three subjects. In another study (Pear & Wilkie, 1970), published after the termination of the present experiment, positive contrast occurred in the VI components of two mixed VI extinction schedules in which high densities of reinforcement were obtained. The two VI components were first scheduled in isolation in separate experiments, then each was alternated with an extinction component at 5-min. intervals. Positive contrast appeared in the VI components, one of which provided 60 reinforcements during each hour-long session and the other, 90 reinforcements during each session.

These findings argue that Reynolds' criterion does not apply to all procedures that produce positive contrast and may not have the generality he assumed.

SUMMARY AND CONCLUSION

The present study attempted to determine whether the suppression of responding that produces contrast does so because it renders the component in which it occurs aversive relative to the unchanged component. Six pigeons were exposed to a multiple fixed-interval fixed-interval schedule of reinforcement with equal reinforcement rates in the two components, and, on alternate days, to a concurrent chain schedule having terminal links identical to the components of the multiple schedule. When responding was suppressed in one multiple-schedule component and in one terminal link, three subjects showed positive contrast in the unchanged multiple component and indicated decreased preference for the terminal link in which responding was suppressed. Two additional subjects showed no contrast in the multiple schedule and increased preference for the terminal link in which responding was suppressed. The conclusion that the increased aversiveness of the component in which responding was suppressed was sufficient to account for the occurrence of contrast in the multiple schedules is prevented by the performance of the last subject, who showed decreased preference for the manipulated component but did not show contrast. However, only those subjects who showed decreased preference for the terminal link where response rate was suppressed also showed contrast in the unchanged terminal link. This result suggests that establishing increased aversiveness in one terminal link may be both necessary and sufficient for the appearance of positive contrast in the unchanged terminal link of concurrent chain schedules of reinforcement.

An additional finding of the present study was a higher response rate in the FI components when they were the terminal links of concurrent chains than when they were the components of the multiple schedule. This contrast effect was interpreted as resulting from the absence of reinforcement just prior to the onset of the first fixed intervals in the terminal links.

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