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TWO PARAMETERS OF REINFORCEMENT DELAY IN TEMPORALLY DEFINED SCHEDULES

by

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ABSTRACT

Two Parameters of Reinforcement Delay in Temporally Defined Schedules

by

Thomas W. Garrett

The present investigation undertook the exploration of the behavioral effects of presenting delayed reinforcers after an ordinally and temporally, as well as topographically defined class of response. Topographically, responses produced state changes in a microswitch which was positioned behind an illuminated disc. Temporally, responses occurred during a fixed portion, t^D, of a repeating time-cycle, T. Finally, only the first of these responses was labeled R_i (identified response), and each R_i was followed after a maximum delay, D_{mx}, by one reinforcing stimulus, S^R, in the same time-cycle.

Different values of the reinforcement schedule vector ($\bar{T}$, D_{mx}), where $\bar{T} = t^D/T$, were presented to four groups of pigeons. Each group of four pigeons was exposed to a different sequence of vector values. Some of the values were presented to more than one group for comparison purposes. Some values were also presented to the same group more than once to obtain a measure of the recoverability of the original behavioral effects. For all groups of pigeons, T was 60 seconds.

Groups 1 and 2 were first exposed to the vector value (0.10$\bar{T}$, 0"D_{mx}). They were then shifted after 20 sessions to (0.10$\bar{T}$, 6"D_{mx}) for 30 sessions, and then returned to the first vector value for another 10 sessions. The value of $\bar{T}$ for Group 1 was then changed to 0.05 and, for 15 sessions at each value, D_{mx} was zero, then 1, 2, 4, 6, 12, 24, 48, and again zero seconds. For Group 2 the value of $\bar{T}$ was maintained at 0.10 while D_{mx} was changed to 1, 2,

4, 6, 12, 24, 48 and then again returned to zero seconds for 15 sessions at each value. The other eight birds (Groups 3 and 4) began with the schedule (1.00$\overline{T}$, 0"D_{mx}) for 15 sessions and then were shifted to (0.80$\overline{T}$, 6"D_{mx}) for another 15 sessions. Then Group 3 first had $\overline{T}$ held constant at 0.80 while, for 15 sessions at each value, D_{mx} increased to 12, 24, and 48 seconds, in that order; then while D_{mx} was held constant at 48 seconds, $\overline{T}$ was changed to 0.40, 0.20, 0.10, and 0.05, in that order. Finally, this group was returned to its first vector value, (1.00$\overline{T}$, 0"D_{mx}). Group 4, after exposure to the first two vector values, first had D_{mx} held constant at 6 seconds while $\overline{T}$ was changed to 0.40, 0.20, 0.10, and 0.05, in that order; then, while $\overline{T}$ was maintained constant at 0.05, D_{mx} was increased to 12, 24, and 48 seconds, 15 sessions at each value. Finally, this group was also returned to its first vector value, (1.00$\overline{T}$, 0"D_{mx}).

In general, the results of the study were: 1) as $\overline{T}$ was reduced and D_{mx} increased, overall response rates went down and average post-reinforcement pause time and inter-reinforcement time went up; 2) generally, the temporal classes of response that most closely preceded S^Rs were the strongest; 3) where comparative data were available, the groups were quite similar quantitatively, in spite of having been exposed to different sequences of vector values; 4) when experimental conditions were repeated for a group, the values of the dependent variables generally were similar to the original values; 5) even a few instances of presenting S^Rs after longer than the customary times since the last response was sufficient to reduce the overall rates of that response per session.

DEDICATION

This work is dedicated to Sibylle Klotz Garrett for her continuous support and unfailing devotion.

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Lack of space prevents me from individually recognizing each of my fellow students who contributed time and intellectual stimulation during the months of data collection. I therefore thank them collectively.

TWO PARAMETERS OF REINFORCEMENT DELAY IN TEMPORALLY DEFINED SCHEDULES

INTRODUCTION---1

METHOD---13

Figure 1---17

Tables 1 through 4---19

Figure 2---25

RESULTS---27

Figure 3---28

Figures 4 through 11---31

Figures 12 through 20---49

Table 5---68

Figures 21 through 29---70

Table 6---89

Figures 30 through 38---91

Figure 39---111

Figures 40 through 43---114

Figures 44 through 47---123

DISCUSSION---131

Figures 48 through 51---140

Table 7---148

APPENDIX A---149

Tables A1 and A2---152

Figure A1---156

Figures A2 through A5---159

Figures A6 through A9---168

Figures A10 through A13---177

REFERENCES---188

INTRODUCTION

When reinforcing stimuli (S^Rs) are presented to organisms, different response rates and patterns of response rates may develop under different schedules of reinforcement. The term "schedule of reinforcement" as used by Ferster and Skinner (1957) refers to the rules by which experimenters have identified responses and timed the delivery of reinforcers. Schoenfeld and Cole (1975) have observed that most "schedules of reinforcement" are really rules for identifying responses to be reinforced. They have suggested that inclusion of response identification rules under the heading of "schedules of reinforcement" is incorrect, and that the term should refer only to response-independent restrictions on the temporal distributions of S^Rs. Definitional considerations aside, repeated presentations of S^Rs to organisms according to fixed rules has proved a powerful method in the investigation of the behavior of organisms.

The now-classical schedules of reinforcement were dichotomized into two major categories: ratio schedules, involving the ordinal enumeration of responses; and interval schedules, involving restrictions on the times between reinforced responses (Skinner, 1938). Typically, in both cases, whenever an S^R was presented to the organism, it was immediately preceded by a prespecified response identified first by its membership in a particular topographical response class and second by its ordinal position relative to some previous event such as the previous S^R (the ratio schedules), or by its temporal position relative to some previous event such as the previous reinforcer (the interval schedules). Because of the close temporal relationship specifically arranged by the experimenter between the R_i (the identified response) and the subsequent S^R, the S^R was said to be "contingent" on that response. Any subsequent increase in the frequency of that response and topographically similar responses was assumed to be attributable to the contingency relationship, and to induction effects from R_i.

The two main classical procedures for scheduling contingent reinforcers in studies of operant behavior - the response-count procedure, and the response-time procedure - were initially assumed to produce characteristically different patterns of responding (see Schoenfeld and Cole, 1972, p. 5). The ratio schedules were supposed to produce a "break-run" pattern, a pattern consisting of an initial pause after reinforcement followed by a rather sudden change to a constant response rate which was maintained until responding was interrupted by the subsequent reinforcer. Interval schedules were supposed to produce a "scalloped" response pattern, consisting of an initial pause after reinforcement followed by a gradual acceleration in response rate until responding was interrupted by the subsequent reinforcer (however, see Cumming and Schoenfeld, 1958, for further data on this point). The production of two characteristic patterns of response rates by these two schedule procedures, the one controlling the number of responses between reinforced responses, the other controlling the minimum time between reinforced responses, was one of the first outstanding uniformities found in the experimental analysis of behavior. Given the seeming irreducibility of the counting and timing operations, most operant conditioning investigators gave themselves over to the study of the effects of different combinations and permutations of these two operations, combined with varieties of discriminative stimulation, drugs, species, and responses. Few investigators have felt compelled to go against this trend and to query the essentiality of both operations in the production of behavior patterns.

In 1956, Schoenfeld, Cumming and Hearst proposed that the counting of responses was unnecessary for the production of "ratio behavior" (i.e., the behavior observed on ratio schedules), and presented data showing that time-based schedules of reinforcement could produce the "ratio behavior" as well as the "interval behavior" (i.e., the behavior observed on interval schedules). The heart of the new system of scheduling reinforcers, the _t_-system, was the division of time into independent, repeating time units called "t-cycles" during which single S^R could be presented to the organism. These t-cycles were subdivided into two segments, the first called t^D, the second called t^Δ. The S^R, when the system was first formulated, appeared only during the t^D segment, and then only immediately after the first R (the R_i) in the t-cycle. The ratio of t^D to T (where $T = t^D + t^\Delta$), expressed as $t^D/t^D+t^\Delta = \overline{T}$ was an early and important independent variable in the demonstration that a time based system could produce "ratio behavior" (Schoenfeld, Cumming and Hearst, 1956; Schoenfeld and Cumming, 1957). These keynote papers, by taking T to low values, quickly led to the consideration that reinforcement of a response becomes probabilistic when T is very short. If every response is eligible for reinforcement, then $\overline{T}$ represents the probability of reinforcement when T is very short and no synchronization between response times and t-cycles exists. The resultant "random ratio" schedule of reinforcement (Brandauer, 1958) led to a deeper understanding of performance under classical ratio schedules, especially the variable ratio schedules.

The next step in the system development was the synthesis of variable-interval schedules. With reduction in $\overline{T}$, the distribution of S^Rs in time had become variable, but when the t^D size was around the median inter-response time, the obtained inter-reinforcement times or IS^RTs (Farmer and Schoenfeld, 1964) were highly dependent upon individual response rates extant at the initiation of t^Ds. That is, S^Rs were less likely when these response rates were low. This characteristic of differential reinforcement of high momentary response rates is possibly responsible for the response rate increases produced by these schedules.

Millenson (1959) was the first to attempt the controlled synthesis of variable-interval schedules through the manipulation of the t-system variables. As a first approximation to the classical variable-interval schedules, Millenson, recognizing that classical variable-interval schedules were constructed through the concatenation of various fixed intervals of different sizes, chose two values of t-cycle length as a limiting case and alternated them probabilistically. This approach to the synthesis of variable-interval schedules was superseded when the system parameter $\underline{p}$ (probability) was applied to the selection of some t-cycles (single-valued in length) for reinforcement and the remainder for non-reinforcement (Farmer, 1962, 1963; Millenson, 1963). The result was a special variable-interval schedule, the random-interval schedule. The substitution of $\underline{p}$ manipulations for $\bar{T}$ manipulations, brought major control of the S^R distribution back into the hands of the experimenter. No longer were S^Rs more probable when higher response rates occurred in the vicinity of $\bar{T}$; one response per t-cycle was sufficient to raise the overall S^R rate to its maximum. At the same time, certain characteristics special to $\bar{T}$ manipulations, such as production of IS^RTs which are close multiples of the t-cycle time, were preserved. The higher response rates, however, were no longer produced. With t^D now equal to T, response rates in excess of one response per t-cycle no longer received more probable reinforcement and response patterns and rates became very similar to those produced by the classical variable-interval schedules.

The power of the *t*-system for the analysis of the classical schedules into component elements and for the synthesis of related schedules using these same elements has more recently begun to be brought to bear on two more classical topics, reinforcement contiguity and reinforcement contingency (Schoenfeld and Farmer, 1970; Lachter, 1970; Lachter, Cole and Schoenfeld, 1971; Schoenfeld and Cole, 1973). When Skinner (1948) experimentally demonstrated that some responses would increase in frequency with response-independent presentations of S^Rs, and observed that those responses which showed the increase in frequency also typically preceded the S^Rs with short delays (at least toward the end of training), he appealed to "contingency" to elaborate upon this admitted accidental relationship. He stated, "To say that a reinforcement is contingent upon a response may mean nothing more than that it follows the response." (Skinner, 1948).

Thus contiguity (temporal proximity) between responses and subsequent S^Rs became a characteristic by which "contingencies" were detected. This adulteration of the term's meaning has been a source of much confusion among many students of operant conditioning. According to Schoenfeld and Farmer (1970) contingency means "the distribution in time of R determines the distribution in time of reinforcement, while ... noncontingency means that the temporal distribution of reinforcements is not determined by the temporal distribution of responses." Note that displacement in time (i.e., delay) of one distribution relative to the other would not, according to Farmer and Schoenfeld, disqualify the relationship as being a contingent one. Displacement in time of the S^R distribution, even though determined by the response distribution should, for Skinner's use of the term "contingent" to be consistent with his 1948 usage, disqualify the relationship as being a contingent one. However, Skinner also uses the term when not referring to contiguous relationships as when he uses the phrase "contingencies of reinforcement", meaning "schedules of reinforcement." Thus, delay of reinforcement schedules also belong under the rubric "contingencies of reinforcement."

The typical way of arranging a contingency has been to follow a given response with a reinforcer after a very short delay, nominally zero. Skinner early noted (1938, p. 73) that where the permitted delay is greater than zero, there may intervene topographically similar responses (Rs) between the response identified for reinforcement (the R_i) and its reinforcer. These intervening responses have produced one of two effects on the IS^RT distribution. Either each intervening R resets the delay timer, thereby lengthening the mean inter-reinforcement time, or R occurrences in the interim do not reset the delay timer and do not themselves determine the reinforcer distribution. The interim responses in both cases are followed by reinforcement. While the delay after the last response before a reinforcer is variable in the second case, it does have a definite maximum, the delay time of the contingently reinforced response. The first procedure has been called "fixed delay" because the time between any S^R and the immediately preceding R is fixed; the second procedure may be called "variable delay" because the time between any S^R and the immediately preceding R is variable.

All of the response-contingent schedules of reinforcement permit delayed reinforcement of all Rs while at the same time forcing different degrees of immediate reinforcement of selected responses. For example, under the condition of contingent reinforcement with zero delay, the R_is are followed immediately by an S^R, but the remaining Rs are never immediately followed by any S^R; they are followed after some delay. Noncontingent schedules of reinforcement permit delayed reinforcement of Rs but place no restrictions upon the degree of remoteness of any S^R from any response. Under all schedules of reinforcement all Rs may be followed by one or more S^Rs, albeit with greater or lesser delays, and in all experiments involving schedules of reinforcement practically all Rs are so followed, the only true exceptions being those Rs that follow the very last S^R in the experiment. If a period of extinction is given, then an R which precedes that extinction period may be said to be followed by the first S^R in the post-extinction period. Similarly, while a DRO (differential reinforcement of other behavior) schedule (Reynolds, 1961) specifies that a given period of time which does not contain a particular response will terminate in a reinforcer, those responses which preceded the time period are nonetheless followed by that same reinforcer. It is possible, however that this technicality may be of no practical importance, that no reinforcing power is exerted over the response. The degree to which S^Rs may reinforce an entire R-class through their delayed presentations after a subset of that R-class, the R_is, is examined in the present study.

Every schedule of reinforcement necessarily permits delays between some Rs and subsequent S^Rs. However, the usual schedule specifications focus on either the ratio of total Rs to total S^Rs or on the average (or average minimum) inter-reinforcement time permitted. Very often the limits of delays that are permitted between Rs and S^Rs are not explicitly specified; it is then understood that once the specified conditions have been met the R_i is very promptly followed by an S^R. The previous responses are also followed by the reinforcer but necessarily with longer delays. According to Dews (1970, p. 47), all the responses previous to an S^R should be considered reinforced responses since they are followed by the reinforcer, but they should be differentially strengthened because of delays of reinforcement of different length. As stated by Dews and paraphrased here, the above view is possibly misleading. As Schoenfeld has pointed out (personal communication), every response is unique in the sense that no response can be emitted twice. Therefore, a reinforcer which follows a response cannot strengthen that individual response in any sense. It seems that Dews is referring to the strengthening of one or more response classes, rather than to the strengthening of individual responses. This leads to the classification of responses not only according to their topographic, durational and force properties, but also according to their temporal and ordinal positions relative to events such as reinforcers.

For a contingency relationship to hold when a reinforcer may be presented without a defined response immediately preceding it, we need to specify the limits of delays that are to be permitted between specific Rs and specific S^Rs. If we choose S^Rs as reference points, labeling some of them S^R_i (identified reinforcer) and their preceding Rs as R_{-1}, R_{-2}, R_{-3}, ..., R_{-n} in the order of their precedence, delay limits might then be specified between S^R_i and any one of the preceding Rs. If we choose Rs as reference points, labeling some of them R_i and their subsequent S^Rs as S^R_{+1}, S^R_{+2}, S^R_{+3}, ..., S^R_{+n} in the order of their appearance, then delay limits might be specified between these R_is and any following S^R.

Both Rs and S^Rs have been used as points of reference in studies of the effects of delayed reinforcers. The first orientation seems compelling at first glance. If we present S^R_i exactly t-seconds after R_{-1} we should have a direct measure of the reinforcing power of an S^R at that temporal distance. Unfortunately, as Skinner pointed out in 1938, one cannot decide whether the effect of lowered overall response rate is due to the delay *per se*, or is due to the lowering of the ratio of reinforcers to responses, a side effect of the procedure. There is also the possibility that the lowered overall response rate is due to the reinforcement of unspecified interim behaviors which compete with R for expression. Another problem is that when a response is necessary between reinforcers, one cannot increase the average delay of reinforcement without simultaneously lowering the maximum possible rate of reinforcement, an operation which may also produce lowering of the overall rate of responding. In the present study, the second orientation is chosen. The first R in each t^D is the R_i and is followed by an S^R with a maximum delay (D_{mx}) specified by the schedule.

When an experimenter manipulates only one stimulus (the reinforcer, S^R) and arranges relationships of that stimulus with only one behavior (the response, R_i), anything he might arrange may be expressed in terms of inter-reinforcement times (IS^RTs) and response-reinforcement times (RS^RTs). Procedures which directly or indirectly have affected the ratio between number of Rs and number of S^Rs (and thereby the IS^RT distribution) have come to be known as "intermittent" reinforcement schedules; those which have manipulated RS^RT distributions are known as schedules of reinforcement delay, and may or may not be "intermittent" depending on the RS^RT distribution limits. If no restrictions are placed on RS^RTs that are permitted to occur, then the experimenter may specify both upper and lower limits of the distribution of IS^RTs in advance of an experimental session. If, on the other hand, the experimenter does place restrictions upon RS^RTs, then the limits of the IS^RT distribution are affected in a number of ways by the distribution of Rs. First, since an R_i must be detected before each S^R_{+1} is delivered, the PS^RPs (post-reinforcement pause times) limit the lower side of the distribution of IS^RTs. The IS^RTs may not be less than the immediately preceding PS^RPs. Second, if the experimenter's definition of R_i includes some durational property this duration sets an absolute lower limit for the size of IS^RTs. Third, the restriction of RS^RTs means that the varibility in IS^RTs is a function not only of experimenter-controlled variables but also is a function of the variability in PS^RPs, and IRTs (inter-response times).

The present research explored the behavioral effects of scheduling delayed reinforcers within the temporal system proposed by Schoenfeld, Cumming and Hearst (1956). The two analytic variables manipulated in the study were $\overline{T}$ and the maximum time between an R_i and its S^R_{+1} (hereafter called D_{mx}).

METHOD

Subjects

The subjects were 16 White Carneaux hen pigeons. They were about 6 years old and were retired breeders from the Palmetto Pigeon Plant (Sumter, South Carolina). None of the birds had been used in previous research. They were housed in individual living cages in rooms separate from that containing the experimental chamber. All rooms were air-conditioned and a temperature of 68 to 72 degrees Fahrenheit (20 to 23 degrees Celsius) was maintained except for a few days when the air-conditioning system was shut down for servicing and the temperature rose to about 80 degrees Fahrenheit (27 degrees Celsius).

Immediately upon arrival the subjects were placed on a free-feeding and watering schedule, and weighed at the same times daily until on five successive days the range of weights for an individual bird was less than 5% of the lowest weight for that series of days. These weights were then averaged and the average taken as the ad libitum weight for that subject. The subjects were then reduced to 80% of their ad libitum weights by removing all food from their food cups for two days (grit and water continued to be provided ad libitum), then giving them three grams of the laboratory grain mixture (primarily kafir corn, vetch and hemp seed) per day until the 80% weight was reached. The weight reduction process took between two and three weeks per subject. For the rest of the experiment the weight for an individual subject was required to be within 15 grams of her 80% weight, her "running weight", at the start of an experemental session or the subject was not run. In cases where the weight exceeded the criterion, the subject was run out of turn a few hours later, if the weight was then in tolerance; otherwise, she was run the following day. If the weight was below criterion, a few grams of grain were fed to the subject and after about an hour the subject was reweighed. If the subject was then within tolerance, she was run.

The above procedure was maintained throughout the entire experiment for all but two subjects. One bird from Group 1 (B04), because of a very erratic and low rate of responding in comparison to the other subjects in her group, was, after Session 411 (see Table 1), further reduced to 75% of her ad libitum weight and thereafter run at that weight. The other animal (B225) was from Group 3. This animal began to lose weight toward the end of the experiment (from Session 1101) in spite of increased post-session feeding. She was nevertheless continued in the experiment to the end. Shortly after the termination of the experiment she died.

Apparatus

One experimental chamber was used in this experiment. The chamber, a Lehigh Valley Electronics pigeon chamber, Model 1519, had a three key intelligence panel containing a house light, a grain feeder (Model 1347), and three pecking keys (Model 1348) mounted symmetrically above the feeder, 2.5 inches apart at their centers, with a stimulus projection unit (Model 1348Q) mounted behind each key. Only the center key, which required a lateral pressure of about 20 grams to operate, was operative.

Programming and recording equipment were located in the same room as the experimental chamber. Programming was accomplished with solid state logic modules (BRS Digibits). Recording was done with electromechanical counters (Sodeco) and a cumulative recorder (Gerbrands, Model C-S). A Grason Stadler noise generator (Model 901-B) was used to provide 0.15 volts RMS (i.e., -20 db re 1.5 volts RMS) of white noise to the 4 ohm speaker mounted on the intelligence panel. From the experimenter's subjective standpoint, this intensity produced a noise level in the chamber that was loud, but not so loud as to be aversive.

Preliminary training

When the subjects had reached their 80% weights, they were placed one at a time in the experimental chamber and subjected to one of two shaping procedures. In both procedures the *t*-system restriction of a maximum of one reinforcement per t-cycle was maintained, but the response requirements were relaxed. Details of these procedures, which might be classified as "auto-shaping" procedures, may be found in Appendix A.

Experimental design and procedure

The experiment proper began after Session 020 for Groups 1 and 2, and after Session 003 for Groups 3 and 4. That is, Groups 1 and 2 had 20 pretraining sessions and Groups 3 and 4 had 3 pretraining sessions. All groups received reinforcement in a t-cycle only if there was an R_i in that same t-cycle. Both before and after the sessions, all lights were off in the chamber. During the sessions, the houselight was on continuously, and the center-key light was on except during reinforcement. Reinforcements were three seconds long and during each reinforcement the t-cycle timer was halted.

The subjects were run at approximately the same times daily and with few exceptions were run seven days a week. Each of the four groups was exposed to a different non-random sequence of values of the two dimensional matrix represented in Figure 1 (see Tables 1, 2, 3, and 4 for the actual sequences for each group of subjects). More than one group received exposure to some of the matrix values. For example, two groups (Groups 1 and 2) were exposed to (0.10$\overline{T}$, 0"D_{mx}), three groups (Groups 1, 2 and 4) were exposed to (0.10$\overline{T}$, 6"D_{mx}), and three groups (Groups 1, 3 and 4) were exposed to (0.05$\overline{T}$, 48"D_{mx}). Exposure to some of the matrix values was also repeated for each

Figure 1. Field of investigation. Points within the bivariate field represent the values of the variables investigated. T was constant at sixty seconds.

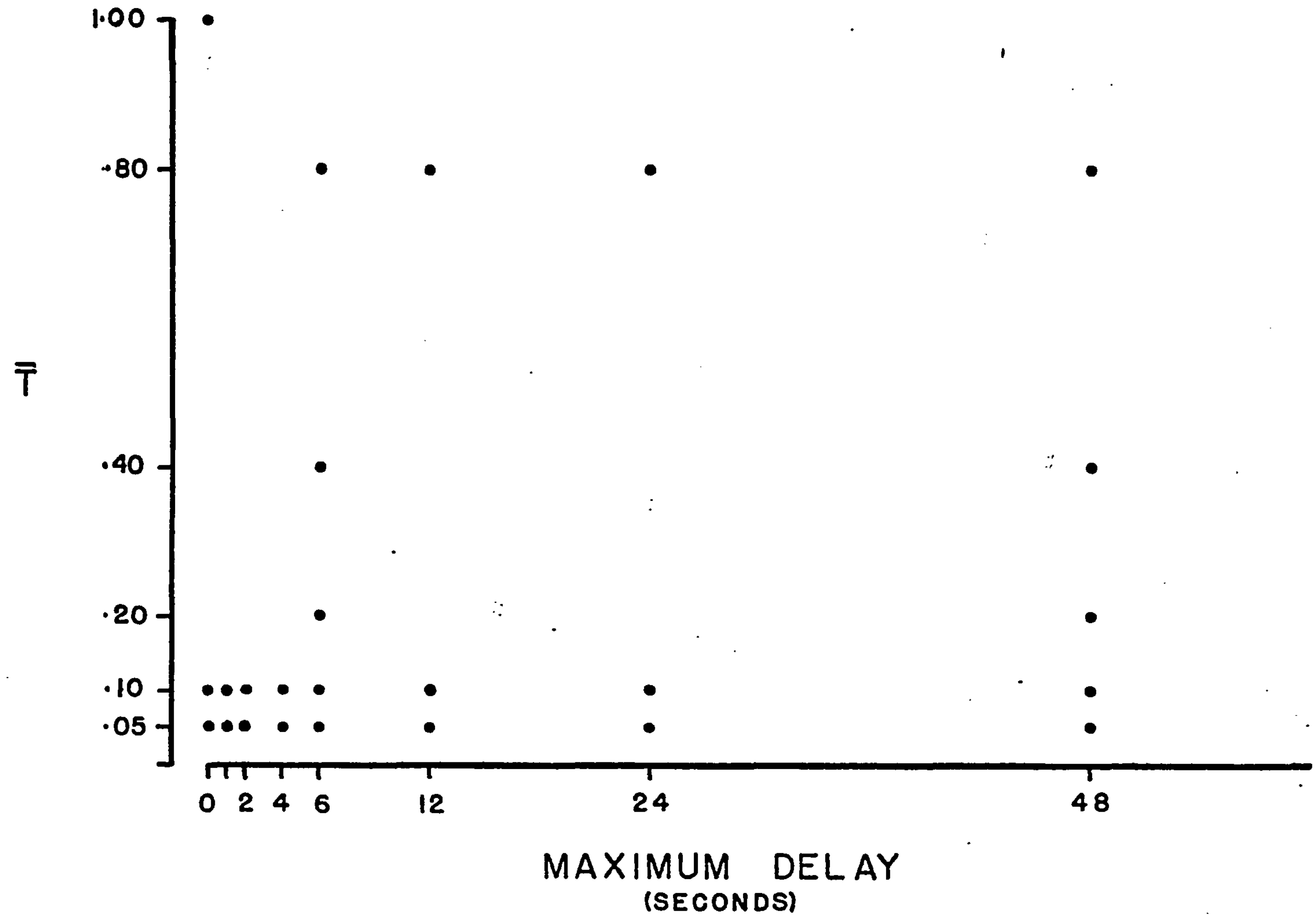

1·00
·80
·40
·20
·10
·05
T̄
0
2
4
6
12
24
48
MAXIMUM DELAY
(SECONDS)

Table 1

Schedules of reinforcement for Group 1.

Subjects: B62, B75, B96, B04

Point	Session	T	$\bar{T}$	D_{mx}	S^D	Cycles
0	001- 006	30	0.20	*	Normal	50-150
0	007- 020	30	0.20	0	Normal	50
1	101- 113	60	0.10	0	Gold	50
1	114- 120	60	0.10	0	Gold	25
2	201- 230	60	0.10	6	Purple	25
3	301- 310	60	0.10	0	Gold	25
4	401- 415	60	0.05	0	Gold	25
5	501- 515	60	0.05	1	Blue	25
6	601- 615	60	0.05	2	Red	25
7	701- 715	60	0.05	4	Aqua	25
8	801- 815	60	0.05	6	Purple	25
9	901- 915	60	0.05	12	Olive	25
10	1001-1015	60	0.05	24	Yellow	25
11	1101-1115	60	0.05	48	White	25
12	1201-1202	60	0.10	**	Gold	25
13	1301-1315	60	0.05	0	Gold	25

Note: From Session 411, B04 was run at 75% of her <u>ad libitum</u> weight.

When D_{mx} = * the first shaping procedure was used (see Appendix A).

When D_{mx} = ** the second shaping procedure was used (see Appendix A).

Table 2

Schedules of Reinforcement for Group 2

Subjects: B84, B30, B49, B61

Point	Session	T	$\overline{T}$	D_{mx}	S^D	Cycles
0	001- 005	30	0.20	*	Normal	50-150
0	006- 020	30	0.20	0	Normal	50
1	101- 113	60	0.10	0	Gold	50
1	114- 120	60	0.10	0	Gold	25
2	201- 230	60	0.10	6	Purple	25
3	301- 310	60	0.10	0	Gold	25
4	401- 415	60	0.10	1	Blue	25
5	501- 515	60	0.10	2	Red	25
6	601- 615	60	0.10	4	Aqua	25
7	701- 715	60	0.10	6	Purple	25
8	801- 815	60	0.10	12	Grn-Gold	25
9	901- 915	60	0.10	24	Olive	25
10	1001-1015	60	0.10	48	Yellow	25
11	1101	60	0.10	**	Gold	25
12	1201-1215	60	0.10	0	Gold	25

Note: When D_{mx} = * the first shaping procedure was used (see Appendix A). When D_{mx} = ** the second shaping procedure was used (see Appendix A).

Table 3

Schedules of reinforcement for Group 3

Subjects: B342, B785, B390, B225

Point	Session	T	$\overline{T}$	D_{mx}	S^D	Cycles
0	001- 002	60	0.10	**	Gold	50
0	003	60	0.20	**	Gold	25
1	101- 115	60	1.00	0	Gold	25
2	201- 215	60	0.80	6	Blue	25
3	301- 315	60	0.80	12	Red	25
4	401- 415	60	0.80	24	Purple	25
5	501- 515	60	0.80	48	Aqua	25
6	601- 615	60	0.40	48	Aqua	25
7	701- 715	60	0.20	48	Aqua	25
8	801- 815	60	0.10	48	Aqua	25
9	901- 915	60	0.05	48	Aqua	25
10	1001	60	0.10	**	Gold	25
11	1101-1115	60	1.00	0	Gold	25

Note: When D_{mx} = ** the second shaping procedure was used (see Appendix A).

Table 4

Schedules of reinforcement for Group 4

Subjects: B32, B242, B264, B341

Point	Session	T	$\overline{T}$	D_{mx}	S^D	Cycles
0	001- 002	60	0.10	**	Gold	50
0	003	60	0.20	**	Gold	25
1	101- 115	60	1.00	0	Gold	25
2	201- 215	60	0.80	6	Blue	25
3	301- 315	60	0.40	6	Blue	25
4	401- 415	60	0.20	6	Blue	25
5	501- 515	60	0.10	6	Blue	25
6	601- 615	60	0.05	6	Blue	25
7	701- 715	60	0.05	12	Olive	25
8	801- 815	60	0.05	24	Yellow	25
9	901- 915	60	0.05	48	Aqua	25
10	1001	60	0.10	**	Gold	25
11	1101-1115	60	1.00	0	Gold	25

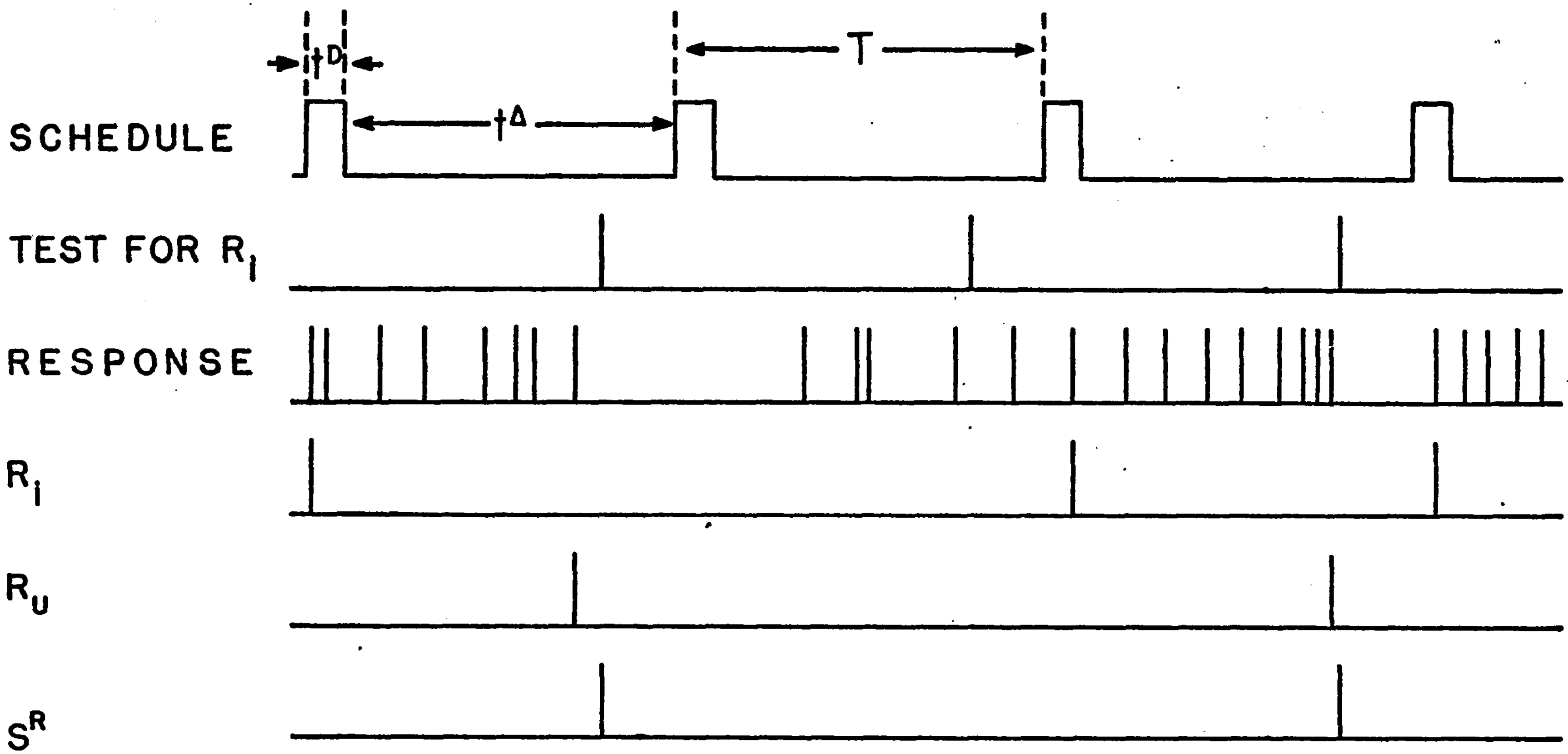
Note: When D_{mx} = ** the second response shaping procedure was used (see Appendix A).

group. Group 1 was exposed two times to ($0.10\overline{T}$, $0''D_{mx}$) and two times to ($0.05\overline{T}$, $0''D_{mx}$). Group 2 was exposed three times to ($0.10\overline{T}$, $0''D_{mx}$) and twice to ($0.10\overline{T}$, $6''D_{mx}$). Groups 3 and 4 were each exposed twice to the matrix value ($1.00\overline{T}$, $0''D_{mx}$).

Following exposure to ($0.05\overline{T}$, $48''D_{mx}$) and prior to the return to ($0.05\overline{T}$, $0''D_{mx}$), Group 1 was given two sessions of the second shaping procedure described in Appendix A. Some of the subjects had made no responses for many sessions and failure to re-establish pecking would have resulted in an unpredictably long transition time to recovery of the original behavior. For the sake of consistency, as well as to re-establish pecking in those subjects which had ceased responding, Groups 3 and 4 were also exposed to the second shaping procedure (for one session) prior to being returned to the matrix value ($1.00\overline{T}$, $0''D_{mx}$), and Group 2 was similarly exposed for one session to the second shaping procedure prior to being returned for the second time to ($0.10\overline{T}$, $0''D_{mx}$). The number of sessions of exposure of each group to the matrix values is also given in Tables 1, 2, 3, and 4 along with the color (broad spectrum) of the houselight cover. As a presumed aid to rapid transition to the behavior which would eventually dominate after a change to a new schedule value, the color of the houselight cover (the S^D) was changed each time D_{mx} was changed to a new value. For a given group, each D_{mx} was paired with a unique color of houselight cover.

Figure 2 is presented as an aid to understanding the programming procedure. This figure is a schematic representation of some of the possible relations when the schedule value is (60"T, 0.10$\overline{T}$, 48"D_{mx}). In each t-cycle of sixty seconds, the test for the occurrence of an R_i in that t-cycle comes 48" after the beginning of that t-cycle. If the maximum delay of reinforcement were 4 seconds, then at the end of each 4 second period from the beginning of the t-cycle there would be a test for R_i. Only one S^R per t-cycle is given, so tests for R_i after one S^R has been given in a t-cycle cannot produce further S^Rs in that cycle. While the minimum time permitted between an S^R and the immediately preceding R (i.e., the minimum delay, or D_{mn}) is always zero, the actual time the (RS^RT) may vary between zero and D_{mx}. The minimum time between an S^R and the immediately preceding R_i is determined by the time between the trailing edge of t^D and the first test for R_i in a t-cycle. If this value is negative or zero, then the minimum delay of reinforcement of R_i is zero seconds. If this value is positive then the minimum delay of reinforcement of R_i is equal to this value. In Figure 2 the minimum delay of reinforcement of R_i is 48" minus 6", or 42".

Figure 2. A schematic representation of possible relations between one schedule ($\overline{T}$ = 0.10, D_{mx} = 48 sec.), responses and reinforcing stimuli. R_i is the response identified for reinforcement. R_u is the ultimate response before a reinforcing stimulus presentation.

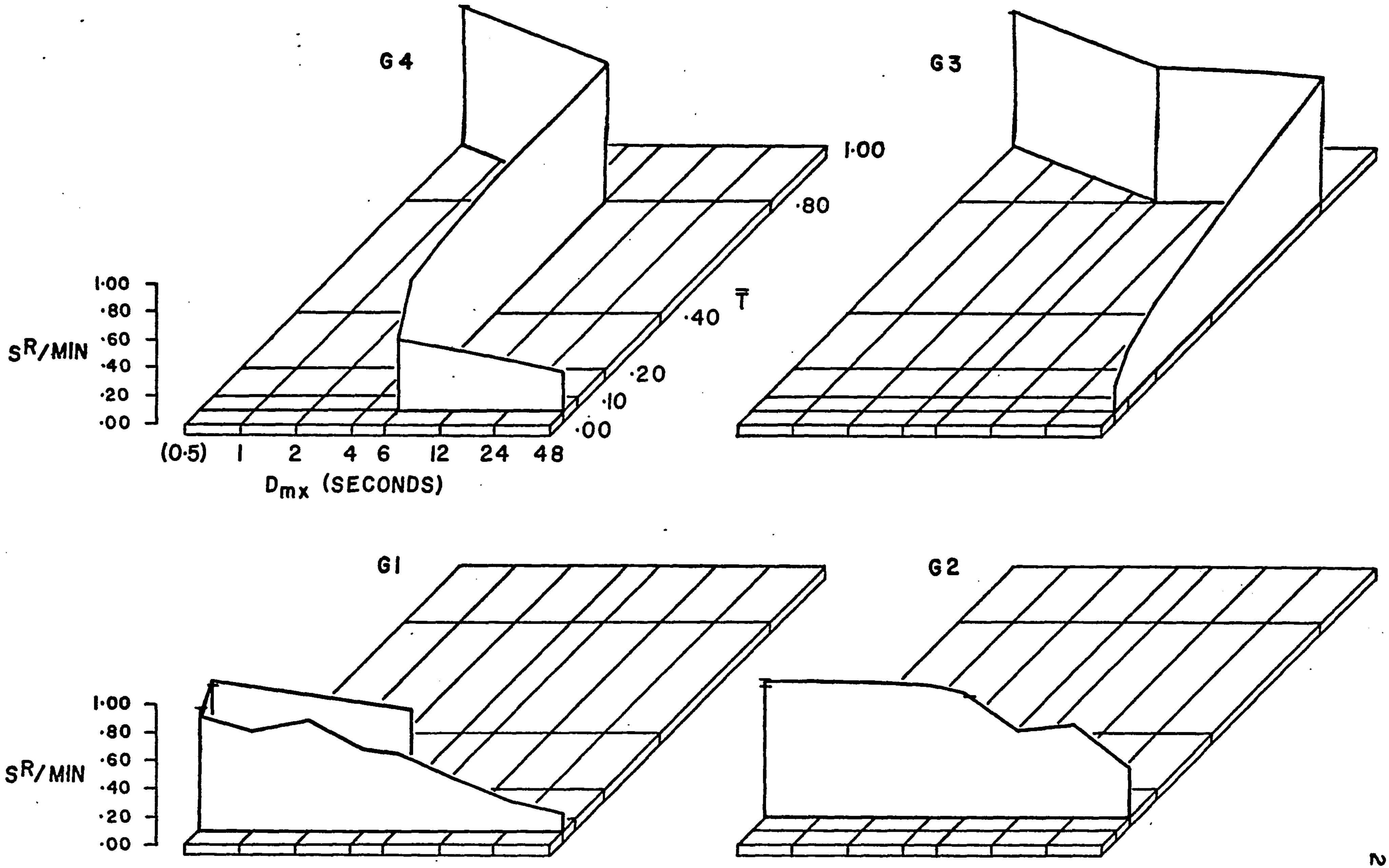

t^D
t^Δ
T
SCHEDULE
TEST FOR R_I
RESPONSE
R_I
R_U
S^R

RESULTS

The course of pretraining and the acquisition of key-peck performance are described in Appendix A. The effects of manipulating $\overline{T}$ and D_{mx} were measured in terms of: 1) overall corrected rate of responding per session — corrected rate of responding was calculated according to the formula $R/(T_t - T_{(S^R)})$ where R is the number of key-pecks recorded, T_t is the total session time, and $T_{(S^R)}$ is the total reinforcement access time; 2) local corrected rate of responding — each t-cycle was divided into ten six-second subintervals and the average corrected rate of key-pecking was separately calculated for each subinterval of the t-cycle; 3) overall running rate of responding — running rate of responding was calculated according to the formula $R/(T_t - T_{(S^R)} - T_{(PS^R P)})$ where R, T_t, and $T_{(S^R)}$ are defined as before, and $T_{(PS^R P)}$ is the total post-reinforcement pause time per session; 4) mean post-reinforcement pause time per session; 5) mean number of responses per reinforcement; and 6) mean number of reinforcements per t-cycle (or per minute).

Figure 3 presents the general effect upon reinforcements per minute of manipulations of $\overline{T}$ and D_{mx}. The values represented are averages across all individuals and all sessions of a group. No simple equation was found which would represent well these data but as a general rule, when $\overline{T}$ decreased and D_{mx} increased, the rate of reinforcement decreased. With D_{mx} at zero

Figure 3. Reinforcement rate as a function of schedule values for each group of subjects. Note that D_{mx} is on a logarithmic scale. Data are the averages over all the sessions for each experimental point for each group. Data values for vector values which were presented multiple times are shown as short horizontal lines for all but one of the repeated values. Shown as horizontal lines are Point 1 and Point 13 for Group 1, Points 1, 2 and 12 for Group 2, Point 11 for Group 3, and Point 11 for Group 4.


G4
G3
G1
G2
1·00
·80
·60
·40
·20
·00
S^R/MIN
1·00
·80
·40
·20
·10
·00
$\bar{T}$
(0·5) 1 2 4 6 12 24 48
D_{mx} (SECONDS)

seconds, a decrease in $\overline{T}$ begins to show an effect when t^D falls below six seconds. Apparently, with a D_{mx} of zero, such high response rates are generated that few IRTs (inter-response times) exceed six seconds and PS^RPs are typically terminated during the same t-cycle in which they are initiated. A large D_{mx} has a similarly small effect upon reinforcement rate when $\overline{T}$ is large (e.g., 0.80). Even if the response rate was reduced substantially by a larger D_{mx}, when $\overline{T}$ is 0.80 IRTs would have to exceed 48 seconds in order for a t-cycle of 60 seconds not to contain a reinforcer. The response rate reductions produced by increases in D_{mx} and the lower probability of reinforcement of a given distribution of IRTs as $\overline{T}$ is reduced combine, however, to produce a very low probability of reinforcement at the schedule (0.05$\overline{T}$, 48"D_{mx}).

The mean reinforcements per t-cycle for each consecutive session and point of the entire experiment (including pretraining and reshaping sessions) are presented for each group in Figures 4, 5, 6, and 7. Figures 8, 9, 10, and 11 present the same data in five session means for each group and the associated individuals. The consecutive experimental conditions or "points" are separated by vertical lines. The conditions obtaining at each point for each group may be found in Tables 1 through 4. The data for all points are calculated taking into account only the response-produced reinforcements.

In Figures 4 and 8, which present data from Group 1,

Figure 4. Mean reinforcements per t-cycle for each session and successive experimental condition (i.e., "point") for Group 1. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 1.

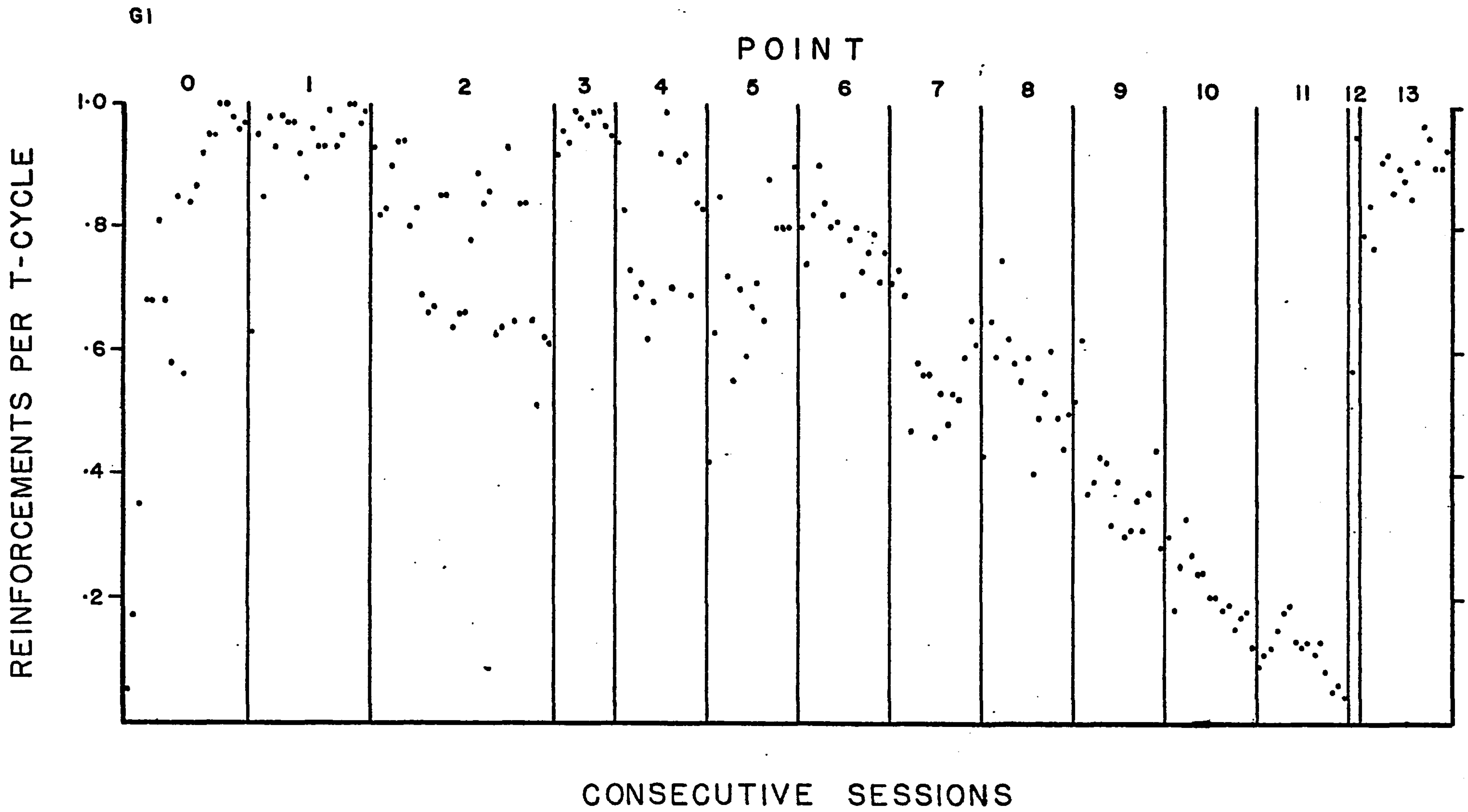

G1
POINT
0 1 2 3 4 5 6 7 8 9 10 11 12 13
1·0
·8
·6
·4
·2
REINFORCEMENTS PER T-CYCLE
CONSECUTIVE SESSIONS

Figure 5. Mean reinforcements per t-cycle for each session and consecutive experimental condition (i.e., "point") for Group 2. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 2.

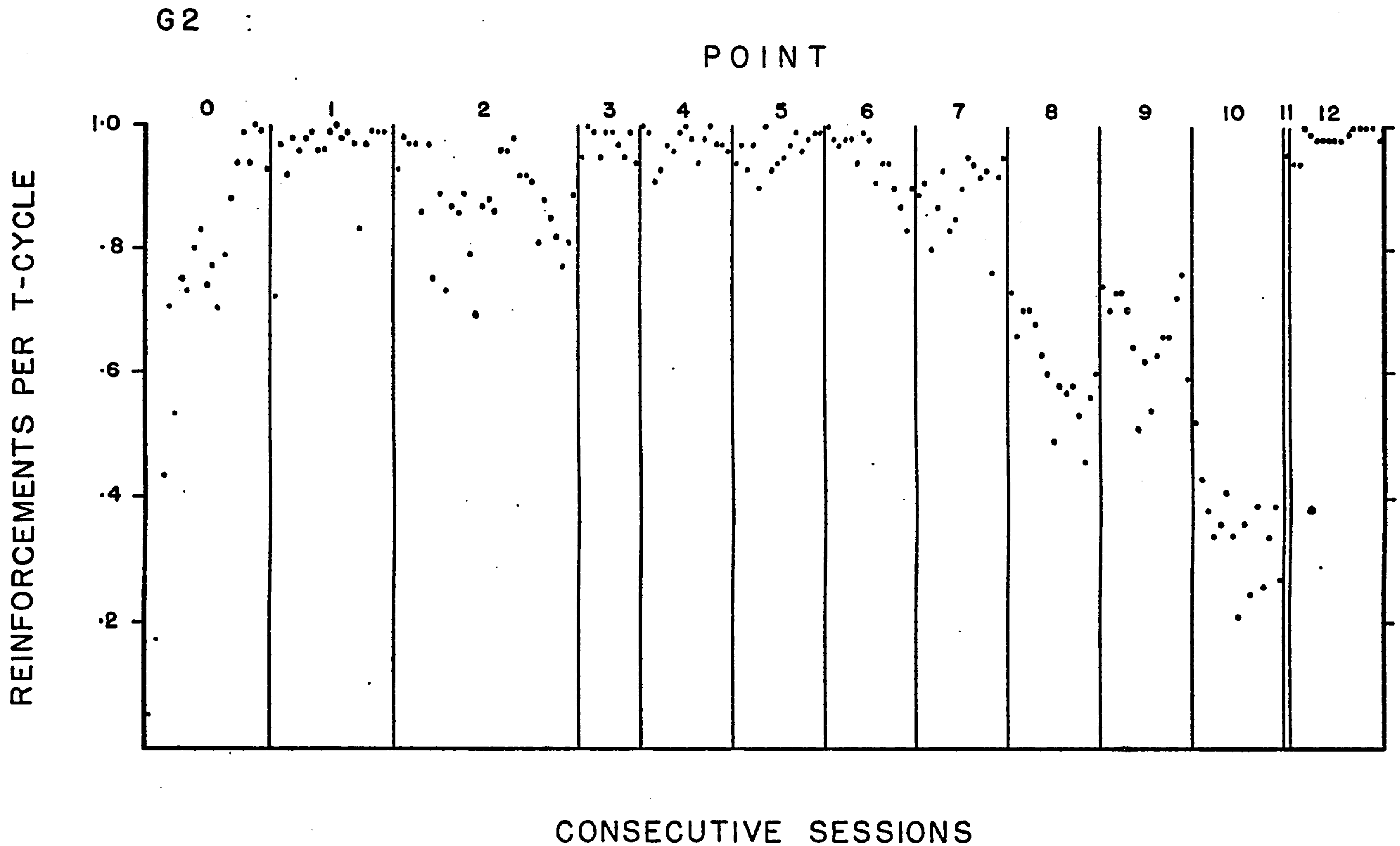

G2
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
1·0
·8
·6
·4
·2
REINFORCEMENTS PER T-CYCLE
CONSECUTIVE SESSIONS

Figure 6. Mean reinforcements per t-cycle for each session and consecutive experimental condition (i.e., "point") for Group 3. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 3.

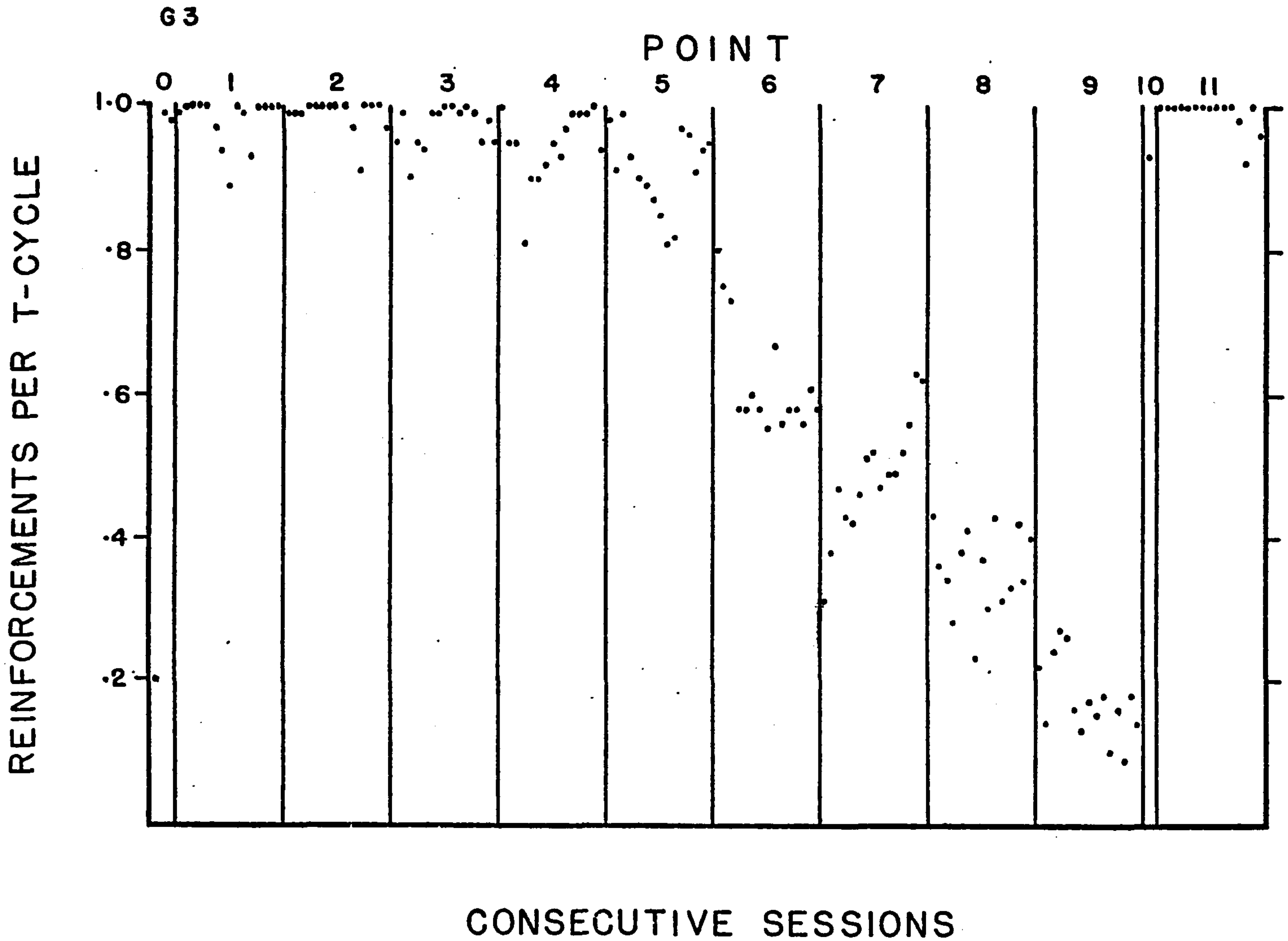

G3
POINT
0 1 2 3 4 5 6 7 8 9 10 11
1·0
·8
·6
·4
·2
REINFORCEMENTS PER T-CYCLE
CONSECUTIVE SESSIONS

Figure 7. Mean reinforcements per t-cycle for each session and successive experimental condition (i.e., "point") for Group 4. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 4.

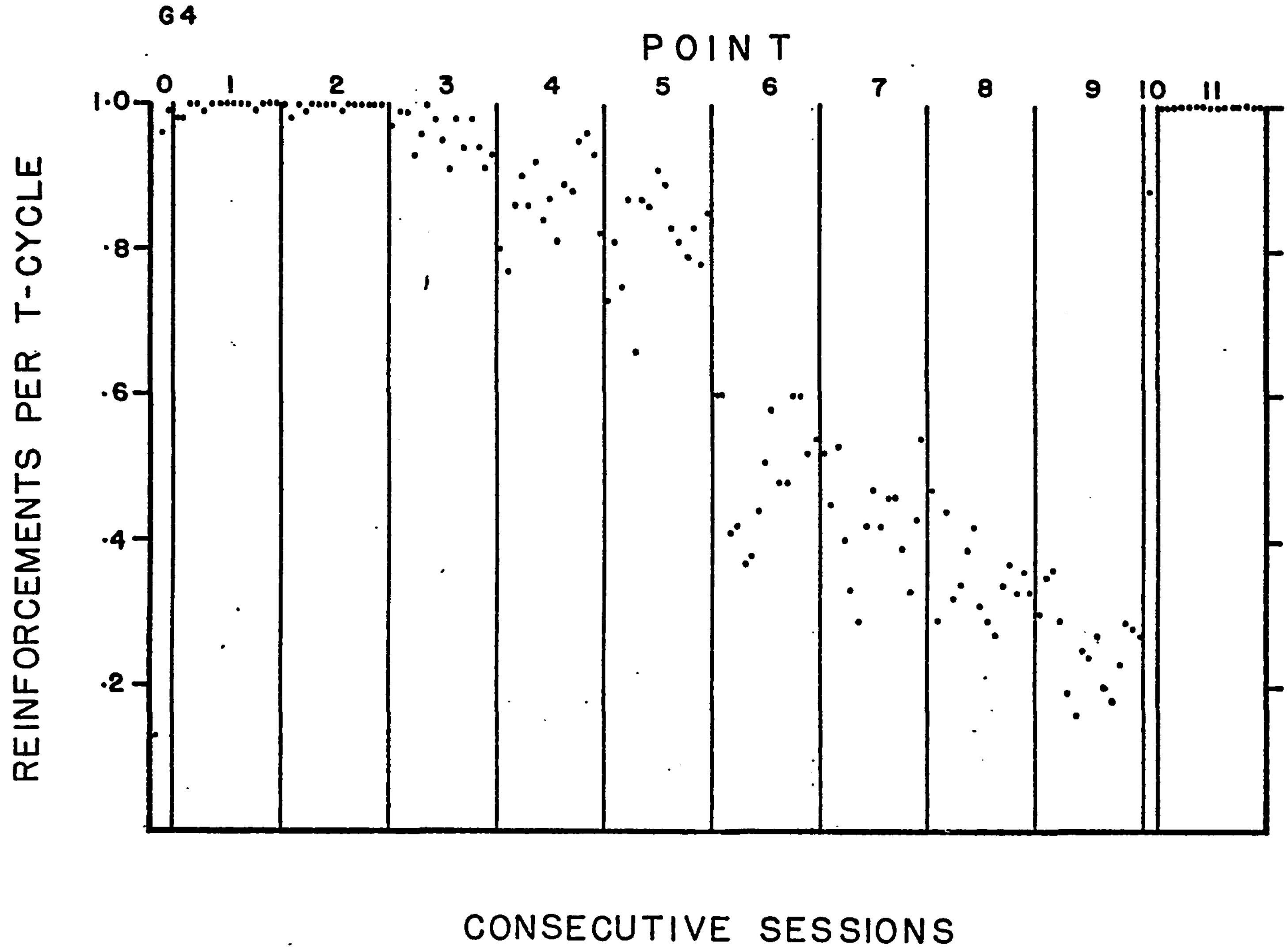

G4
POINT
0 1 2 3 4 5 6 7 8 9 10 11
1·0
·8
·6
·4
·2
REINFORCEMENTS PER T-CYCLE
CONSECUTIVE SESSIONS

Figure 8. Reinforcements per t-cycle. Presented are consecutive five-session means for each individual subject of Group 1 and the consecutive five-session means for Group 1 as a whole. When a point consisted of less than five sessions then the mean of the actual number of sessions is presented. Conditions obtaining at each point may be found in Table 1.

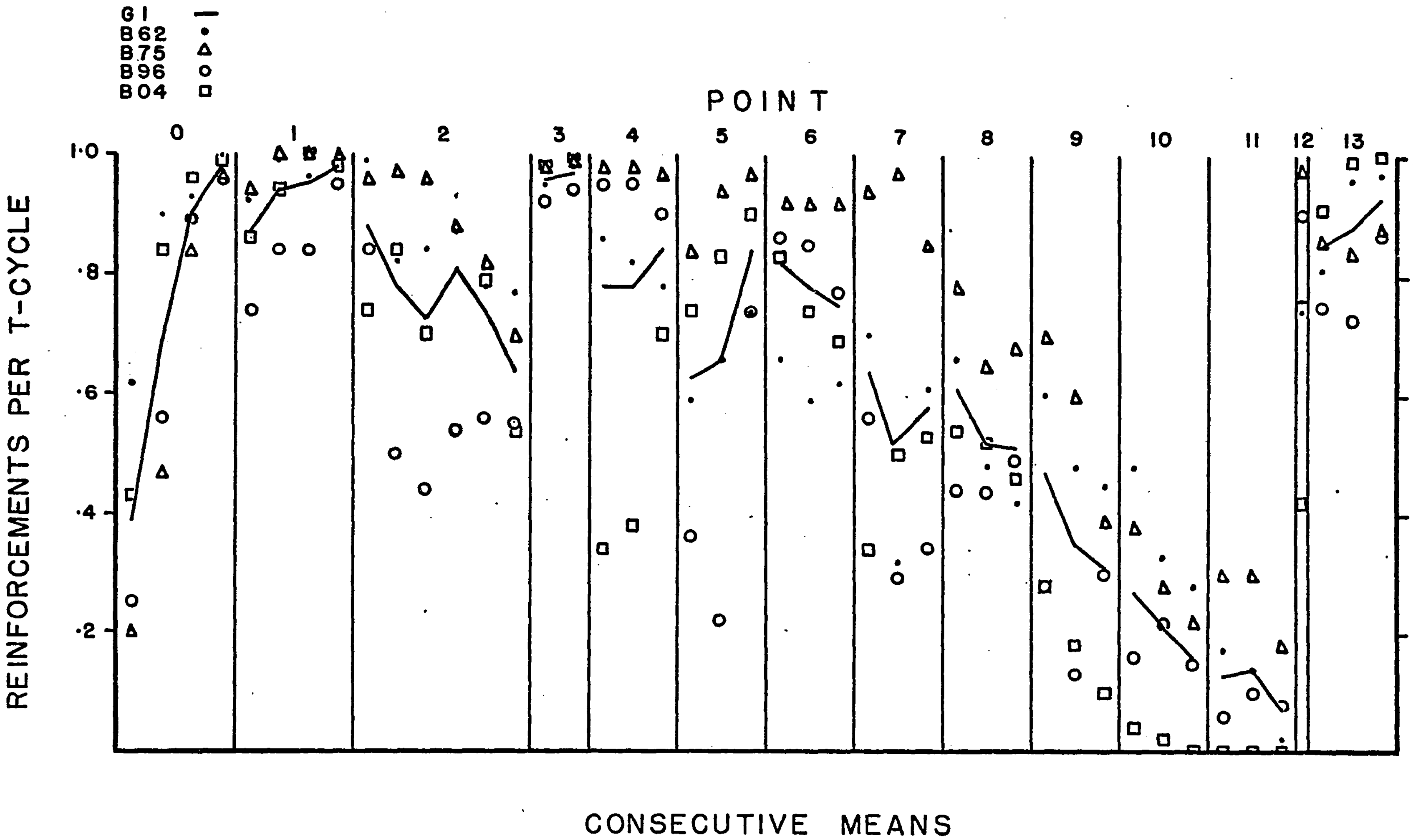

G1
B62
B75
B96
B04
POINT
0 1 2 3 4 5 6 7 8 9 10 11 12 13
1·0
·8
·6
·4
·2
REINFORCEMENTS PER T-CYCLE
CONSECUTIVE MEANS

Figure 9. Reinforcements per t-cycle. Presented are consecutive five session means for each individual subject and the means of the group for Group 2. When a point consisted of less than five sessions then the mean of the actual number of sessions is presented. Conditions obtaining at each point may be found in Table 2.

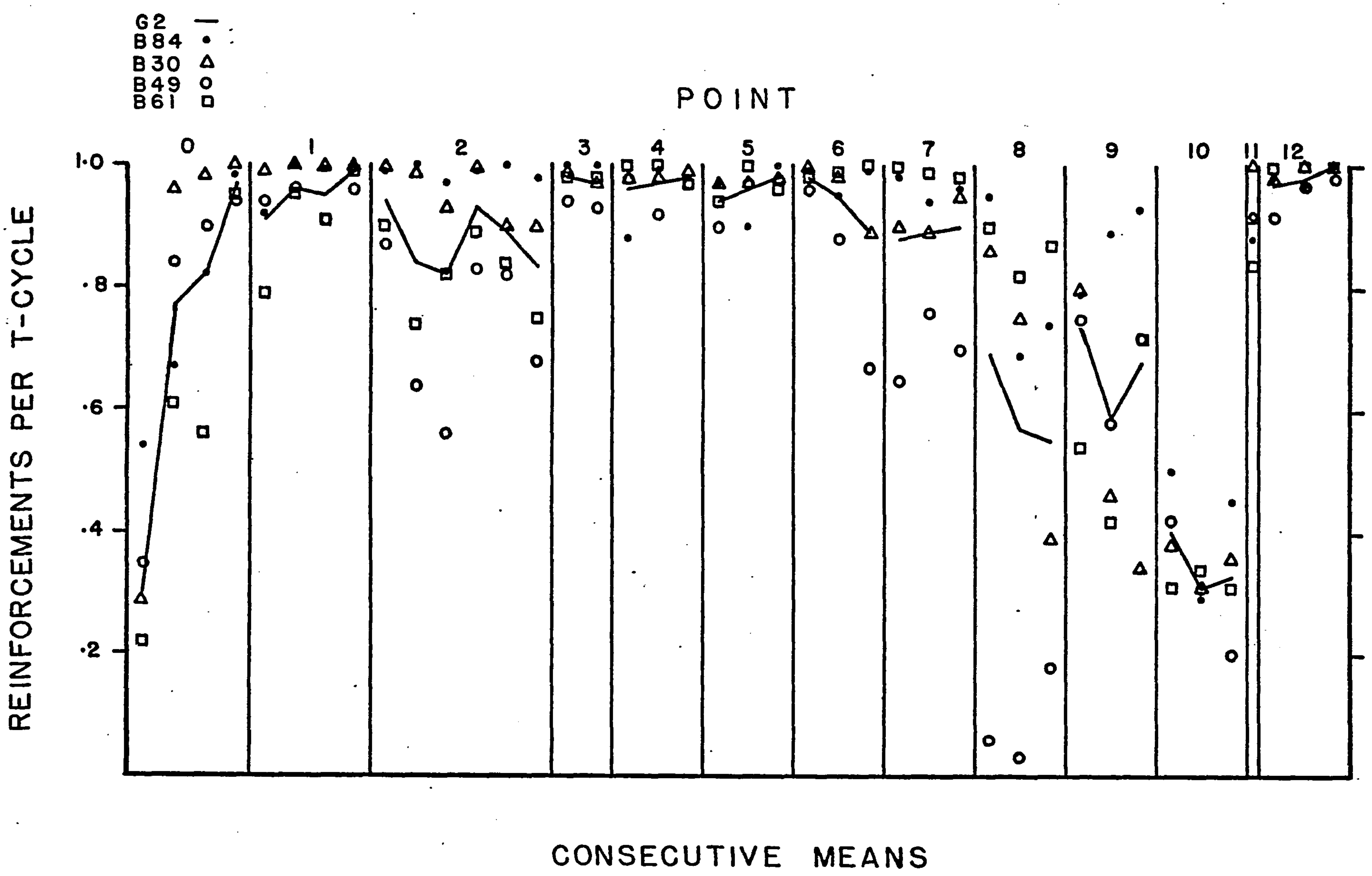

G2
B84
B30
B49
B61
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
1·0
·8
·6
·4
·2
REINFORCEMENTS PER T-CYCLE
CONSECUTIVE MEANS

Figure 10. Reinforcements per t-cycle. Presented are consecutive five session means for each individual subject and the means of the group for Group 3. When a point consisted of less than five sessions then the mean of the actual number of sessions is presented. Conditions obtaining at each point may be found in Table 3.

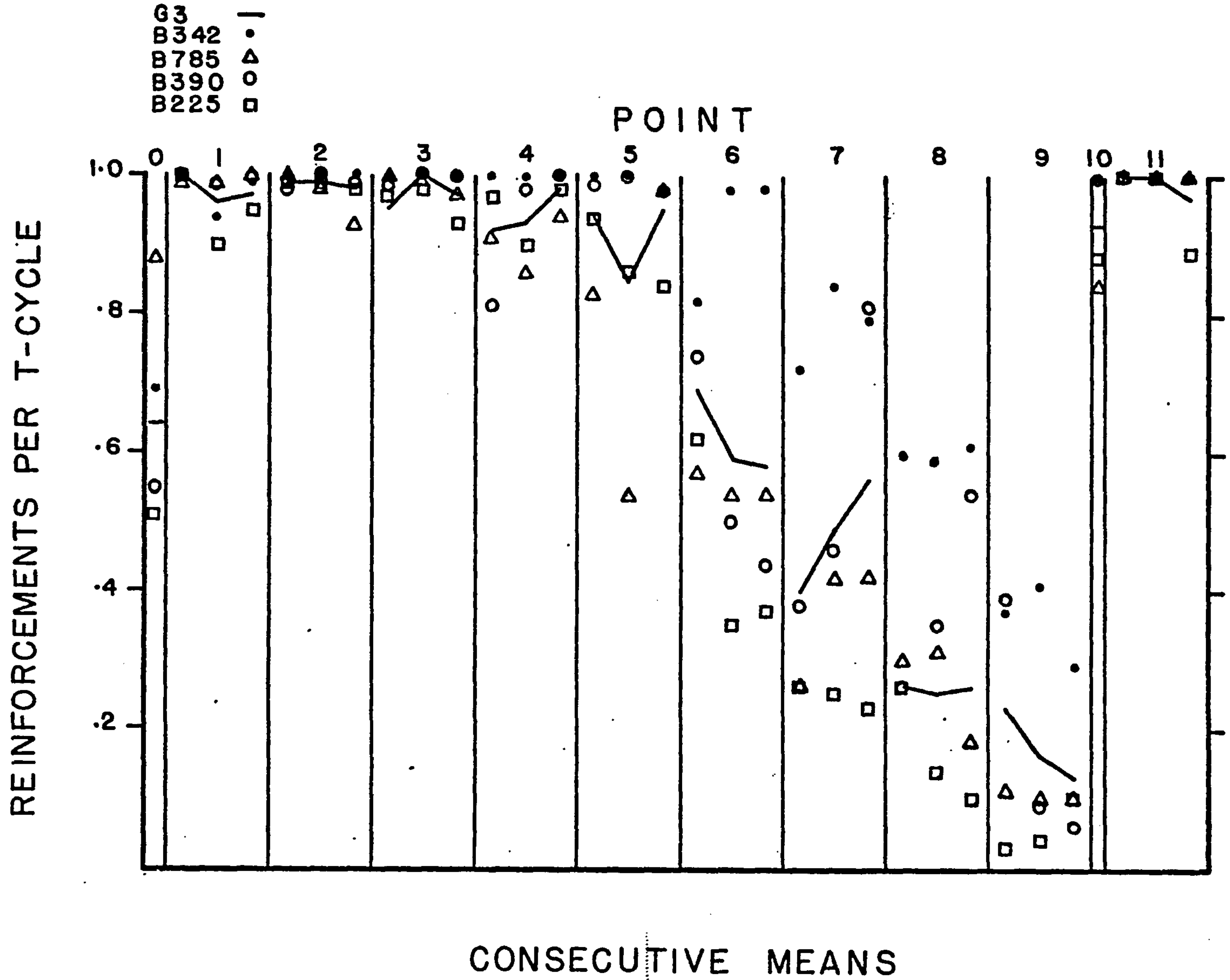
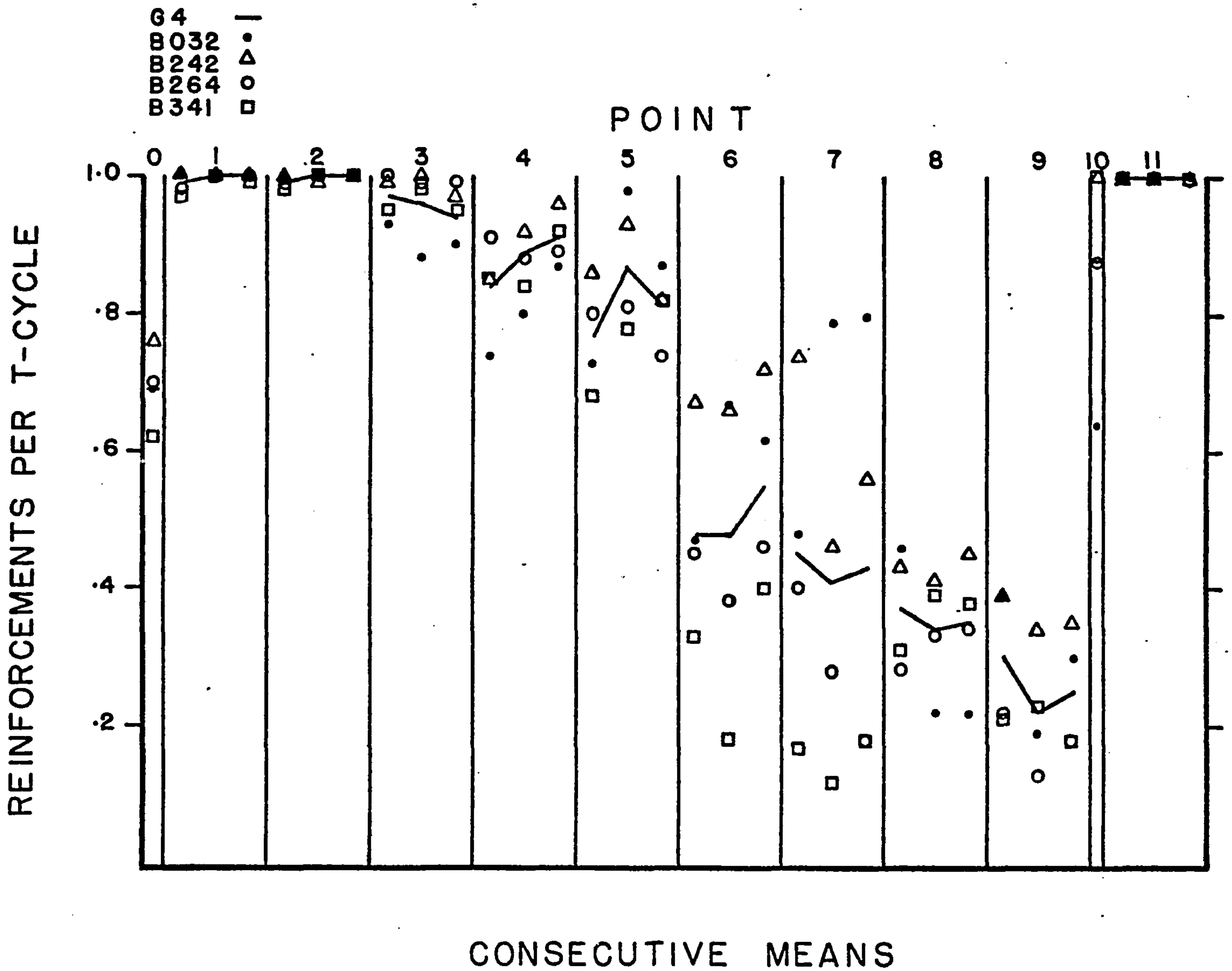

G3
B342
B785
B390
B225
POINT
0 1 2 3 4 5 6 7 8 9 10 11
1·0
·8
·6
·4
·2
REINFORCEMENTS PER T-CYCLE
CONSECUTIVE MEANS

Figure 11. Reinforcements per t-cycle. Presented are consecutive five session means for each individual subject and the means of the group for Group 4. When a point consisted of less than five sessions then the mean of the actual number of sessions is presented. Conditions obtaining at each point may be found in Table 4.



G4 —
B032 •
B242 Δ
B264 o
B341 □
POINT
0
1
2
3
4
5
6
7
8
9
10
11
1·0
·8
·6
·4
·2
REINFORCEMENTS PER T-CYCLE
CONSECUTIVE MEANS

Points 1 and 3 are repetitions of the matrix value ($0.10\overline{T}$, $0''D_{mx}$) while Points 4 and 13 are repetitions of ($0.05\overline{T}$, $0''D_{mx}$). It can hardly be said that asymptotic performance was obtained at each point before conditions were changed. The trend is distinctly downward for Points 8 through 11 for this group. It is possible that asymptotic performance for some or all of the associated matrix values is zero reinforcements per t-cycle. It may also be that the rate at which the rate of reinforcement approaches zero is greater for the larger values of D_{mx}. That the reinforcement rate reduction is due to the schedule manipulations rather than to other, unknown factors is evidenced by the reinforcement rate recovery at Point 13.

The comments concerning the figures for Group 1 (Figures 4 and 8) apply in general to the figures for Group 2 (Figures 5 and 9). The schedule conditions for each session and point are listed in Table 2. For this group the D_{mx} must be larger for a comparable reduction in reinforcement rate. It is not as apparent that asymptotic performances are not reached by the end of the fifteen sessions at each point. Points 1, 3 and 12 are consecutive repetitions of the same matrix value ($0.10\overline{T}$, $0''D_{mx}$), and Points 2 and 7 are consecutive repetitions of ($0.10\overline{T}$, $6''D_{mx}$). For Group 3 (Figures 6 and 10) there was a sharp decrease in reinforcement rate when the schedule value changed from ($0.80\overline{T}$, $48''D_{mx}$) to ($0.40\overline{T}$, $48''D_{mx}$), indicating a sudden interaction with the prevailing IRT distribution.

Peculiar is the positive trend shown during Point 7. As can be seen from Figure 10, this trend cannot solely be attributed to the peculiarities of any one animal since three of the four subjects show this same trend. However, one subject, (B390) is possibly responsible for the major part of this positive trend. This same subject also showed a very large increase in overall corrected response rate during this point. For this subject, the third five-session mean was 3.5 times the size of the first five-session mean corrected rate.

The overall corrected response rates (R/min) for each group are shown in Figure 12 for each matrix value presented. The general trend is for response rates to decrease as $\overline{T}$ decreases and D_{mx} increases. Figures 13, 14, 15 and 16 present the corrected response rates (R/sec) per consecutive session and point. Figures 17, 18, 19 and 20 present the mean corrected response rates for successive five session blocks. For Group 3 (Figures 15 and 19) there is an apparent cycle with a period of some 28 sessions during the first half of the experiment. At least three full cycles may be discerned. Inspection of Figure 19, which presents individual data, suggests that this periodicity is purely coincidental. It does not appear in any single individual of Group 3. Nor is this periodicity shown by any of the other groups or individuals. The high overall corrected response rates shown by Group 3 in Points 2 through 8 are almost completely attributable to the abnormally high

Figure 12. Corrected rate of responding (R/min) as a function of the value of the schedule vector for each group of subjects. Data are the averages of all the sessions for each experimental point for each group. Data values for schedules which were presented multiple times are shown as short horizontal lines for all but one of the repeated schedules. Shown as short horizontal lines are Points 1 and 13 for Group 1, Points 1, 2 and 12 for Group 2, Point 11 for Group 3, and Point 11 for Group 4. Note that D_{mx} is on a logarithmic scale.

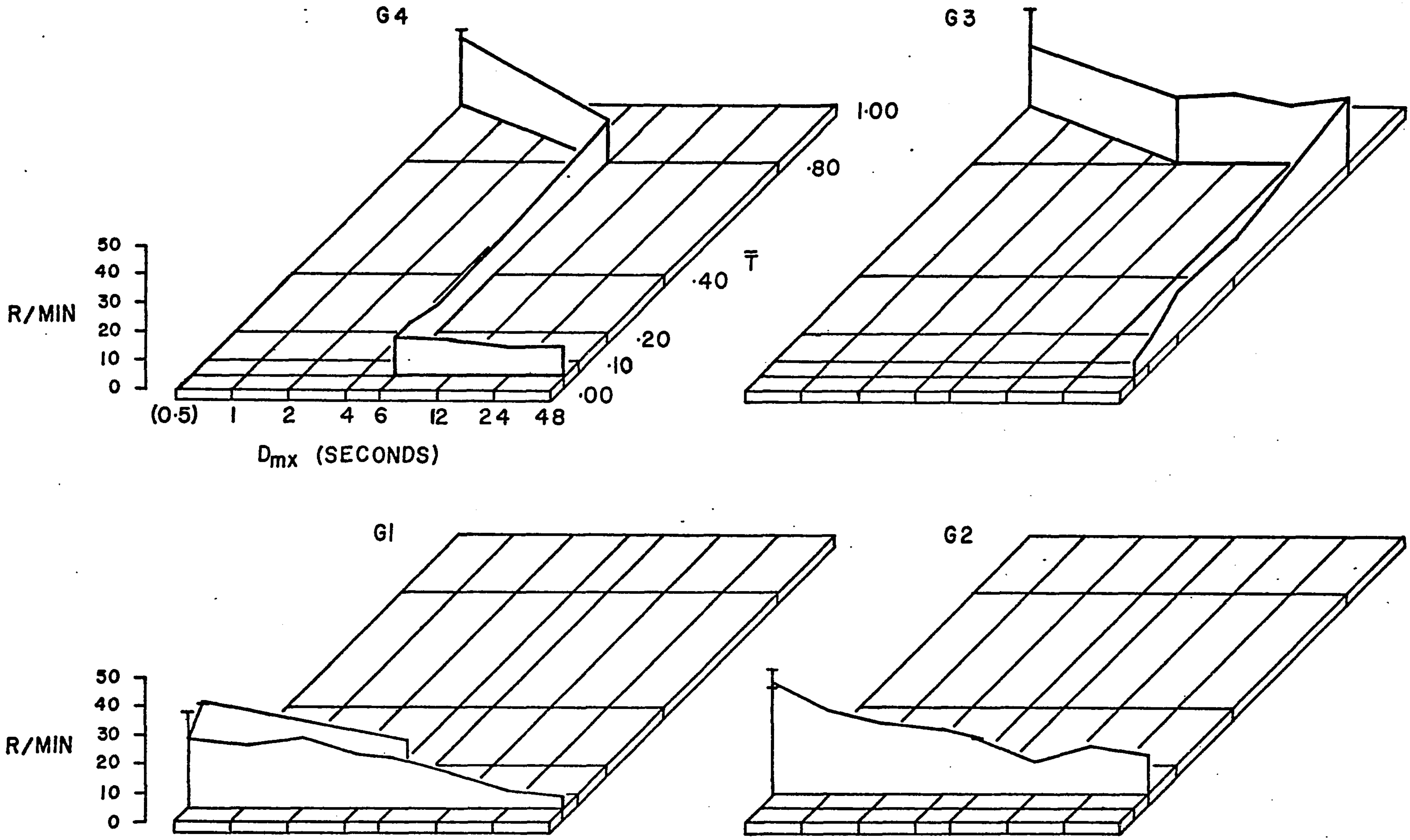

G4
G3
G1
G2
R/MIN
50
40
30
20
10
0
(0·5)
1
2
4
6
12
24
48
Dmx (SECONDS)
1·00
·80
·40
·20
·10
·00
T̄
R/MIN
50
40
30
20
10
0

Figure 13. Overall corrected rate of responding (R/sec) per session for Group 1. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 1.

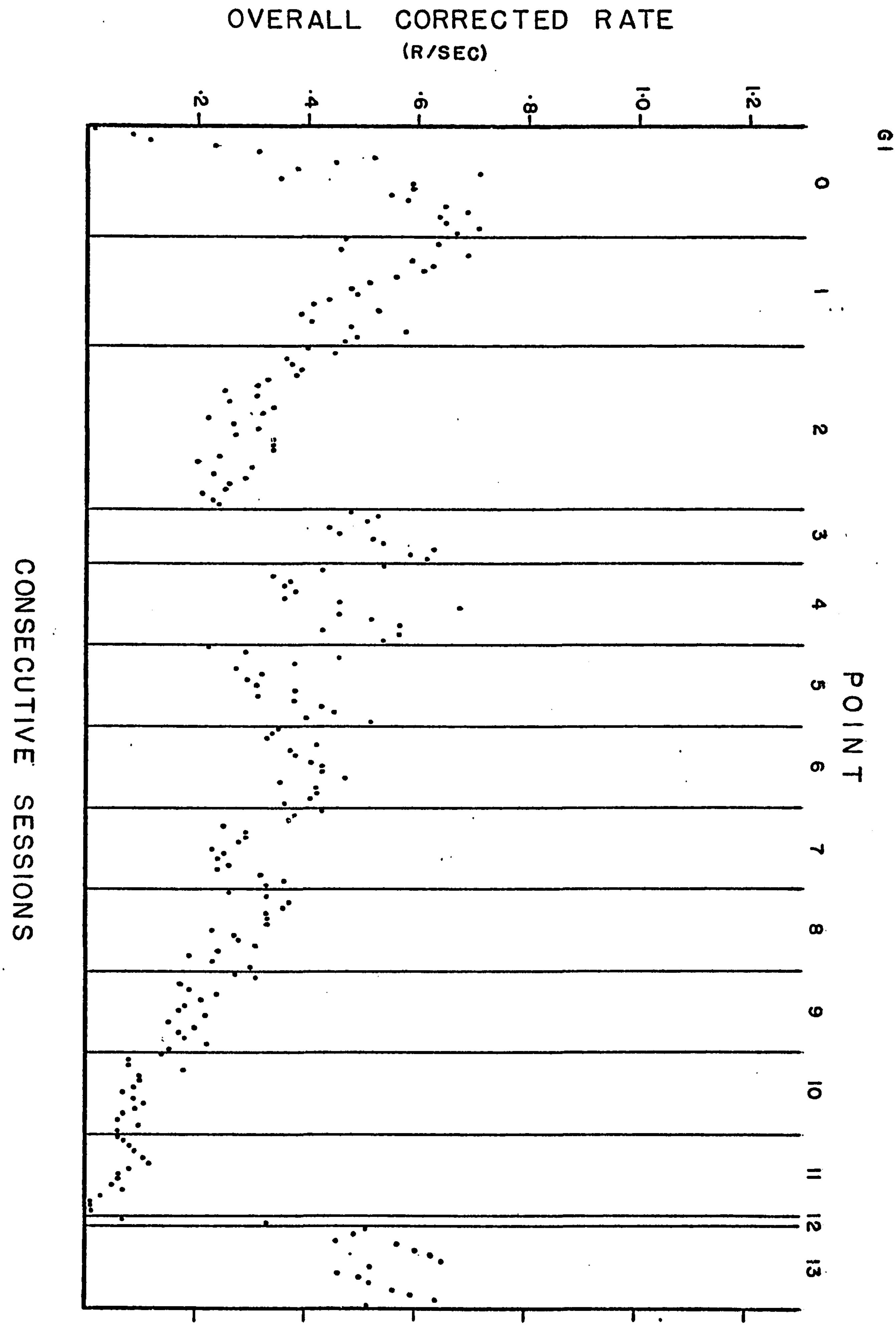

OVERALL CORRECTED RATE
(R/SEC)
·2
·4
·6
·8
1·0
1·2
G1
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
13
CONSECUTIVE SESSIONS

Figure 14. Overall corrected rate of responding (R/sec) per session for Group 2. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 2.

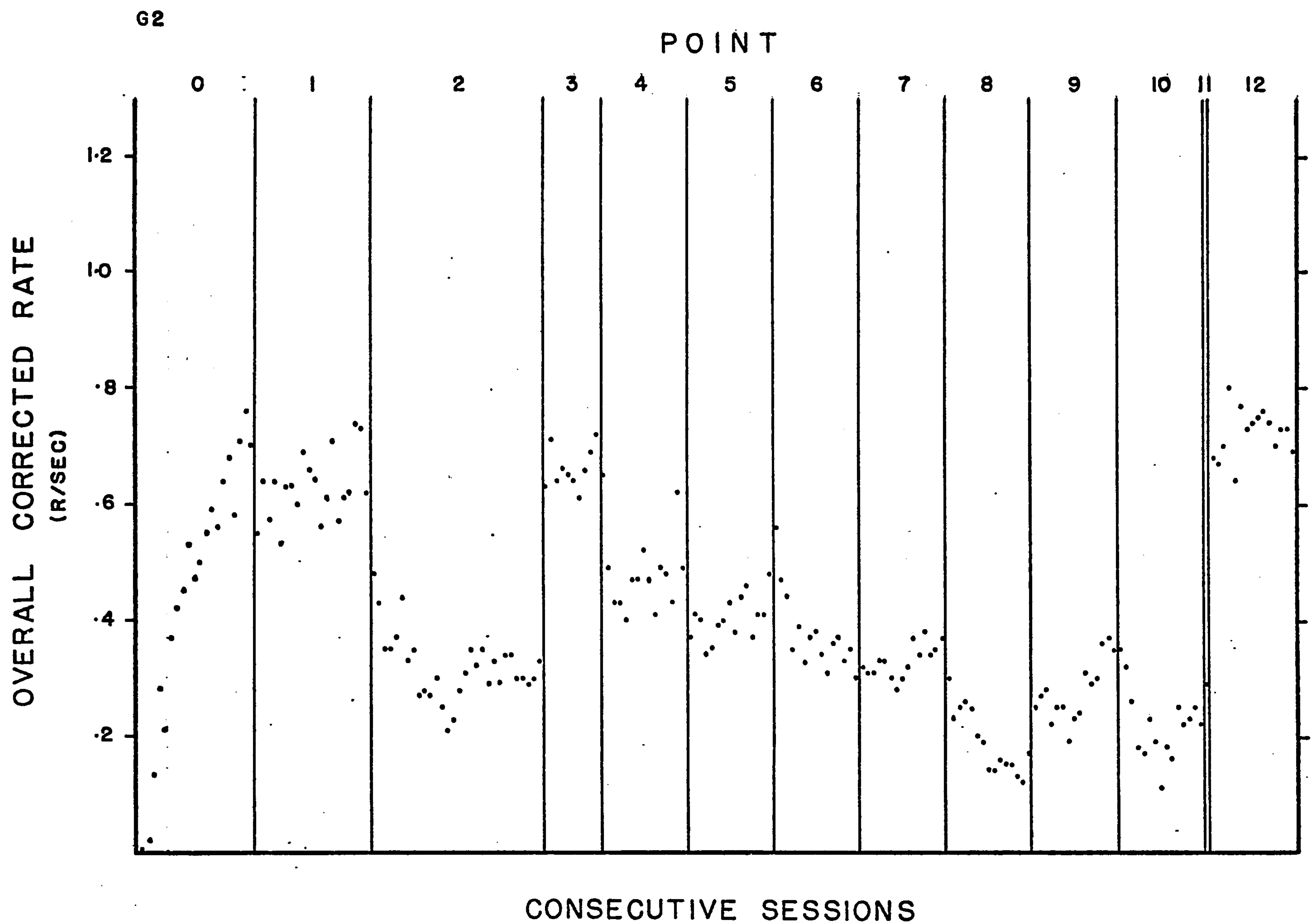

G2
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
OVERALL CORRECTED RATE
(R/SEC)
1·2
1·0
·8
·6
·4
·2
CONSECUTIVE SESSIONS

Figure 15. Overall corrected rate of responding (R/sec) per session for Group 3. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 3.

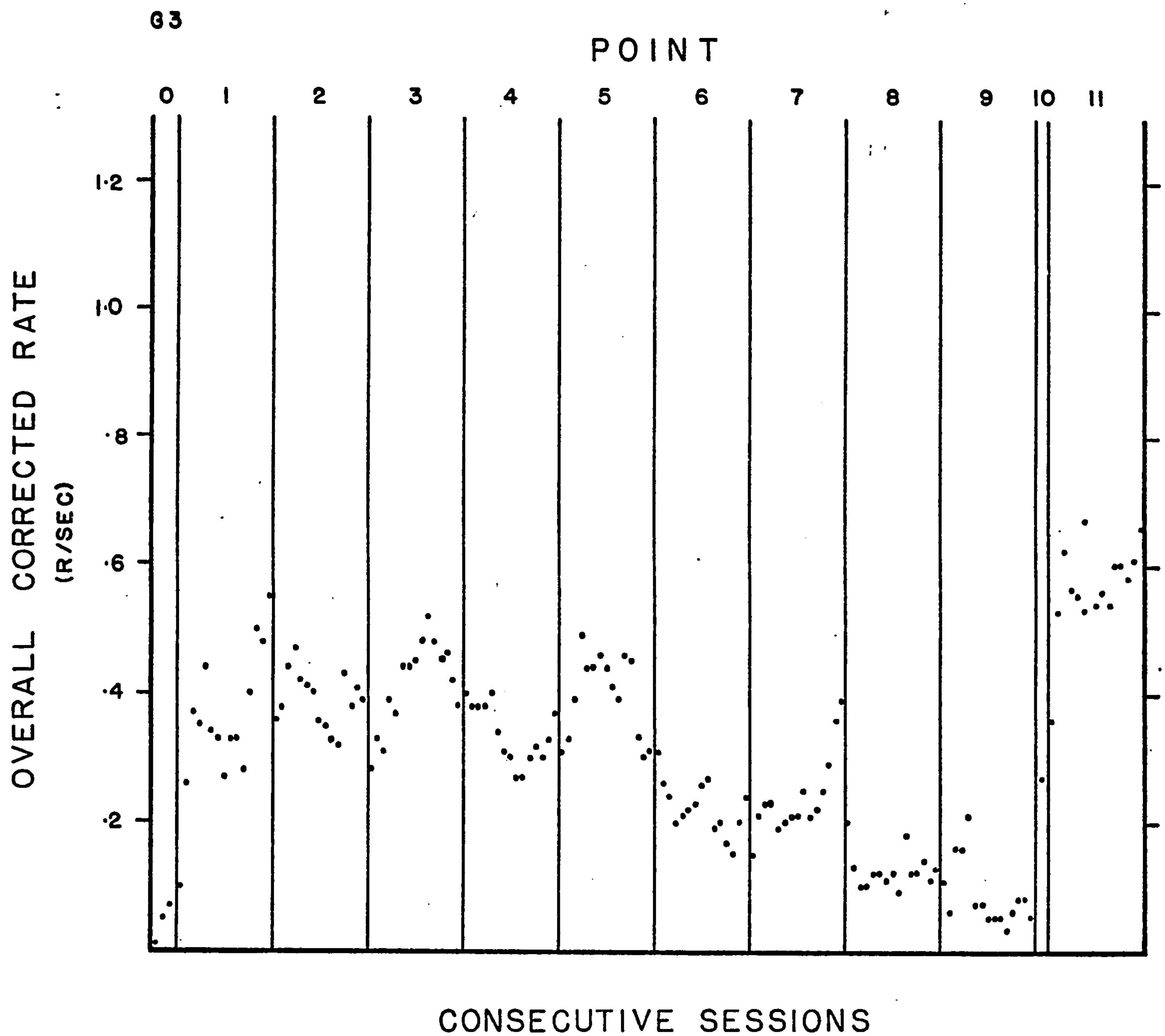

G3
POINT
0
1
2
3
4
5
6
7
8
9
10
11
OVERALL CORRECTED RATE
(R/SEC)
1·2
1·0
·8
·6
·4
·2
CONSECUTIVE SESSIONS

Figure 16. Overall corrected rate of responding (R/sec) per session for Group 4. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 4.

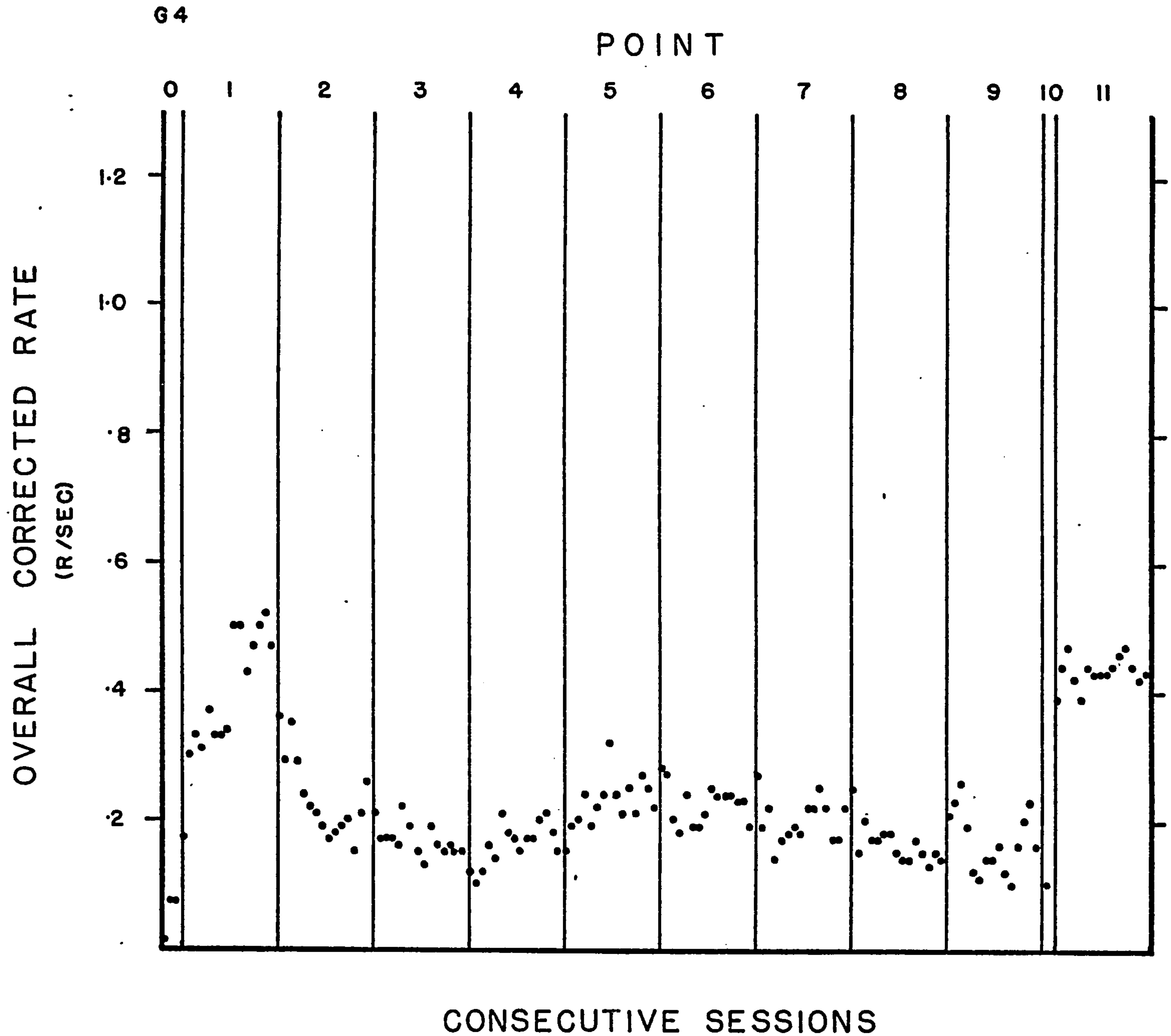

G4
POINT
0
1
2
3
4
5
6
7
8
9
10
11
OVERALL CORRECTED RATE
(R/SEC)
1·2
1·0
·8
·6
·4
·2
CONSECUTIVE SESSIONS

Figure 17. Overall corrected rate of responding (R/sec) for Group 1 and the individual subjects of Group 1. Presented are consecutive five-session means for each individual and the group. For points consisting of less than five sessions, the means are of the sessions presented. Conditions obtaining at each point may be found in Table 1

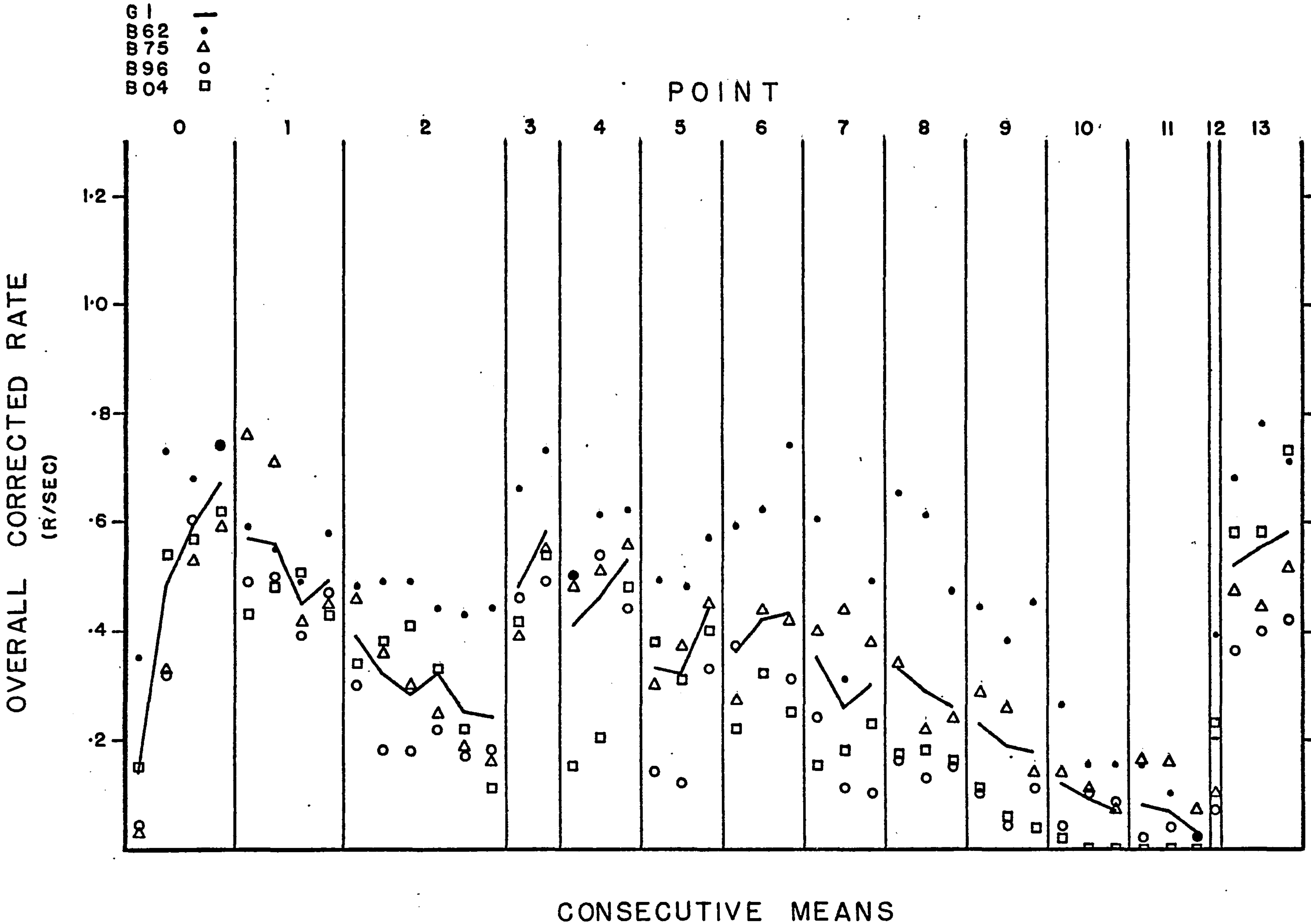

G1
B62
B75
B96
B04
POINT
0 1 2 3 4 5 6 7 8 9 10 11 12 13
1·2
1·0
·8
·6
·4
·2
OVERALL CORRECTED RATE
(R/SEC)
CONSECUTIVE MEANS

Figure 18. Overall corrected rate of responding (R/sec) for Group 2 and its individual subjects. Presented are consecutive five-session means for each individual and the group. For points consisting of less than five sessions, the means are of the sessions presented. Conditions obtaining at each point may be found in Table 2.

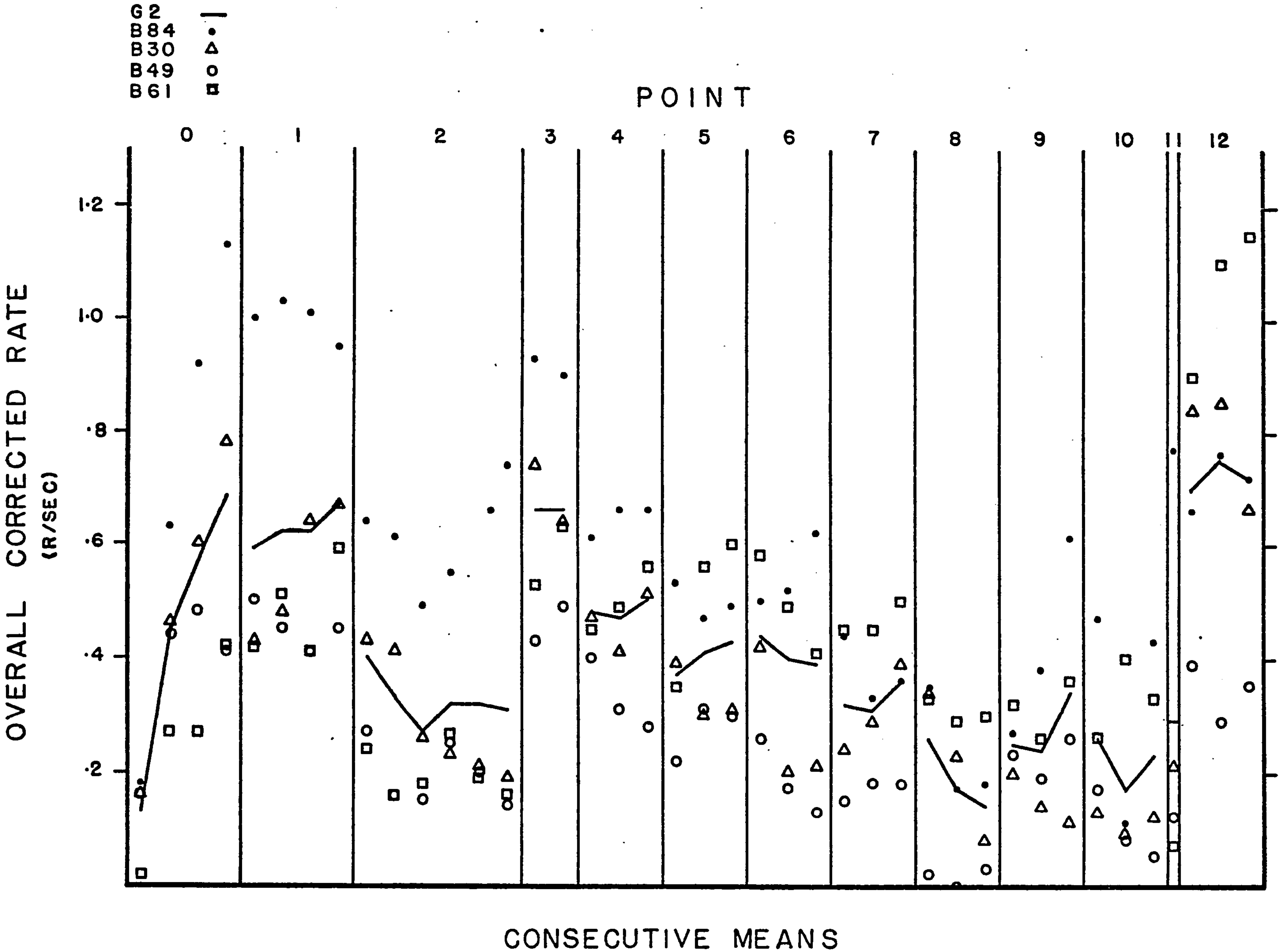

G2
B84
B30
B49
B61
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
1·2
1·0
·8
·6
·4
·2
OVERALL CORRECTED RATE
(R/SEC)
CONSECUTIVE MEANS

Figure 19. Overall corrected rate of responding (R/sec) for Group 3 and its individual subjects. Presented are consecutive five-session means for each individual and the group. For points consisting of less than five sessions, the means are of the sessions presented. Conditions obtaining at each point may be found in Table 3.

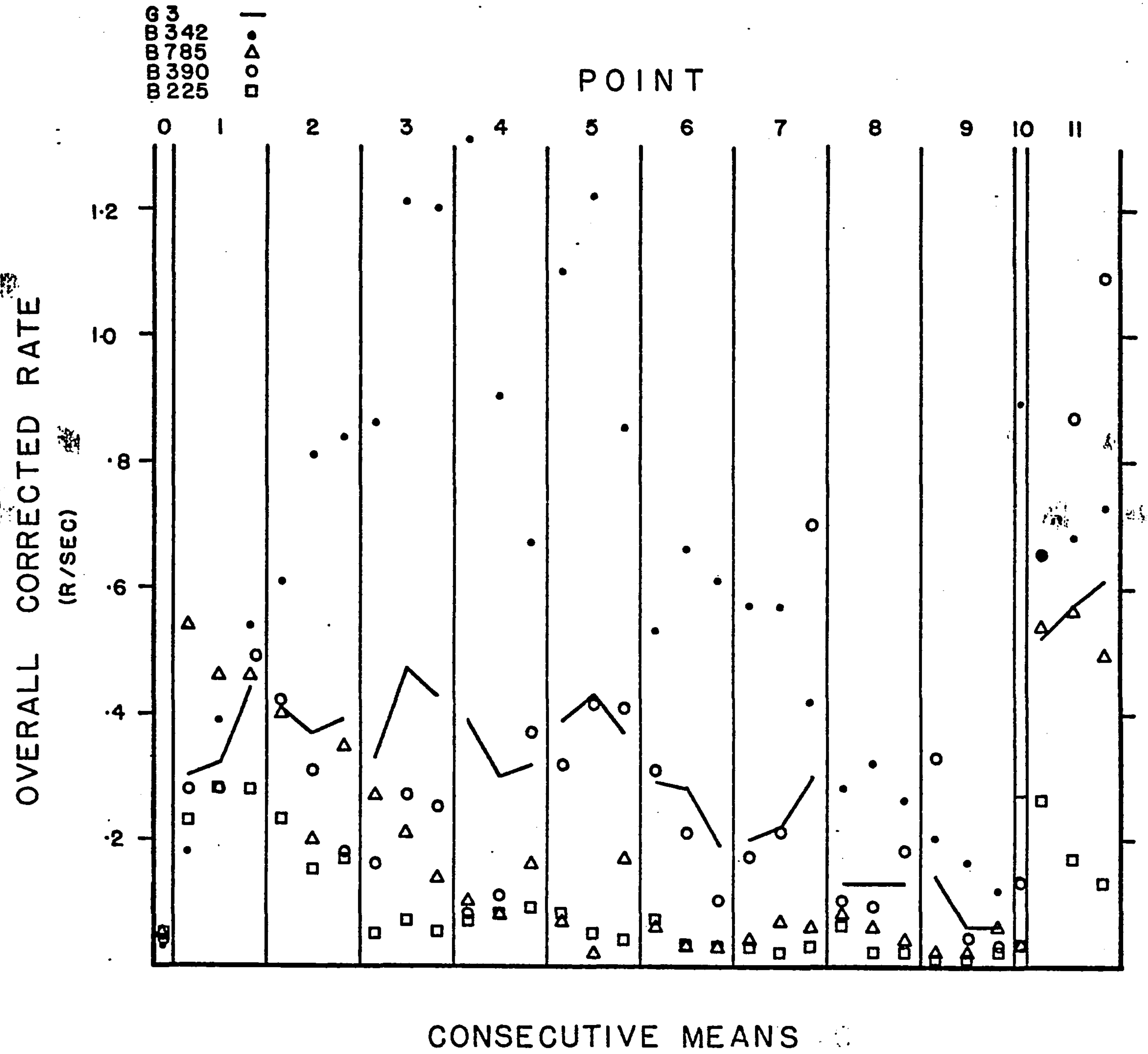
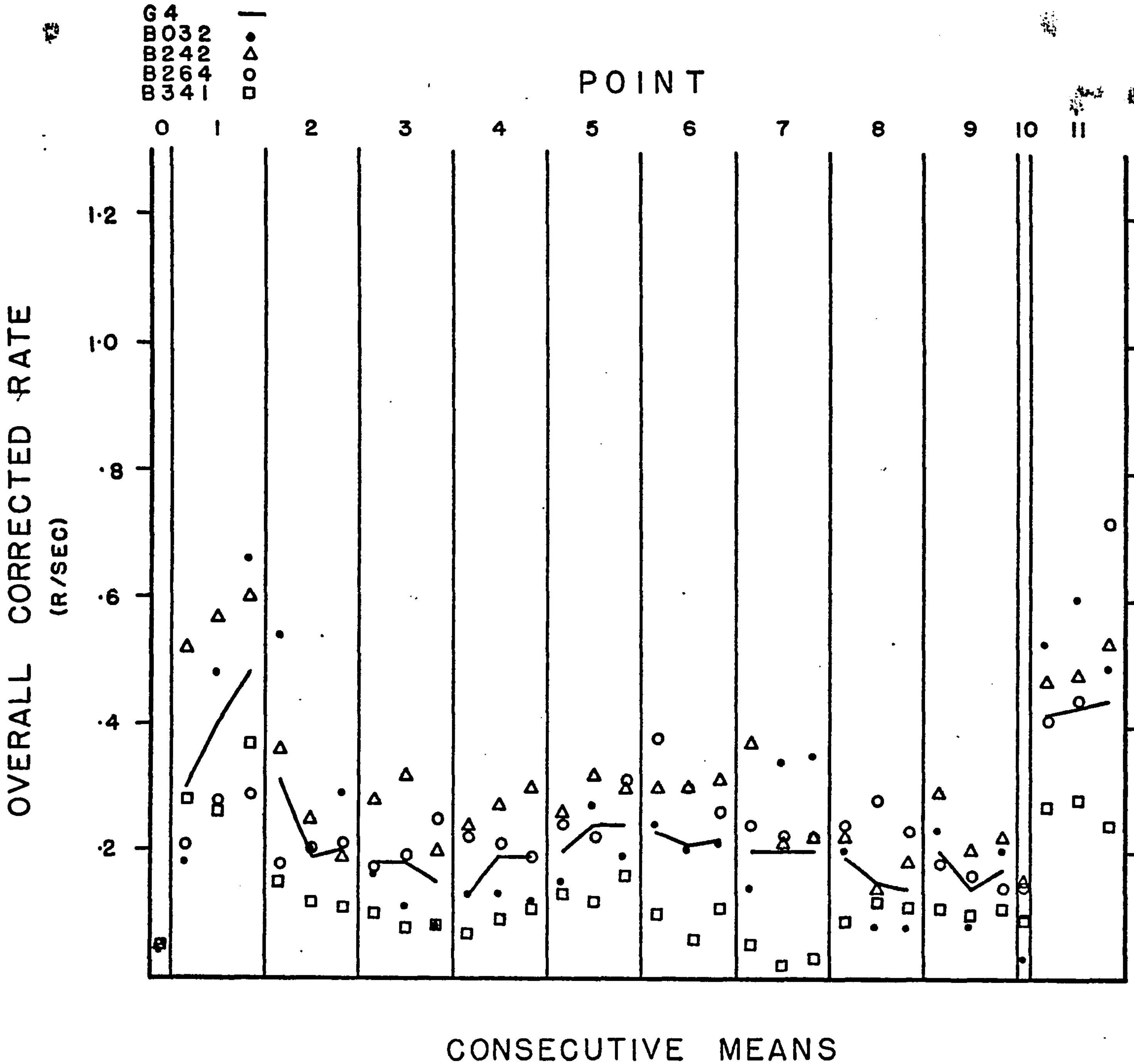

G 3
B 342
B 785
B 390
B 225
POINT
0 1 2 3 4 5 6 7 8 9 10 11
OVERALL CORRECTED RATE
(R/SEC)
1·2
1·0
·8
·6
·4
·2
CONSECUTIVE MEANS

Figure 20. Overall corrected rate of responding (R/sec) for Group 4 and its individual subjects. Presented are consecutive five-session means for each individual and the group. For points consisting of less than five sessions, the means are of the sessions presented. Conditions obtaining at each point may be found in Table 4.



G4 —
B032 •
B242 △
B264 o
B341 □
POINT
0 1 2 3 4 5 6 7 8 9 10 11
OVERALL CORRECTED RATE
(R/SEC)
1·2
1·0
·8
·6
·4
·2
CONSECUTIVE MEANS

response rates of a single individual, B342. For the other groups, the group means are quite representative of individual performances.

The local corrected response rates (R/min) for each group are presented in Table 5. Except for Point 1 for Groups 1 and 2, these data are averages across all the sessions of a point. Because of the lack of PS^RP data per subinterval for the first three sessions of Point 1 for these two groups, averages of the last 17 sessions are presented so that comparisons might be made with the running rates per subinterval, later to be presented. In general, the lowest response rates are observed in the subinterval immediately following reinforcement and the highest response rates in the first subinterval immediately prior to reinforcement. Notable exceptions are Points 4, 5, and 6 for Group 3. For Points 4 and 5, the peak response rate was in the fourth subinterval prior to reinforcement. For Point 6, the peak occurred in the sixth subinterval prior to reinforcement. In this case the shifts in locus of peak responding was not due to abnormal responding by one or two subjects; all subjects of this group demonstrated the same phenomenon.

One other point of interest concerning Table 5 is that when a reinforcement could occur within a subinterval, as for D_{mx}s of 0, 1, 2, or 4 seconds, rather than at the end of a subinterval, the response rate was generally intermediate between the highest and the lowest response rates. When D_{mx}

Table 5

Corrected Rate (R/Min)

Point	T-cycle Subinterval 1	2	3	4	5	6	7	8	9	10	Group
1	10	3	7	15	25	36	46	52	57	60	G1
2	33	2	4	8	12	17	21	25	28	31	
3	11	5	9	16	25	37	47	53	57	60	
4	9	4	7	12	19	30	40	49	54	58	
5	11	4	7	10	14	20	29	35	41	44	
6	19	6	9	13	19	26	33	36	39	43	
7	23	5	7	10	12	17	21	26	29	30	
8	26	9	8	10	13	17	20	23	24	24	
9	18	18	6	6	7	9	12	14	15	17	
10	7	7	8	8	3	4	4	5	5	6	
11	4	3	4	4	4	4	4	4	2	3	
12	32	8	8	9	10	11	10	10	11	10	
13	12	8	12	18	26	36	45	53	58	61	
1	10	4	10	21	33	44	54	61	66	70	G2
2	38	1	2	6	11	17	23	28	32	36	
3	10	4	10	19	32	46	59	67	73	77	
4	13	2	5	11	20	31	41	50	56	60	
5	18	1	4	10	17	26	35	40	44	47	
6	31	2	2	5	11	20	30	38	42	45	
7	36	2	2	5	9	17	24	31	36	36	
8	19	18	2	3	5	8	11	14	17	18	
9	22	24	27	28	5	6	9	12	16	19	
10	11	12	13	15	15	16	17	18	8	9	
11	40	15	12	14	12	13	16	16	18	18	
12	12	7	14	26	38	50	61	70	75	80	
1	9	6	12	17	20	25	28	31	32	33	G3
2	37	3	7	13	21	26	30	32	34	36	
3	35	36	5	10	14	23	29	31	33	34	
4	29	27	26	25	1	5	14	21	26	29	
5	14	24	31	35	35	33	31	29	1	6	
6	10	14	17	19	18	18	17	16	3	5	
7	12	16	18	18	17	17	17	17	5	8	
8	8	8	9	9	9	8	9	8	4	5	
9	5	6	5	6	6	6	6	5	3	4	
10	49	12	12	14	14	12	14	14	12	13	
11	12	11	17	25	32	38	48	51	53	56	
1	11	9	15	20	25	28	31	32	33	33	G4
2	22	2	6	8	12	14	17	19	20	21	
3	15	3	4	7	9	11	12	12	14	15	
4	15	3	3	5	8	10	12	13	14	14	
5	21	3	5	9	11	15	17	19	18	19	
6	18	7	8	10	13	14	16	16	16	16	
7	16	16	6	8	10	11	12	13	15	14	
8	12	11	11	11	7	8	8	10	10	10	
9	10	9	10	11	11	11	11	12	7	8	
10	45	3	1	2	2	3	2	1	1	1	
11	15	9	13	18	24	29	35	38	40	40	

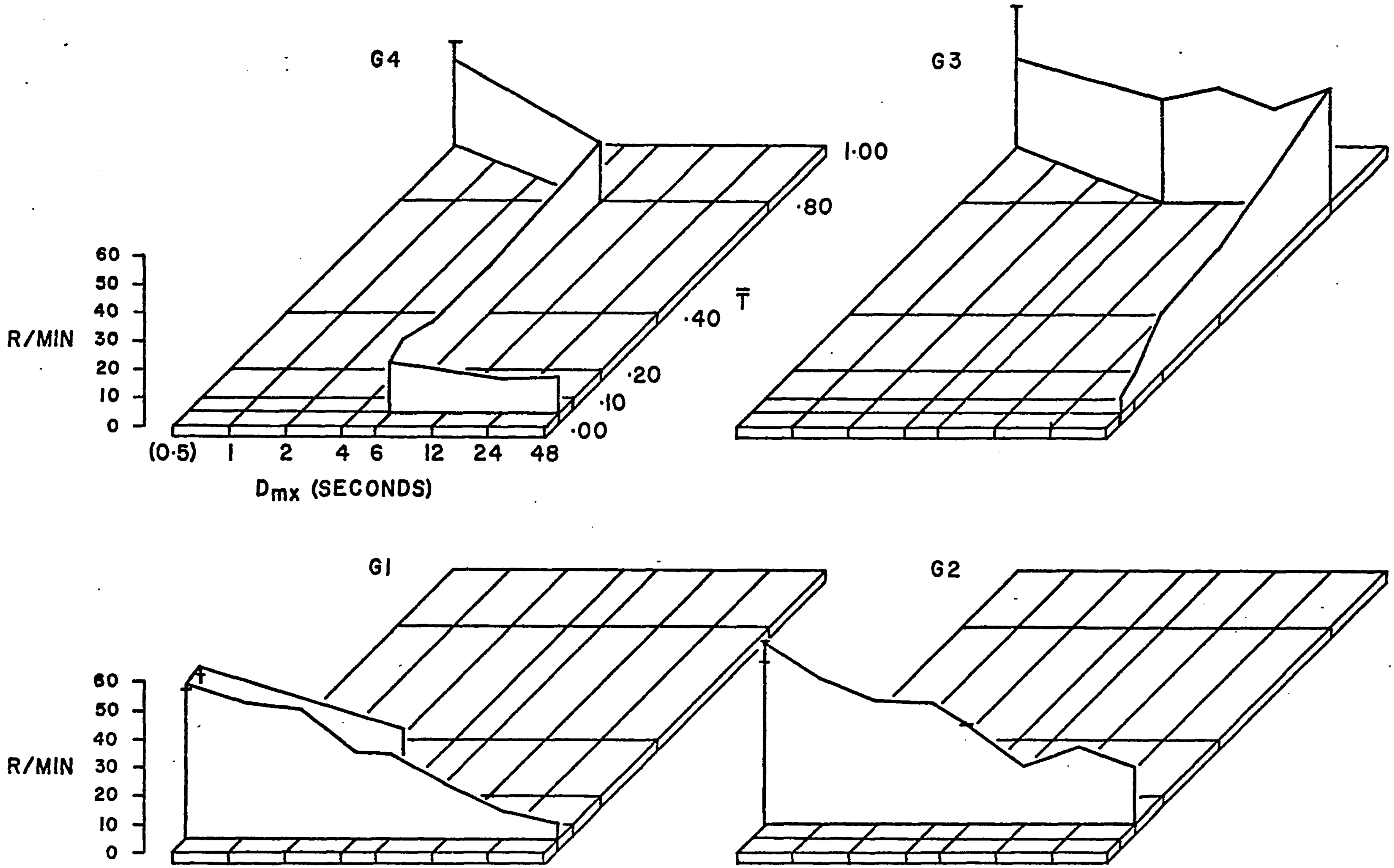
was 0 seconds, the response rate was depressed the most; when D_{mx} was 4 seconds, the response rate was the least depressed.

The running rates of responding (R/min) for each group are shown in Figure 21. The forms are the same as for the overall corrected rates. The overall levels however average 76% higher than the corrected rates for Group 1, 70% higher for Group 2, 50% higher for Group 3 and 41% higher for Group 4. Figures 22 through 25 present the running rates (R/sec) per consecutive session for each of the four groups. Figures 26 through 29 present consecutive five-session means for each of the groups and the individuals of each group. Group 1's running rates of responding go from 70% higher than the corrected rate at Point 1 to 40% higher at Point 11 ($0.05\overline{T}$, $48''D_{mx}$), peaking at 122% higher at Point 6 ($0.05\overline{T}$, $2''D_{mx}$). The running rate at the last point, Point 13 (matrix value ($0.05\overline{T}$, $0''D_{mx}$)), was again higher than the corrected rate by 61%.

Group 2's running rates of responding go from 55% higher than the corrected rate at Point 1 to 55% higher at Point 10 ($0.10\overline{T}$, $48''D_{mx}$), peaking at 91% higher at Point 7 (matrix value ($0.10\overline{T}$, $6''D_{mx}$)). The running rate at the last point, Point 12, was only 48% higher than the corrected rate at that point. Except for the shaping sessions, which were not used in computing the average increases, this was the lowest increase for any point for this group.

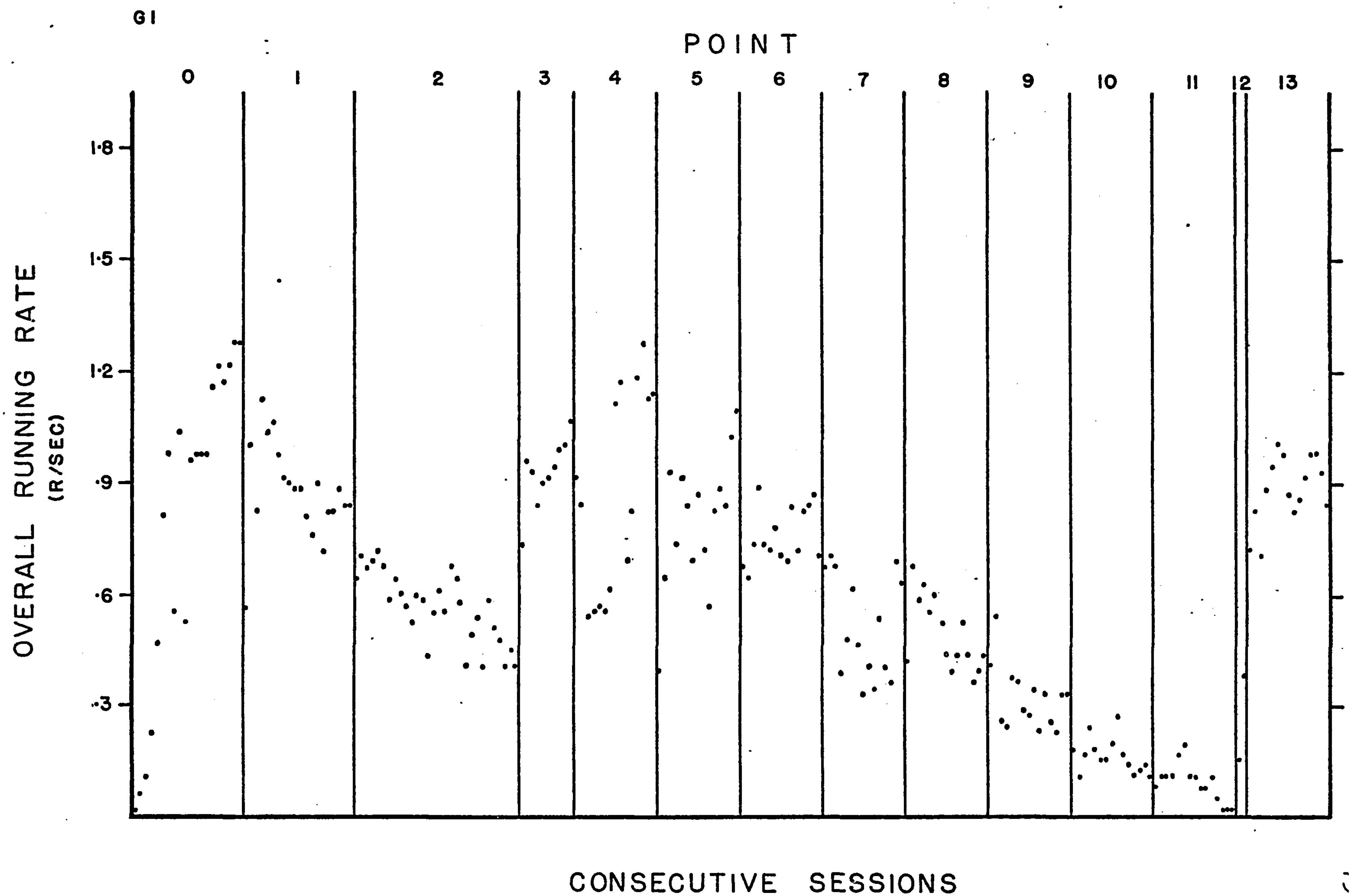
Group 3's running rates went from 42% higher than the

Figure 21. Running rates of responding (R/min) as a function of schedule value for each group of subjects. Data are the averages of all the sessions for each experimental point for each group. Data values for schedules which were presented multiple times are shown as short horizontal lines for all but one of the repeated schedules. Shown as short horizontal lines are Points 1 and 13 for Group 1, Points 1, 2 and 12 for Group 2, Point 11 for Group 3, and Point 11 for Group 4. Data values for the remaining repeated schedules are shown connected to the data values of the unrepeated schedules. Note that D_{mx} is on a logarithmic scale.



G4
G3
G1
G2
R/MIN
60
50
40
30
20
10
0
(0·5)
1
2
4
6
12
24
48
Dmx (SECONDS)
1·00
·80
·40
·20
·10
·00
T̄

Figure 22. Overall running rate of responding (R/sec) per session for Group 1. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 1.



GI
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
13
OVERALL RUNNING RATE
(R/SEC)
1·8
1·5
1·2
·9
·6
·3
CONSECUTIVE SESSIONS

Figure 23. Overall running rate of responding (R/sec) per session for Group 2. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 2.

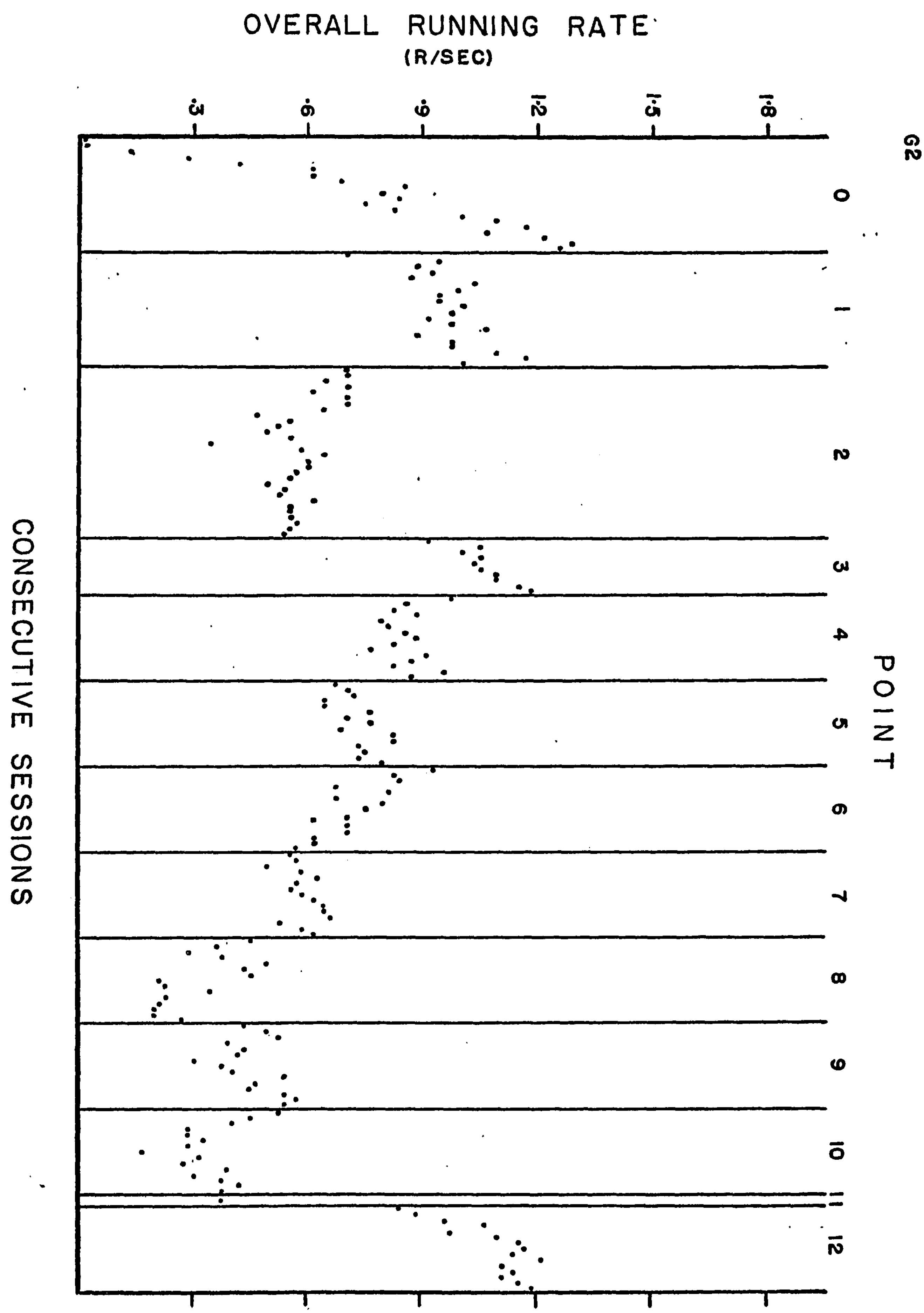

G2
OVERALL RUNNING RATE
(R/SEC)
·3
·6
·9
1·2
1·5
1·8
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
CONSECUTIVE SESSIONS

Figure 24. Overall running rate of responding (R/sec) per session for Group 3. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 3.

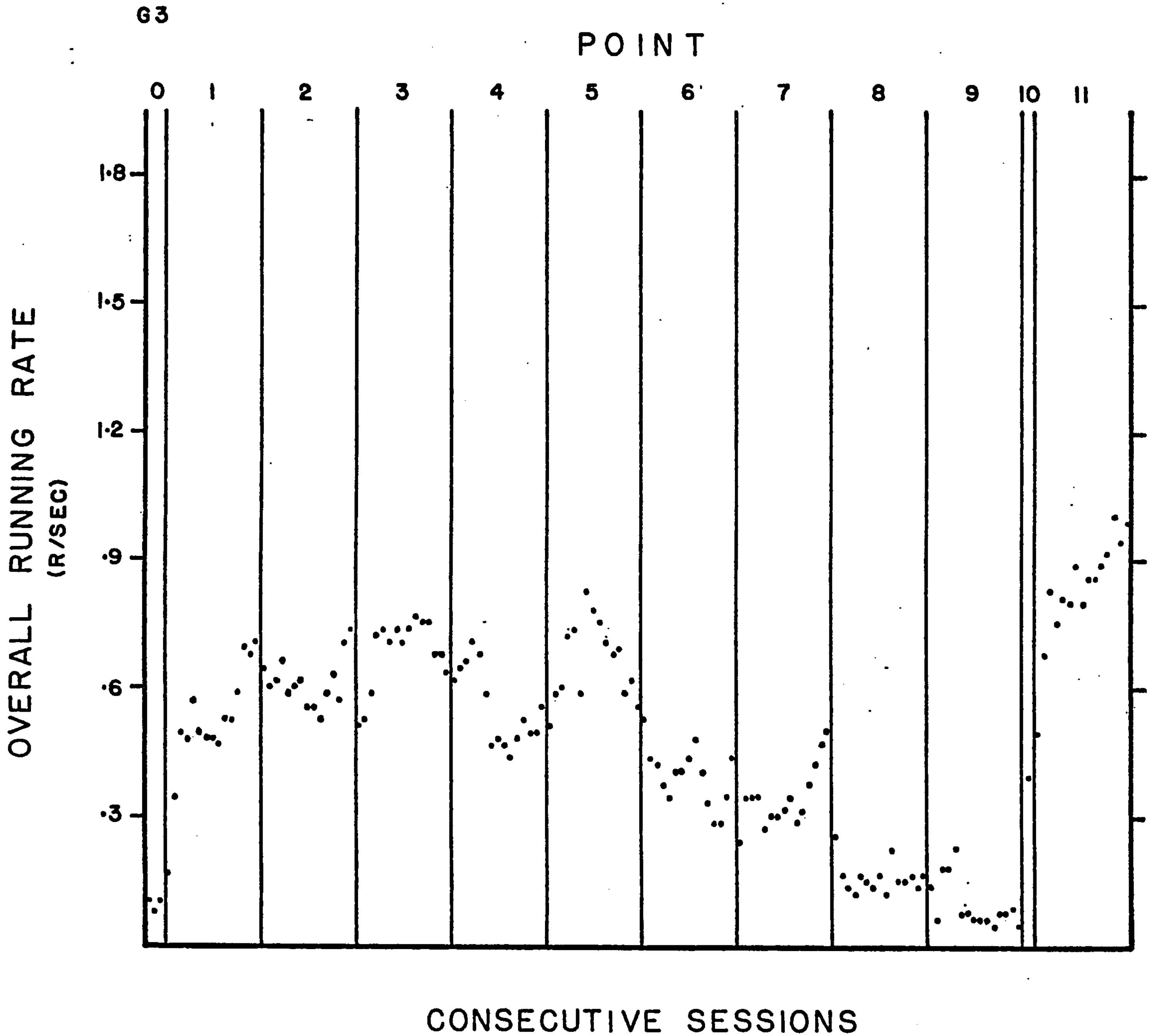

G3
POINT
0 1 2 3 4 5 6 7 8 9 10 11
1·8
1·5
1·2
·9
·6
·3
OVERALL RUNNING RATE
(R/SEC)
CONSECUTIVE SESSIONS

Figure 25. Overall running rate of responding (R/sec) per session for Group 4. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 4.

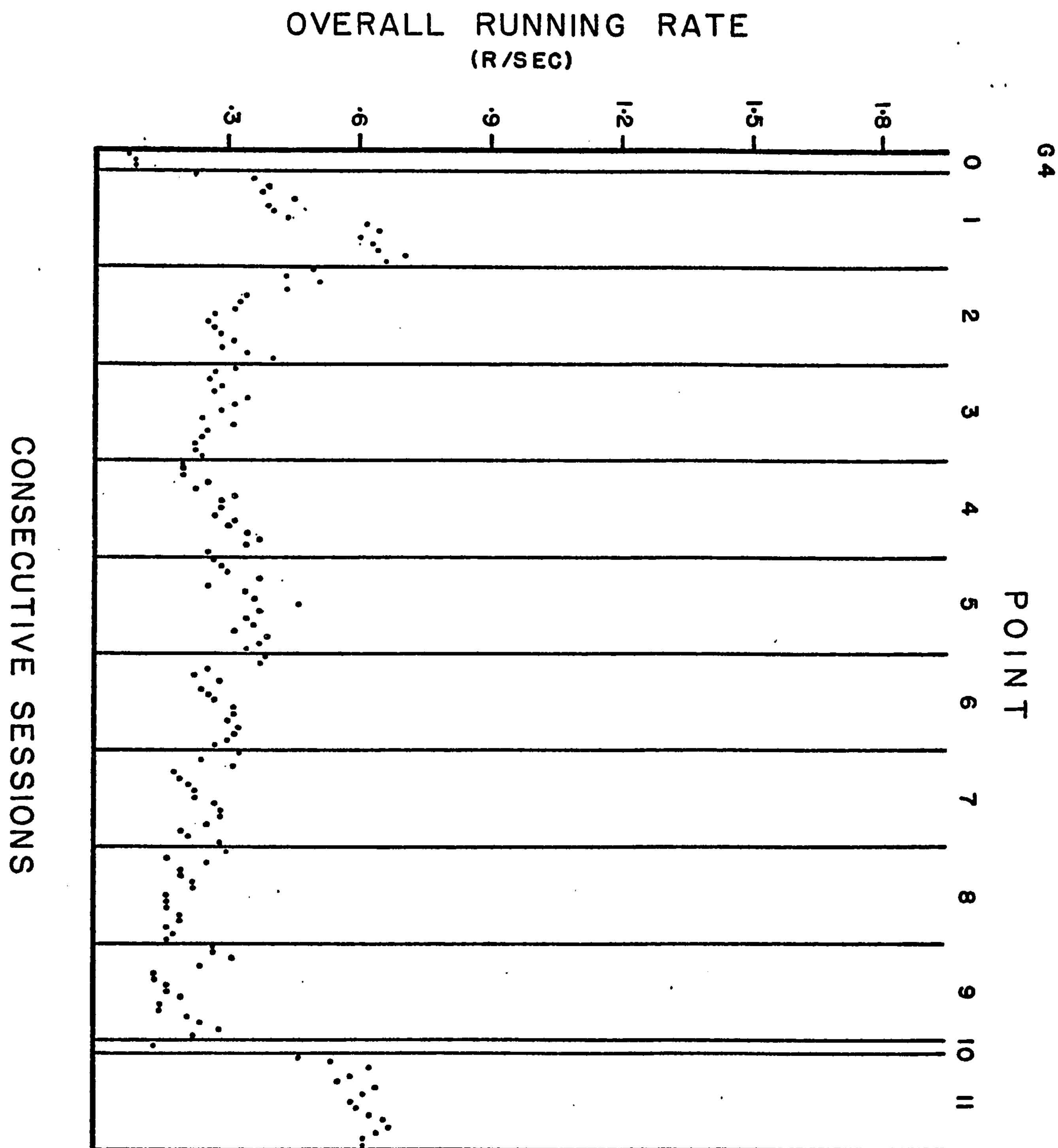
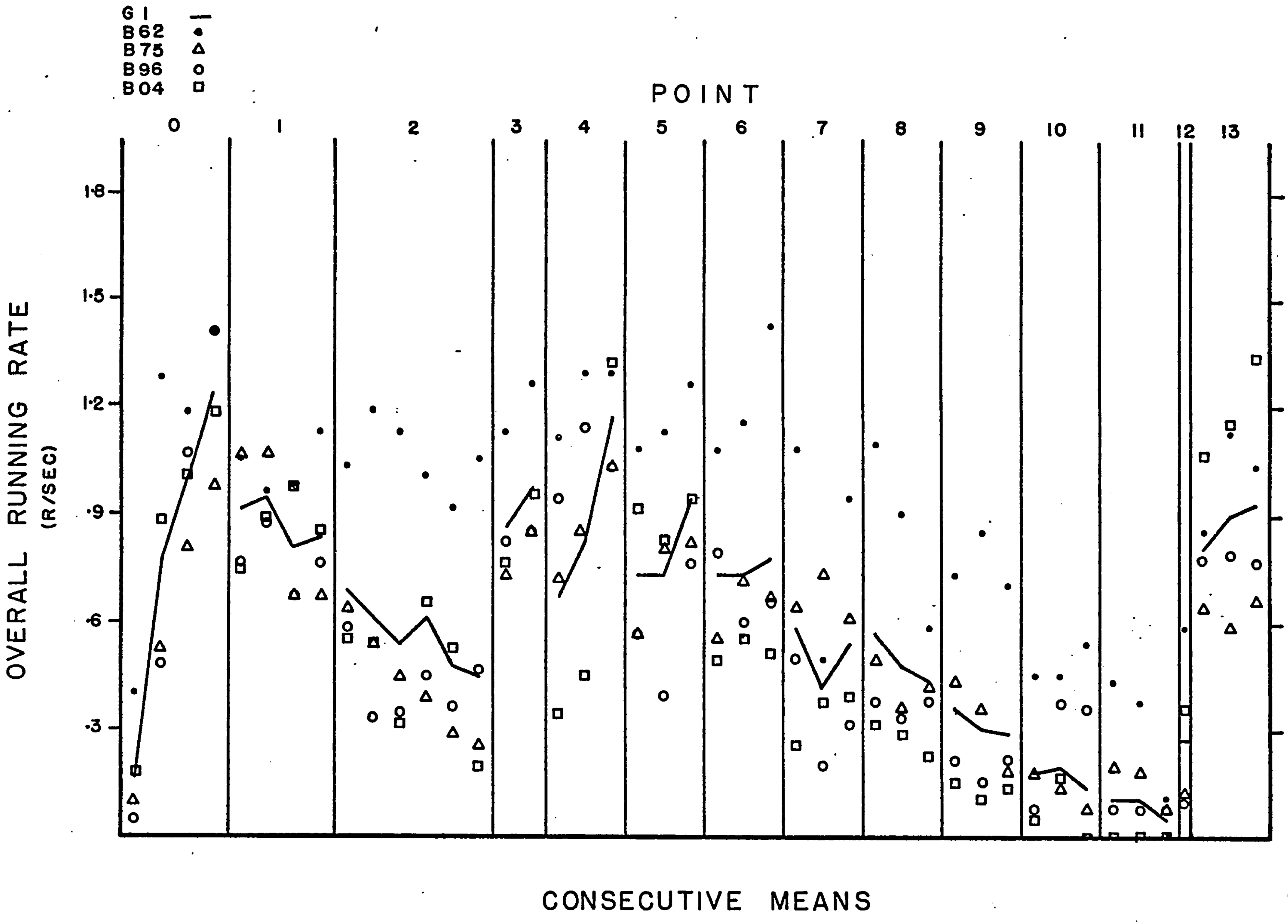
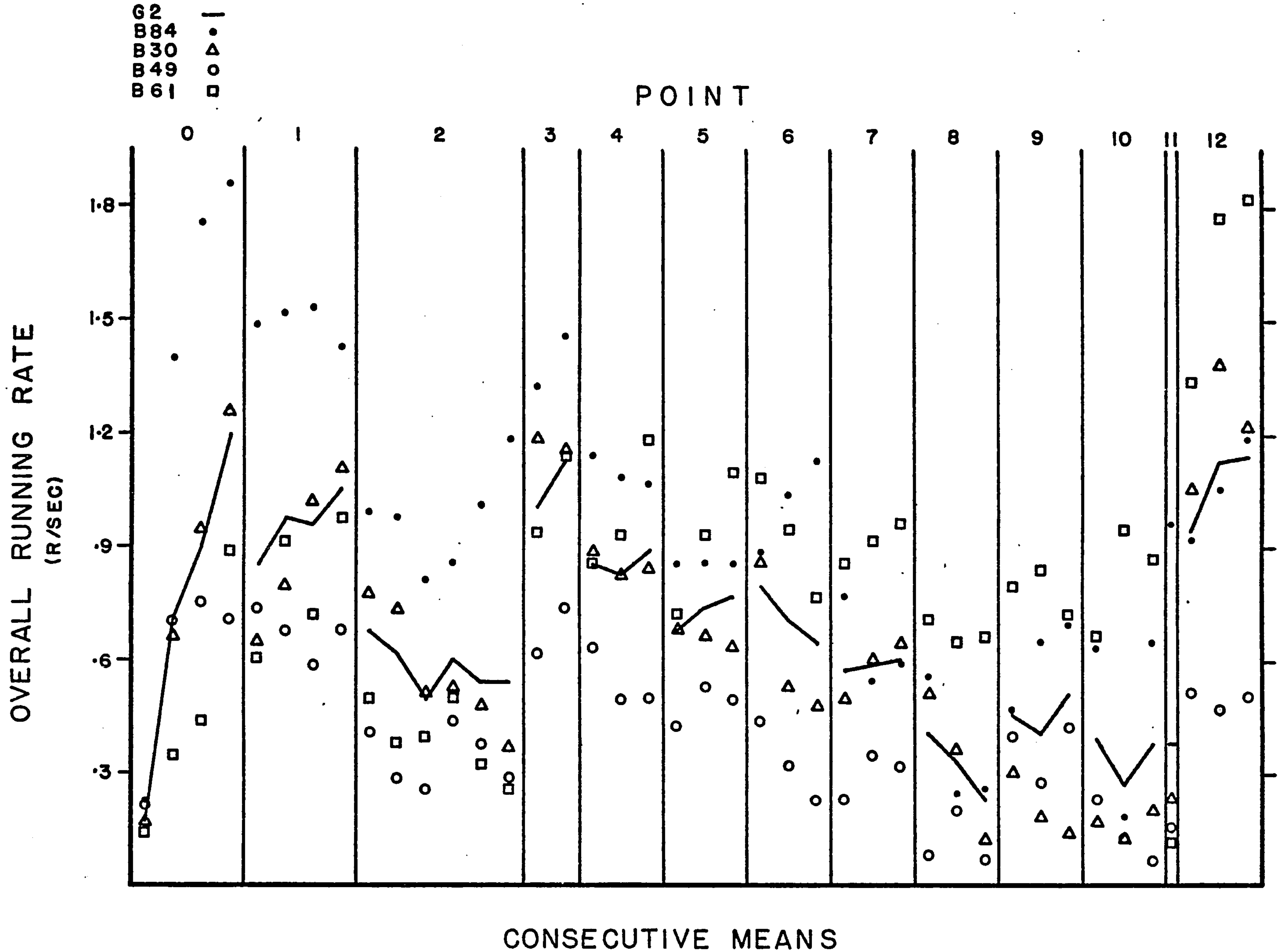

G4
OVERALL RUNNING RATE
(R/SEC)
·3
·6
·9
1·2
1·5
1·8
POINT
0
1
2
3
4
5
6
7
8
9
10
11
CONSECUTIVE SESSIONS

Figure 26. Overall running rates of responding (R/sec) for Group 1 and its individual subjects. Presented are consecutive five-session means. For points consisting of less than five sessions, the means are of the sessions actually presented. Conditions obtaining at each point may be found in Table 1.



G1
B62
B75
B96
B04
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
13
1·8
1·5
1·2
·9
·6
·3
OVERALL RUNNING RATE
(R/SEC)
CONSECUTIVE MEANS

Figure 27. Overall running rates of responding (R/sec) for Group 2 and its individual subjects. Presented are consecutive five-session means. For points consisting of less than five sessions, the means are of the sessions actually presented. Conditions obtaining at each point may be found in Table 2.



G2
B84
B30
B49
B61
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
1·8
1·5
1·2
·9
·6
·3
OVERALL RUNNING RATE
(R/SEC)
CONSECUTIVE MEANS

Figure 28. Overall running rates of responding (R/sec) for Group 3 and its individual subjects. Presented are consecutive five-session means. For points consisting of less than five sessions, the means are of the sessions actually presented. Conditions obtaining at each point may be found in Table 3.

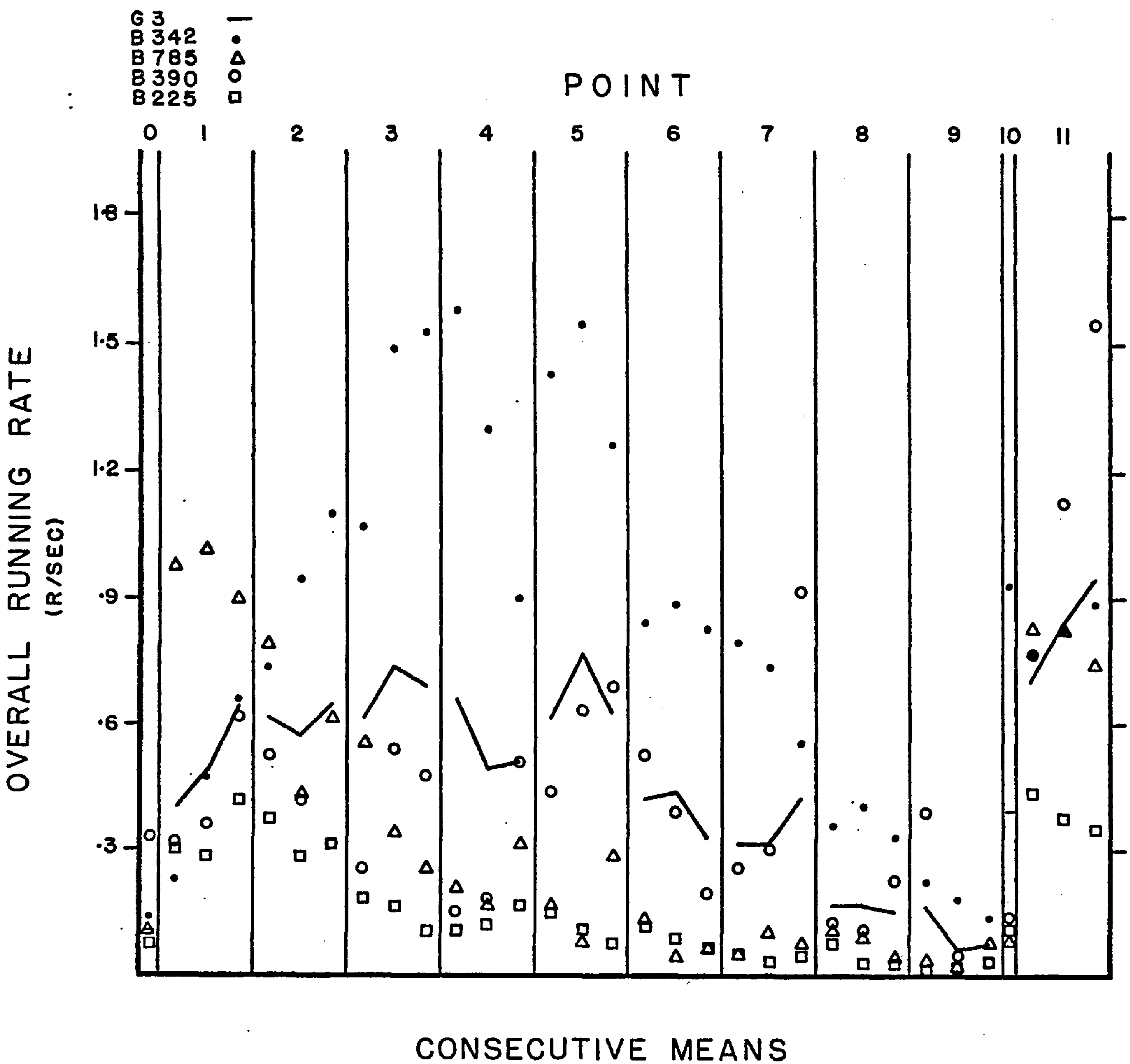
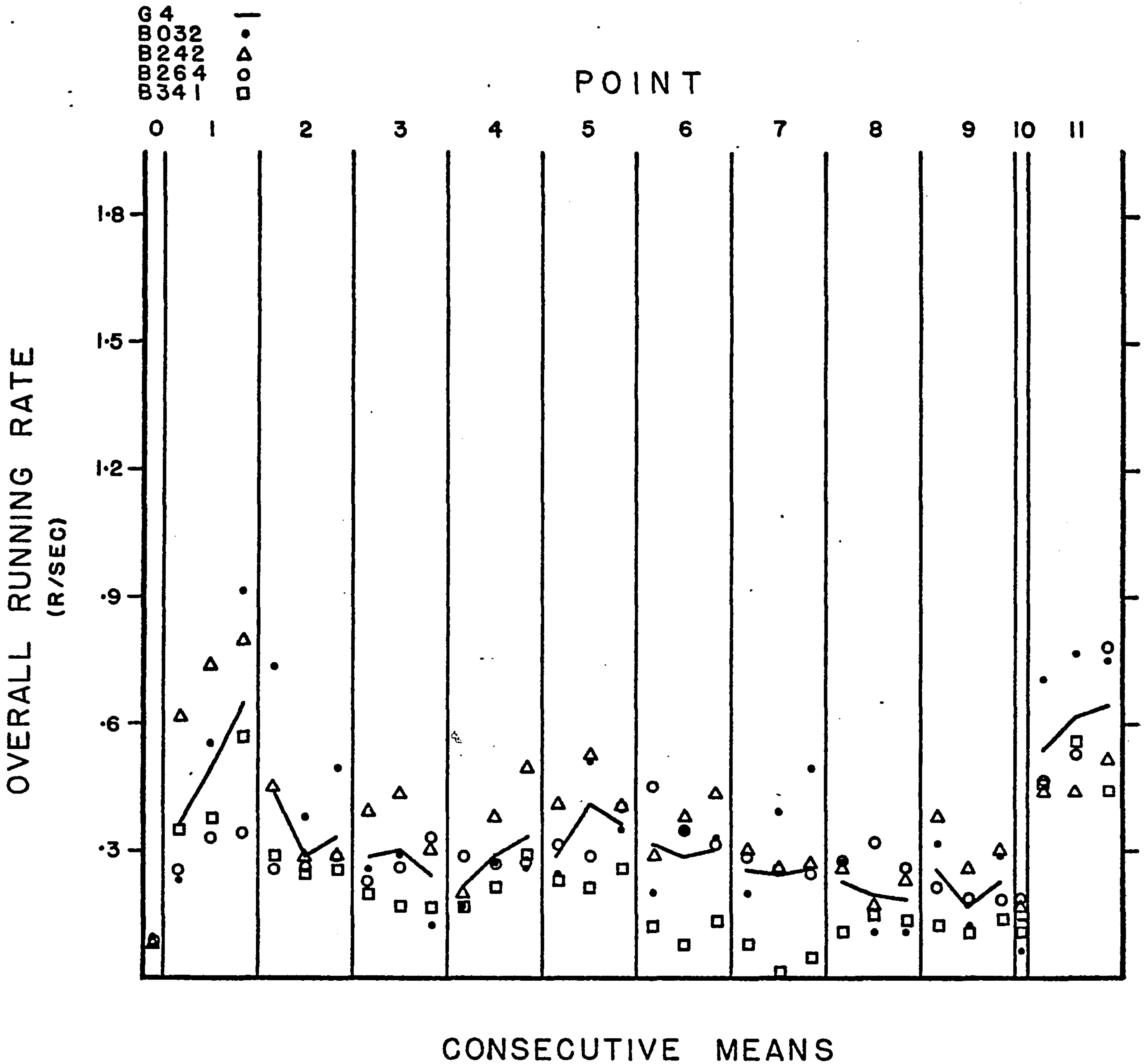

G 3
B 342
B 785
B 390
B 225
POINT
0 1 2 3 4 5 6 7 8 9 10 11
1·8
1·5
1·2
·9
·6
·3
OVERALL RUNNING RATE (R/SEC)
CONSECUTIVE MEANS

Figure 29. Overall running rates of responding (R/sec) for Group 4 and its individual subjects. Presented are consecutive five-session means. For points consisting of less than five sessions, the means are of the sessions actually presented. Conditions obtaining at each point may be found in Table 4.


G4
B032
B242
B264
B341
POINT
0 1 2 3 4 5 6 7 8 9 10 11
1·8
1·5
1·2
·9
·6
·3
OVERALL RUNNING RATE
(R/SEC)
CONSECUTIVE MEANS

corrected response rates at Point 1 (matrix value (1.00$\overline{T}$, 0"D_{mx})) to 13% higher at Point 9 (0.05$\overline{T}$, 48"D_{mx}). Group 4's running rates went from 28% higher than the corrected rates at Point 1 to 26% higher at Point 9. Group 3 peaked at Point 6 (matrix value (0.40$\overline{T}$, 48"D_{mx})) with a 76% rate increase, while Group 4 peaked at Point 4 (matrix value (0.20$\overline{T}$, 6"D_{mx})) with a 72% rate increase.

The running rates of Group 3 do not show the periodicity apparent for the corrected rates of responding by this same group. This indicates that the periodicity in the corrected rates was due primarily to periodicity in the post-reinforcement pause times.

Table 6 gives the distributions of running response rates for each point for each group as a function of t-cycle subinterval. As noted for Table 5, these data are averages of all sessions at a point except for Groups 1 and 2 at Point 1. These data clearly indicate that variability in the PS^RPs accounts for the major part of the positive acceleration in the average response rates per subinterval following reinforcement. However, some acceleration still remains, indicating that the first IRTs after reinforcement are on the average somewhat longer than later IRTs.

While some resemblance exists between the segments of cumulative response records following reinforcers and the patterns of mean response rates as a function of t-cycle subinterval, the mean response rates are not truly representative of the cumulative response records. As the rate of reinforcement

Table 6

Running Rate (R/Min)

Point	T-cycle Subinterval 1	2	3	4	5	6	7	8	9	10	Group
1	76	25	31	39	44	49	53	57	60	63	G1
2	37	17	23	29	32	33	34	35	36	36	
3	77	38	40	44	47	51	56	59	61	63	
4	64	33	34	39	44	49	55	60	62	64	
5	44	29	38	42	44	45	48	51	54	54	
6	45	32	40	43	44	45	46	45	46	48	
7	35	20	23	27	27	29	31	35	36	36	
8	31	27	25	27	29	30	30	31	30	30	
9	22	22	14	13	15	17	19	21	20	21	
10	11	11	12	11	7	8	8	9	9	10	
11	5	5	5	5	5	6	6	6	4	4	
12	80	11	10	11	12	14	12	12	13	12	
13	61	30	34	38	44	49	54	59	62	64	
1	94	31	35	40	47	52	60	65	69	73	G2
2	40	18	21	26	29	31	34	35	37	39	
3	99	32	37	42	49	56	64	70	75	78	
4	63	34	36	37	41	44	48	54	58	61	
5	50	29	33	36	38	40	44	45	46	48	
6	45	24	28	33	36	40	43	45	46	46	
7	37	17	21	24	29	34	35	37	39	38	
8	23	21	12	13	16	19	20	21	22	22	
9	28	28	30	32	21	23	24	24	26	27	
10	20	20	20	21	21	21	22	22	18	20	
11	97	21	15	17	15	16	18	19	21	21	
12	96	35	40	48	52	58	65	72	76	80	
1	36	25	25	26	27	30	32	33	34	35	G3
2	38	35	37	38	38	37	36	36	36	37	
3	39	38	22	34	45	47	47	43	41	39	
4	35	31	29	27	19	26	35	38	41	40	
5	43	48	48	46	42	38	35	32	41	40	
6	25	28	29	29	25	23	21	19	14	18	
7	20	24	25	23	21	21	20	19	13	16	
8	11	10	10	11	10	9	9	9	7	8	
9	6	6	6	6	6	6	6	6	4	5	
10	106	18	18	20	19	16	19	18	16	17	
11	63	42	38	41	43	45	53	54	55	57	
1	40	26	23	25	28	30	31	32	33	33	G4
2	22	24	24	20	20	20	21	21	22	22	
3	16	12	20	20	19	18	16	15	16	16	
4	16	13	19	18	18	18	18	17	16	15	
5	21	18	21	24	22	21	21	21	19	19	
6	18	15	16	18	20	19	19	18	17	16	
7	16	16	11	13	14	15	15	15	16	15	
8	13	12	11	12	11	12	12	12	12	12	
9	15	12	13	14	12	12	12	13	11	12	
10	82	3	2	2	3	3	3	1	2	1	
11	51	27	26	29	32	34	38	39	40	40	

falls below 1.00 per t-cycle, the mean response rates per subinterval become even less like the cumulative response patterns following reinforcement because, while the point at which a reinforcer comes in a t-cycle is relatively constant, both PS^RP time and run time become more evenly distributed among the different subintervals as a larger percentage of the t-cycles contain no reinforcer.

To obtain a curve representative of the individual cumulative response curves one might plot the cumulative responses after reinforcements on the ordinate of a graph as a function of the average times since the previous reinforcement to those ordinal responses.

Unlike the response rates per subinterval for the corrected response rates, the highest running response rates are often found in the subintervals which may contain a reinforcer (i.e., D_{mx} = 0, 1, 2, or 4 seconds). This is especially true when D_{mx} = 0 seconds.

The overall mean post-reinforcement pauses showed a much greater range of values than did any other dependent variable. In order to present these data in a compact form, the reciprocals of the mean PS^RPs, as measured in t-cycle units (i.e., t divided by mean PS^RP), are presented in Figures 30 through 38. In addition, presentation of the reciprocal PS^RPs has the advantage of showing a generally negative slope of values as a function of the schedule vector, similar to those of the other dependent variables already discussed. Figure 30 shows the $T/\overline{PS^RP}$ data

Figure 30. Reciprocals of the mean post-reinforcement pauses as measured in t-cycle units (i.e., $T/\overline{{}_{PS}R_P}$) as a function of the vector value for each group of subjects. Data are the averages of all the sessions for each experimental point for each group. Data values for schedules which were presented multiple times are shown as horizontal lines for all but one of the repeated schedules. Shown as short horizontal lines are Points 1 and 13 for Group 1, Points 1, 2 and 12 for Group 2, Point 11 for Group 3, and Point 11 for Group 4. Note that D_{mx} is on a logarithmic scale.

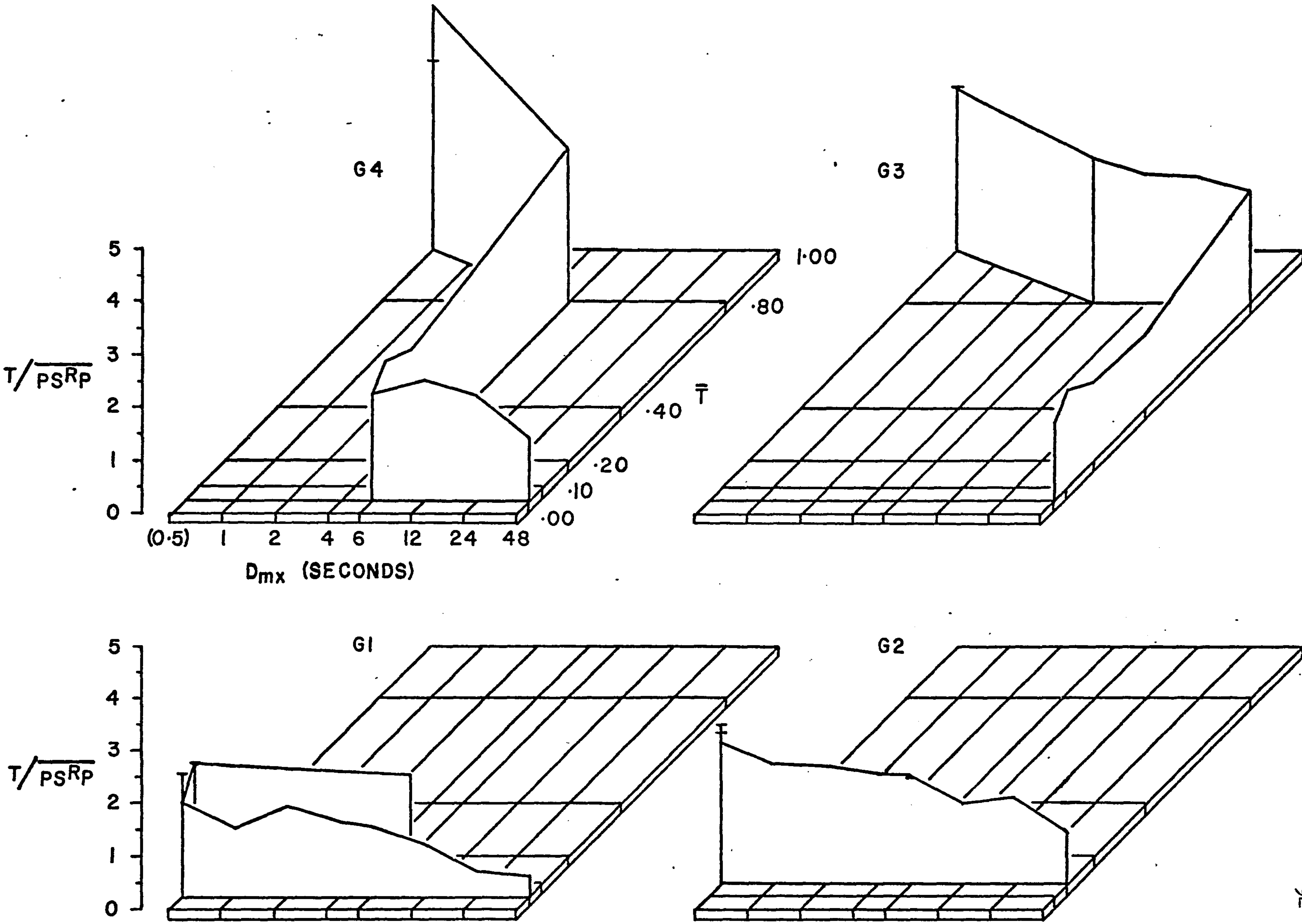
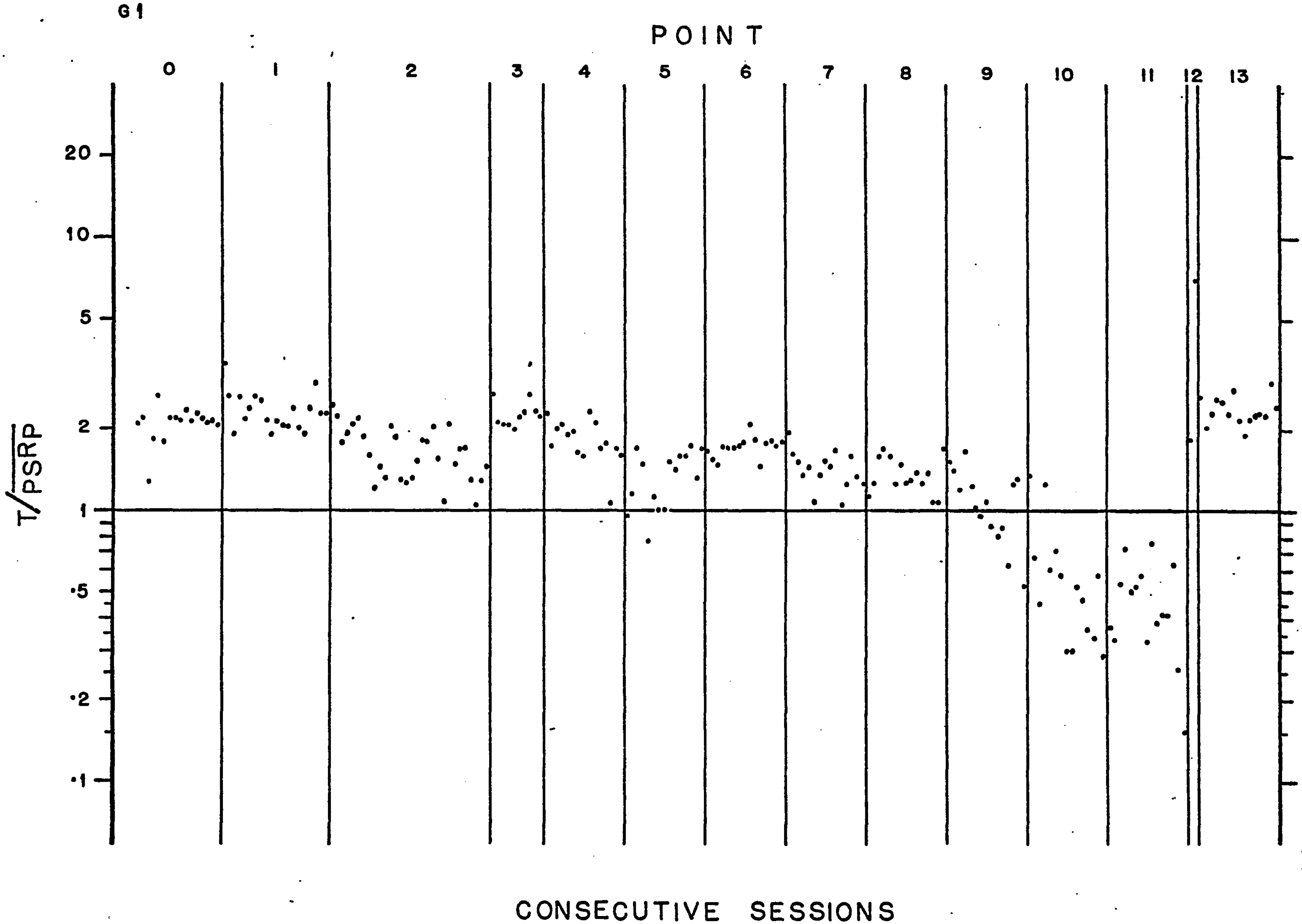

G4
G3
G1
G2
5
4
3
2
1
0
T/PS^Rp
1·00
·80
·40
T̄
·20
·10
·00
(0·5)
1
2
4
6
12
24
48
Dmx (SECONDS)

Figure 31. Reciprocals of the mean post-reinforcement pauses as measured in t-cycle units (i.e., $T/\overline{_{PS}R_{P}}$) per session for Group 1. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 1.



G1
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
13
20
10
5
2
1
·5
·2
·1
T/PSRP
CONSECUTIVE SESSIONS

Figure 32. Reciprocals of the mean post-reinforcement pauses as measured in t-cycle units (i.e., $T/\overline{_{PS}R_{P}}$) per session for Group 2. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 2.

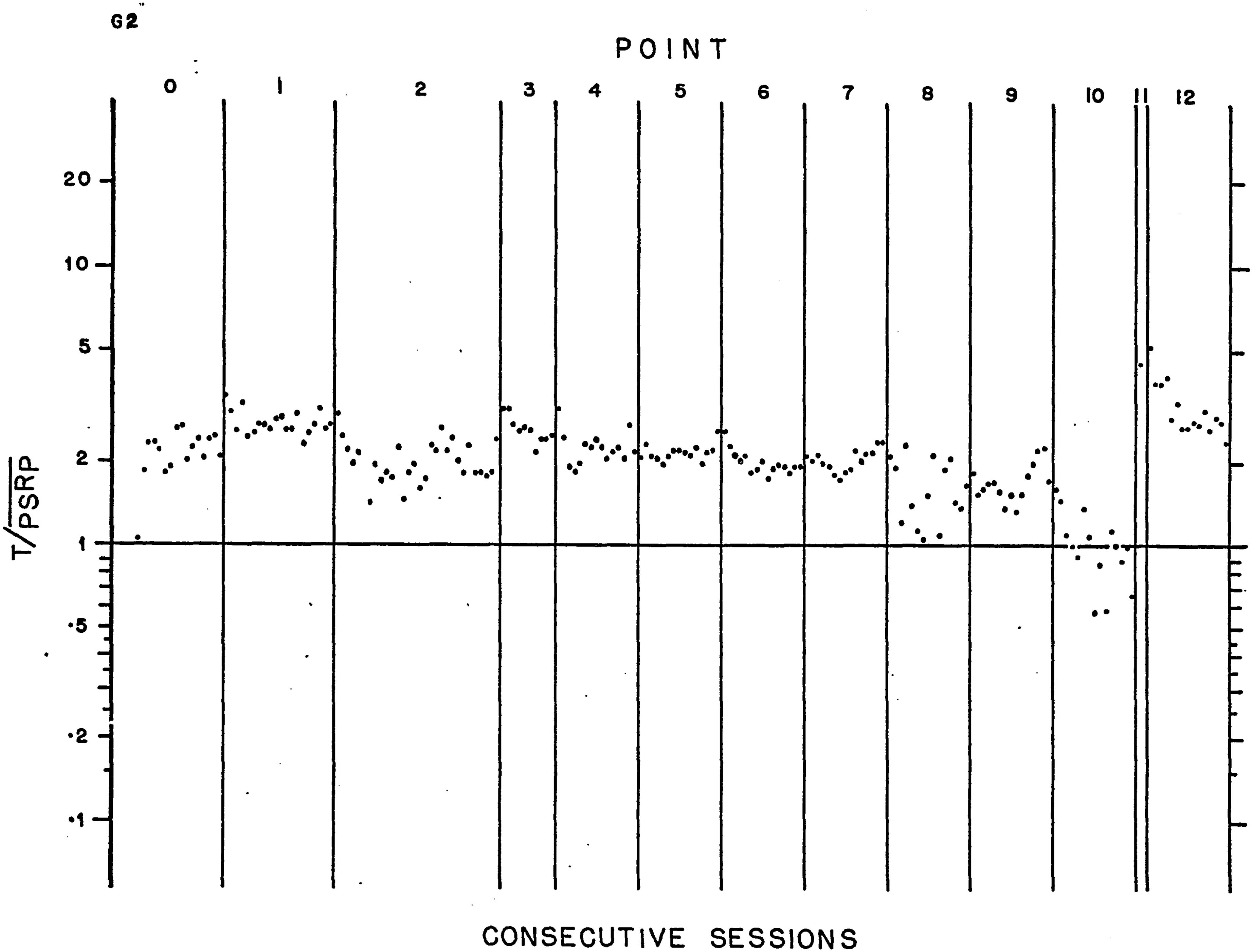
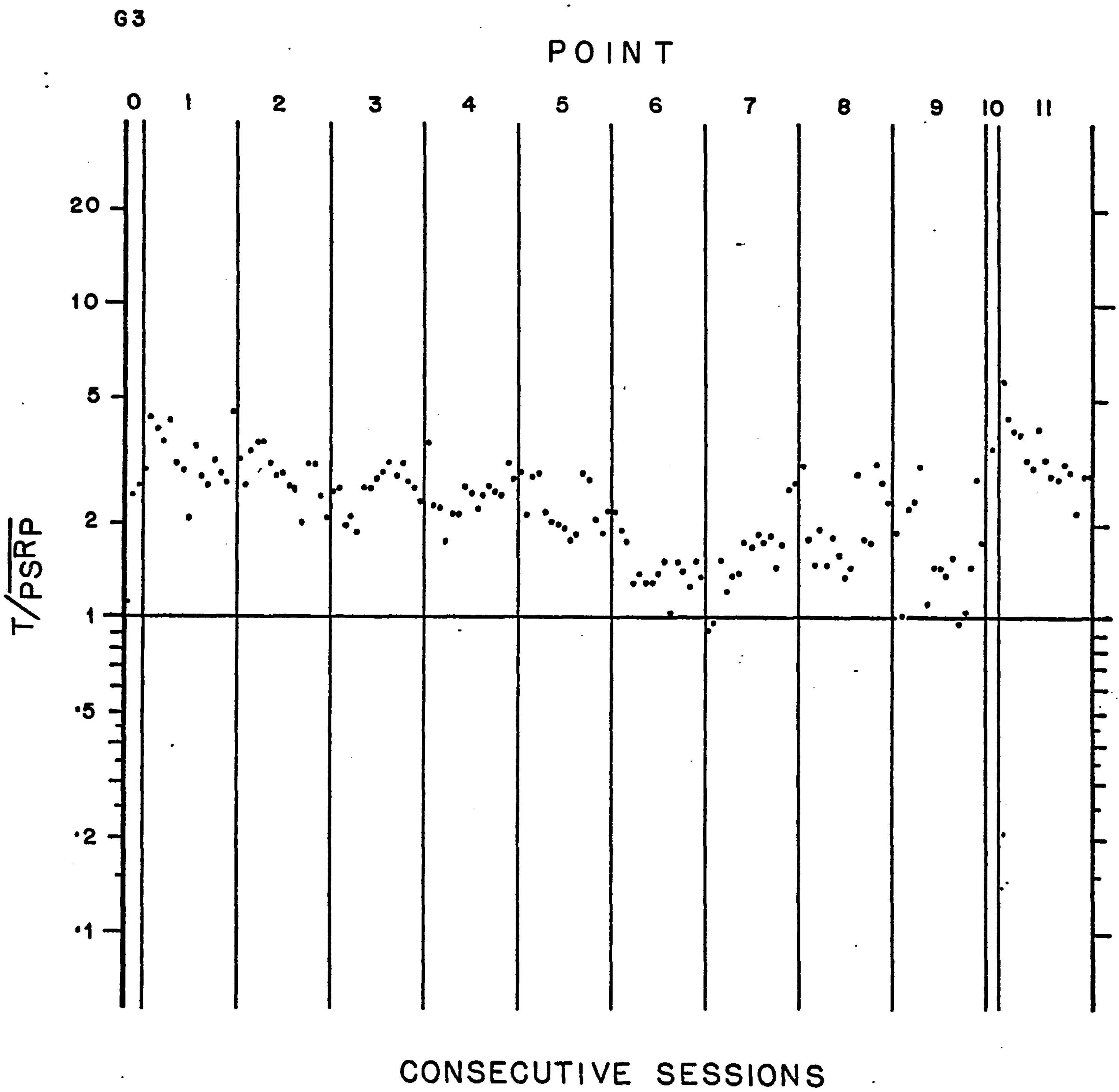

G2
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
20
10
5
2
1
·5
·2
·1
T/PSRP
CONSECUTIVE SESSIONS

Figure 33. Reciprocals of the mean post-reinforcement pauses as measured in t-cycle units (i.e., T/ $\overline{_{PS}R_P}$) per session for Group 3. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 3.



G3
POINT
0
1
2
3
4
5
6
7
8
9
10
11
20
10
5
2
1
·5
·2
·1
T/PSRP
CONSECUTIVE SESSIONS

Figure 34. Reciprocals of the mean post-reinforcement pauses as measured in t-cycle units (i.e., T/ $\overline{_{PS}R_P}$) per session for Group 4. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 4.

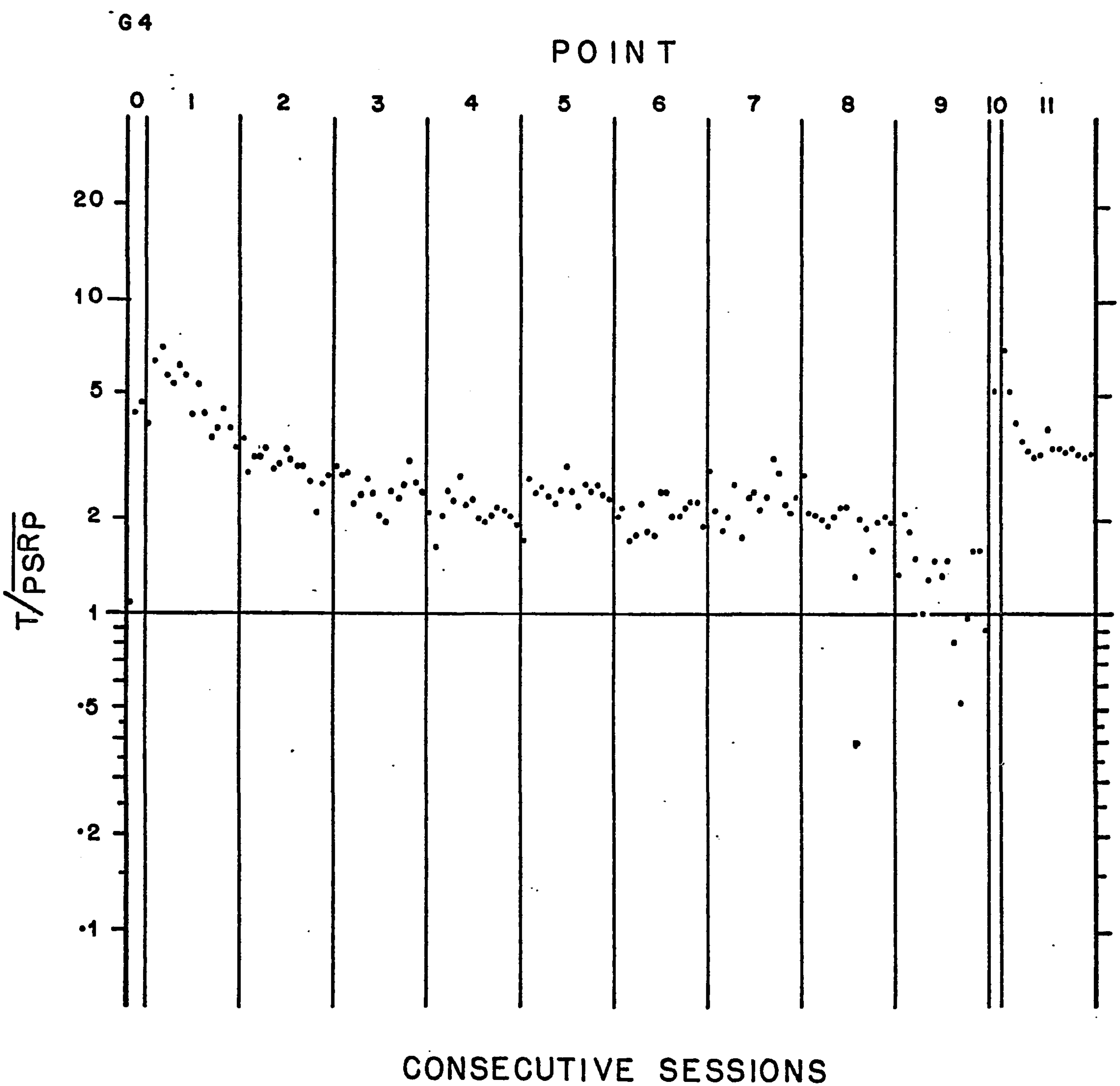

G4
POINT
0
1
2
3
4
5
6
7
8
9
10
11
20
10
5
2
1
·5
·2
·1
T/PSRP
CONSECUTIVE SESSIONS

Figure 35. Reciprocals of the mean post-reinforcement pauses as measured in t-cycle units (i.e., $T/\overline{_{PS}R_P}$) for each individual of Group 1. Presented are consecutive five-session means. For points consisting of less than five sessions, the means are of the sessions presented. Conditions obtaining at each point may be found in Table 1.

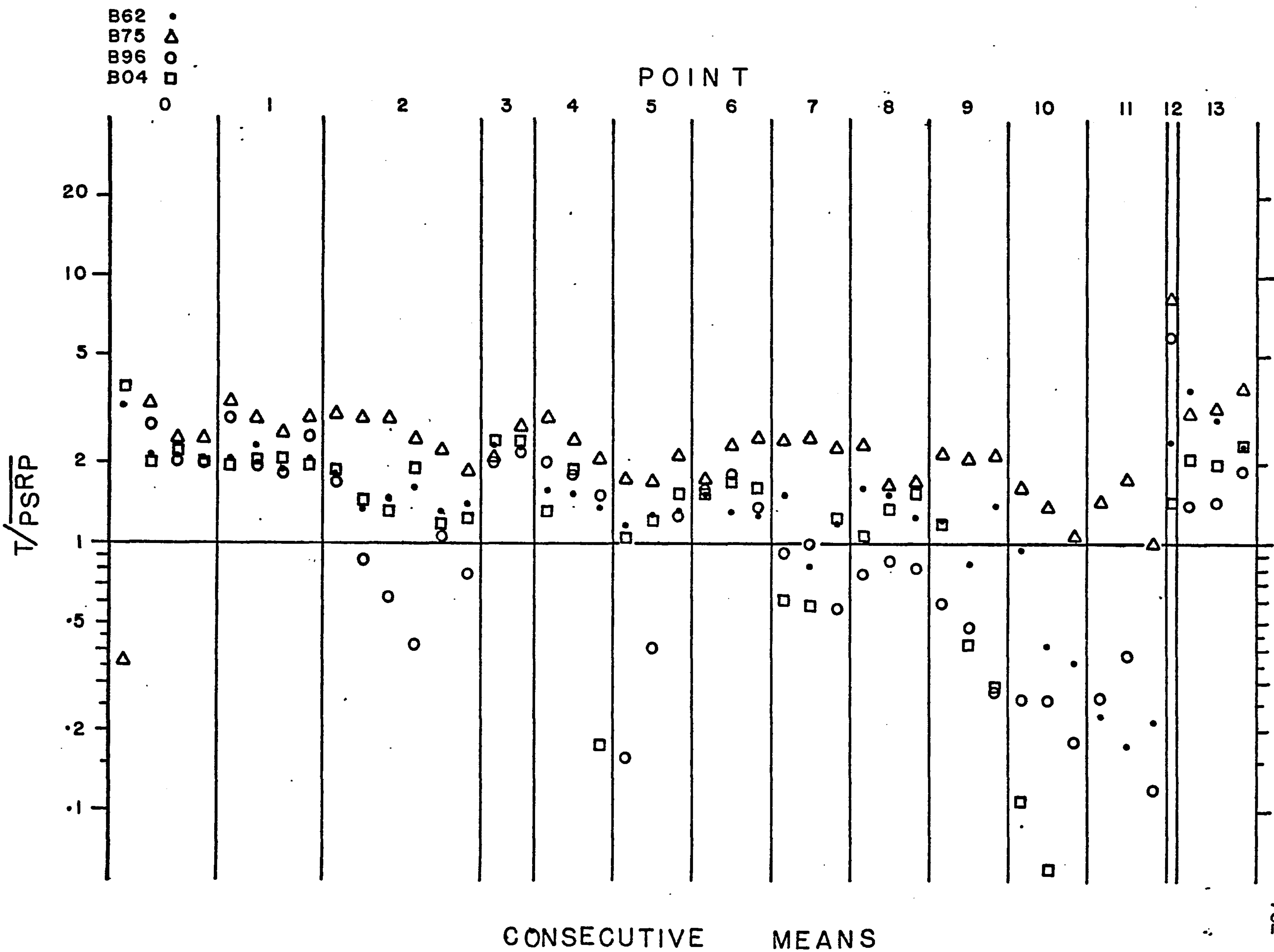
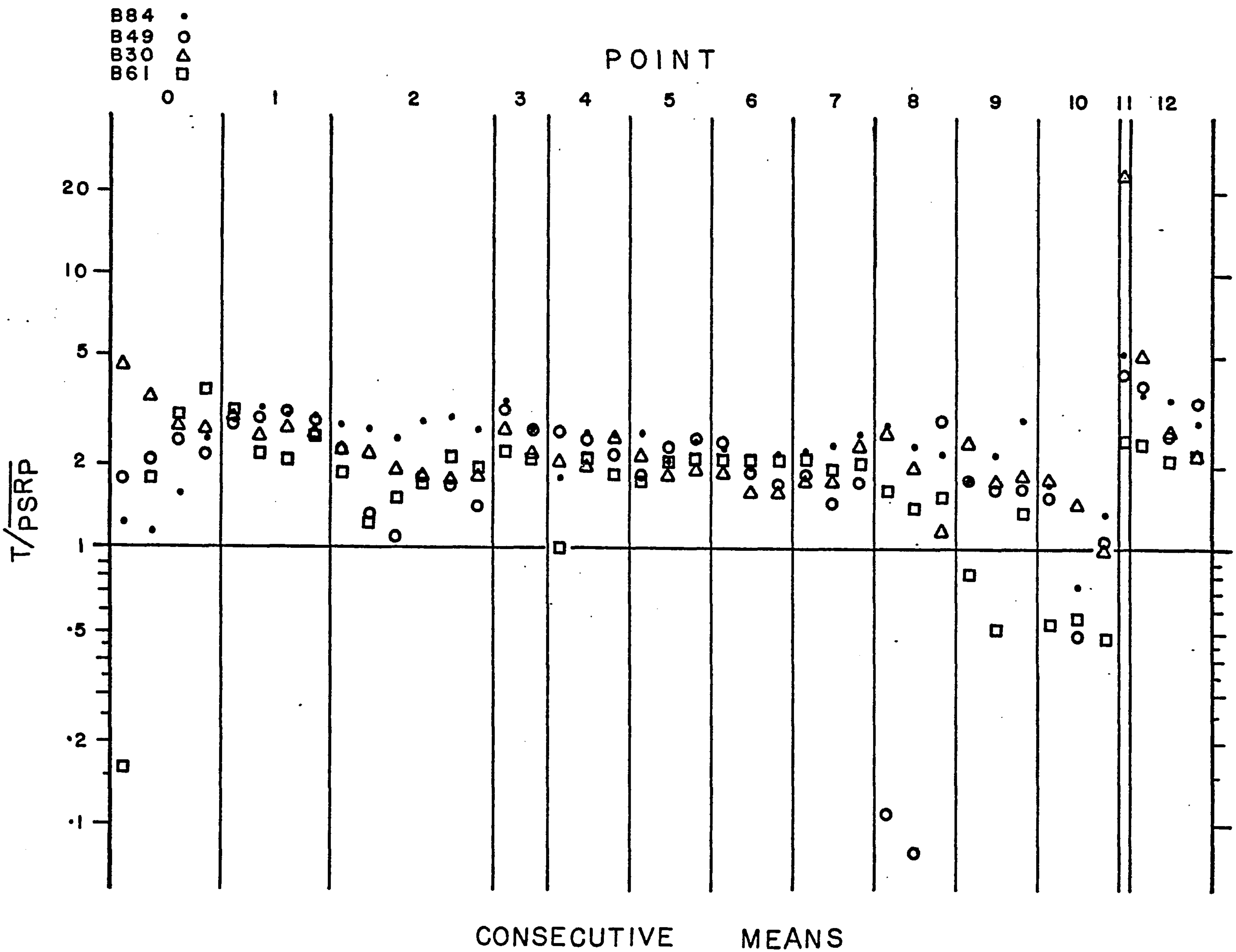

B62 •
B75 Δ
B96 o
B04 □
POINT
0 1 2 3 4 5 6 7 8 9 10 11 12 13
20
10
5
2
1
·5
·2
·1
T/√PSRP
CONSECUTIVE MEANS

Figure 36. Reciprocals of the mean post-reinforcement pauses as measured in t-cycle units (i.e., T/ $\overline{_{PS}R_P}$) for each individual of Group 2. Presented are consecutive five-session means. For points consisting of less than five sessions, the means are of the sessions presented. Conditions obtaining at each point may be found in Table 2.



B84 •
B49 o
B30 Δ
B61 □
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
20
10
5
2
1
·5
·2
·1
T/PSRP
CONSECUTIVE MEANS

Figure 37. Reciprocals of the mean post-reinforcement pauses as measured in t-cycle units (i.e., $T/\overline{_{PS}R_P}$) for each individual of Group 3. Presented are consecutive five-session means. For points consisting of less than five sessions, the means are of the sessions presented. Conditions obtaining at each point may be found in Table 3.

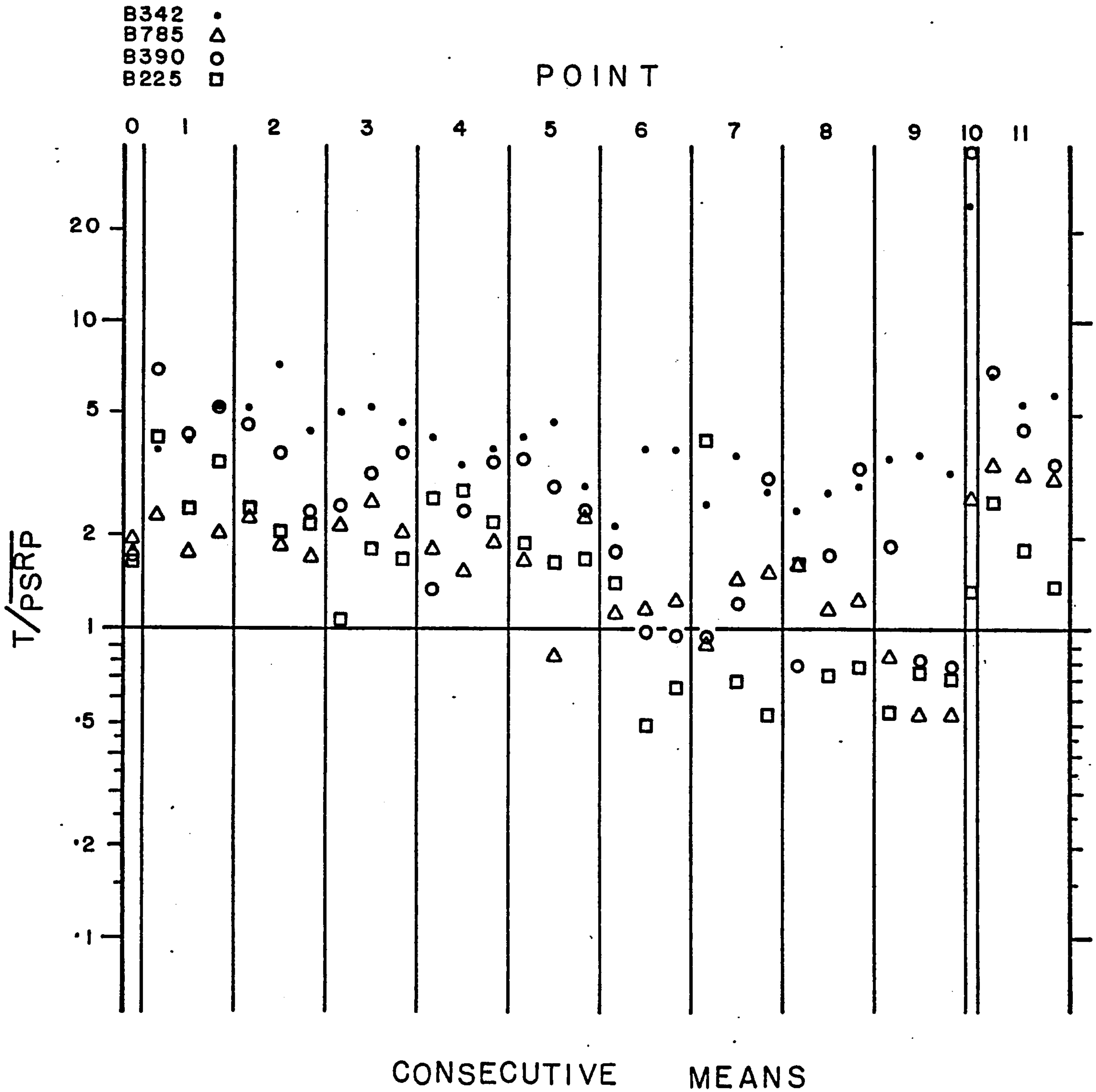
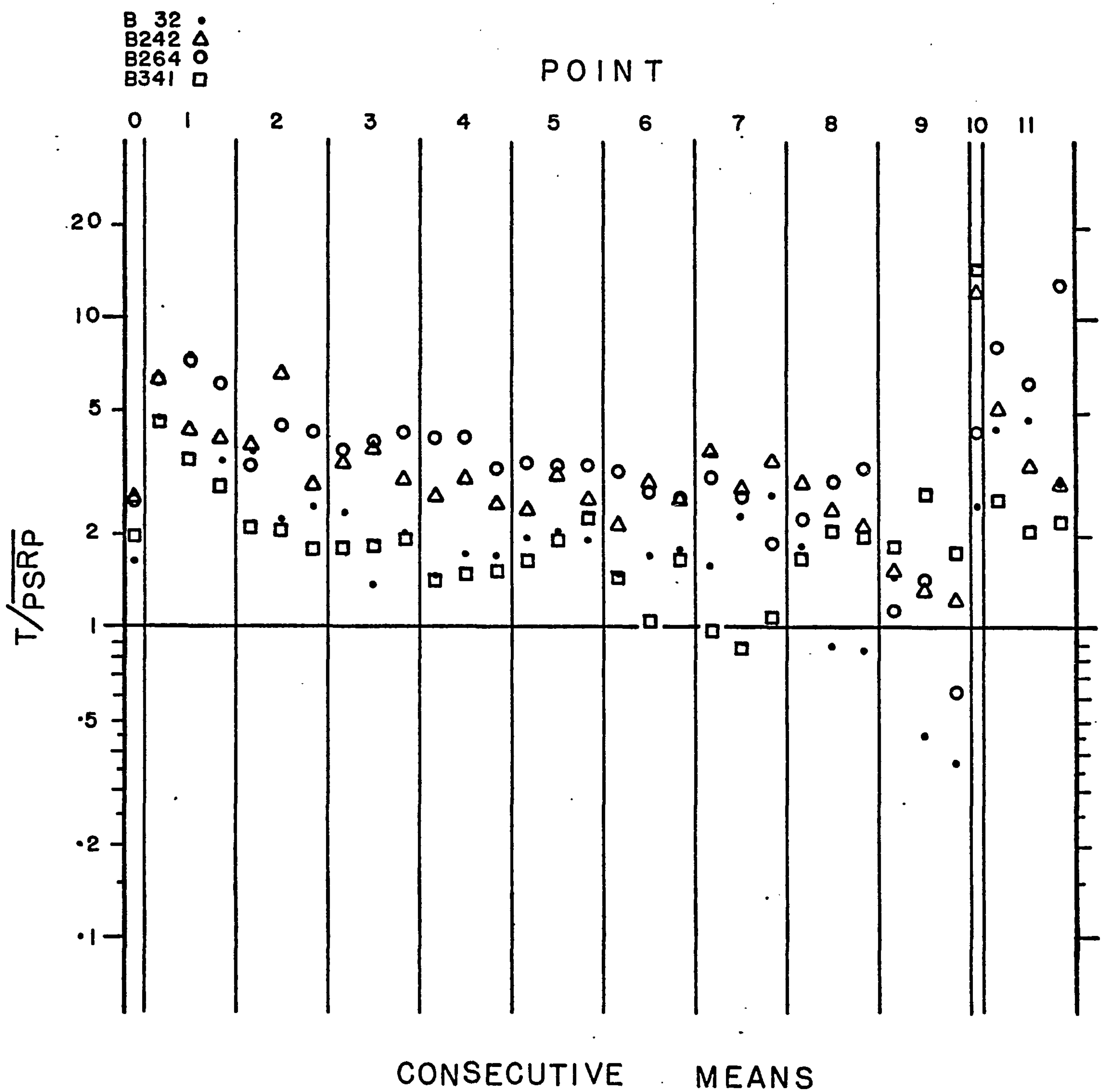

B342 •
B785 △
B390 ○
B225 □
POINT
0
1
2
3
4
5
6
7
8
9
10
11
20
10
5
2
1
·5
·2
·1
T/PSRP
CONSECUTIVE MEANS

Figure 38. Reciprocals of the mean post-reinforcement pauses as measured in t-cycle units (i.e., $T/\overline{_{PS}R_P}$) for each individual of Group 4. Presented are consecutive five-session means. For points consisting of less than five sessions, the means are of the sessions presented. Conditions obtaining at each point may be found in Table 4.

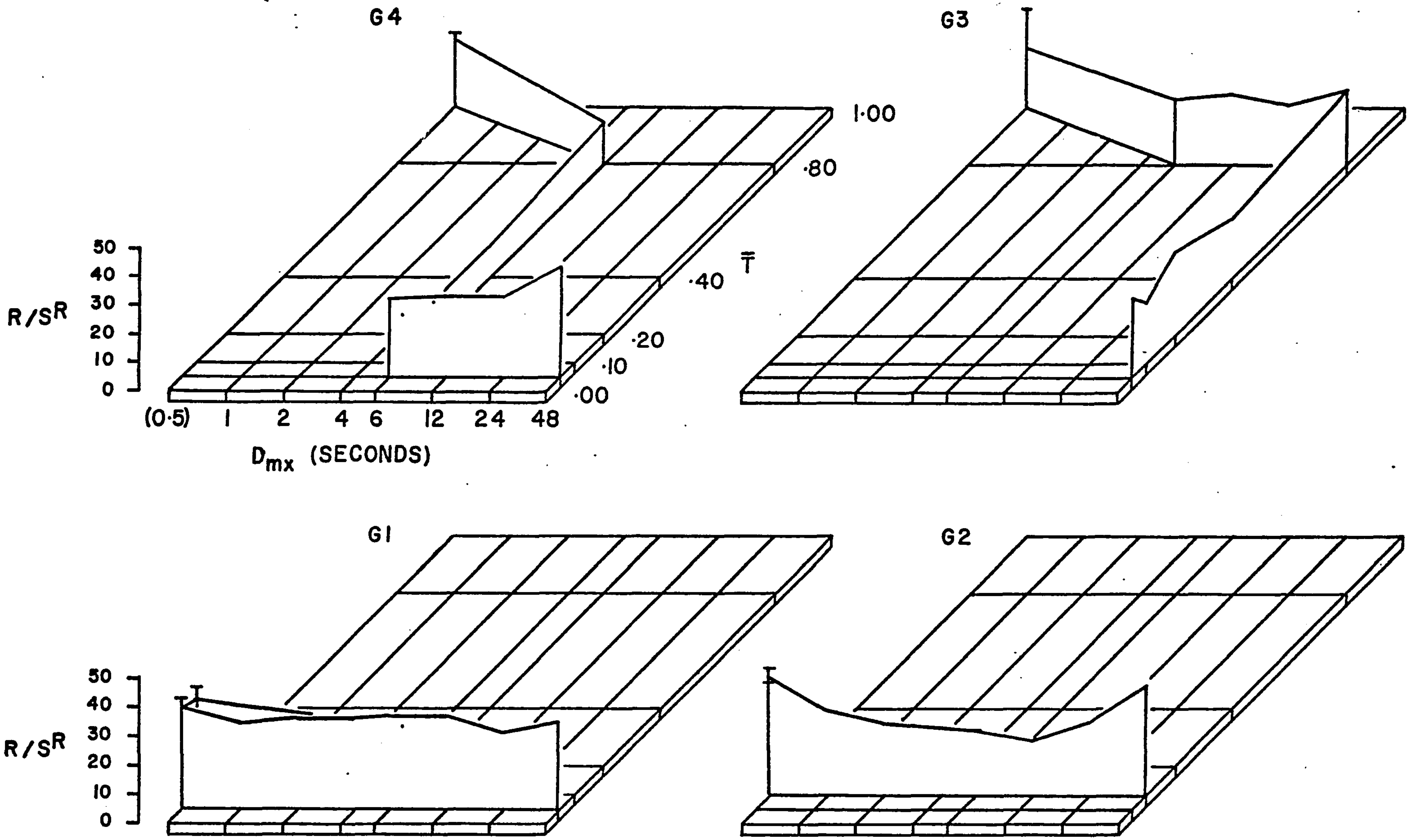

B 32 •
B242 △
B264 ○
B341 □
POINT
0 1 2 3 4 5 6 7 8 9 10 11
20
10
5
2
1
·5
·2
·1
T/PSRP
CONSECUTIVE MEANS

for each group as a function of the matrix values. Of all the groups and points, the reciprocal PS^RP was highest for Group 4 at Point 1, and lowest for Group 1 at Point 11 (matrix value $(0.05\overline{T}, 48''D_{mx})$). Group 4 at Point 1 had a $T/\overline{PS^RP}$ value of 4.67 (corresponding to a mean PS^RP of 0.21 t-cycles). Group 1 at Point 11 had a $T/\overline{PS^RP}$ value of 0.39 (corresponding to a mean PS^RP of 2.56 t-cycles). The $T/\overline{PS^RP}$ data per session for each group and per consecutive block of five sessions for the individuals of each group are presented in Figures 31 through 34 and Figures 35 through 38 respectively. These data display an even greater range of values than did the overall group means. For this reason a logarithmic scale was used in plotting the reciprocal PS^RP data for these figures. It is interesting that the mean post-reinforcement pause times increased rather than decreased as the matrix value $(0.05\overline{T}, 48''D_{mx})$ was approached, because the probability of reinforcement was higher for the shorter PS^RPs at this matrix value. That is, at this matrix value a PS^RP of between 12 and 15 seconds (i.e., a $T/\overline{PS^RP}$ of between 4 and 5) would result in an R_i in the succeeding t-cycle. This method of differentially reinforcing the shorter PS^RPs does not, however, result in short PS^RPs. Even granting that differential reinforcement of shorter PS^RPs may be successful, PS^RP length seems to be much more strongly influenced by other factors.

In his chapter on periodic reconditioning, the number of responses per reinforcement (R/S^R) is a measure that received some attention from Skinner in his 1938 discussion of the theoretical concept of "reflex reserve". According to this concept, a reinforcer was supposed to build up the strength of a reflex while unreinforced responses were supposed to tear down the strength of the same reflex. The number of responses emitted per reinforcement under a schedule which did not differentially reinforce high (or low) response rates was supposed to produce a constant ratio of unreinforced responses to reinforced responses. That is, the number of unreinforced responses needed to tear down a conditioned reflex was more than the number of reinforced responses which had built up that conditioned reflex. A corollary of this concept is that the responses per reinforcer should be greater for the stronger reinforcer than for stimuli which are weak reinforcers. Delayed reinforcers have been assumed to be weaker reinforcers because the rate of responding has generally decreased with increases in reinforcement delay. In this context, it is of interest to note that in this experiment the change in responses per reinforcement is not monotonically decreasing as D_{mx} increases.

Figure 39 shows the overall responses per reinforcement for each group as a function of schedule value. At Point 1, Group 1 emitted a mean of 33.6 R/S^R. While this mean fell to 23.5 for Point 2, of all the experimental points this was the lowest number of responses per reinforcement for this group. At Point 1, Group 2 emitted an average of 39.1 R/S^R. For Group 2

Figure 39. Responses per reinforcement as a function of schedule vector value for each group of subjects. Data are the averages over all the sessions for each point of each group. Values which were repeated are presented as short horizontal lines for all but one of the repeated schedules. Shown as short horizontal lines are Points 1 and 13 for Group 1, Points 1, 2 and 12 for Group 2, Point 11 for Group 3, and Point 11 for Group 4. Note that D_{mx} is on a logarithmic scale.


G4
G3
G1
G2
R/S^R
50
40
30
20
10
0
1·00
·80
·40
·20
·10
·00
T̄
(0·5)
1
2
4
6
12
24
48
Dmx (SECONDS)

the R/S^R fell to 18.6 at Point 8 ($0.10\overline{T}$, $12''D_{mx}$). However, the number of responses per reinforcement at Point 10, where the maximum delay of reinforcement was 48 seconds, was 38.0, only 1.1 R/S^R less than that emitted at Point 1 with zero seconds delay of reinforcement. The data for Groups 3 and 4 support even less the theory that delayed reinforcers have less power to generate a large number of responses per reinforcement than do immediate reinforcers. Except for the second time the matrix value ($1.00\overline{T}$, $0''D_{mx}$) is presented to Group 3, this matrix value produced fewer responses per reinforcement than did ($0.05\overline{T}$, $48''D_{mx}$).

Figures 40 through 43 show the mean number of responses per reinforcement for each consecutive session for each group. Inspection of the data from each point and group does not reveal any notable consistency. The data from Group 1 are essentially flat across sessions, showing only a slight increase in variability across sessions. Point 1 shows an initial increase over Point 0, but its final value is only slightly higher. Group 2, which was exposed to identical experimental conditions until Point 5 also showed the increase in responses per reinforcement at the beginning of Point 1, but this rate was maintained throughout that point. When Groups 1 and 2 began Point 3 ($0.10\overline{T}$, $6''D_{mx}$) the number of responses per reinforcement for Group 1 continued at about the same level while the number for

Figure 40. Mean number of responses per reinforcement for each consecutive session for Group 1. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 1.

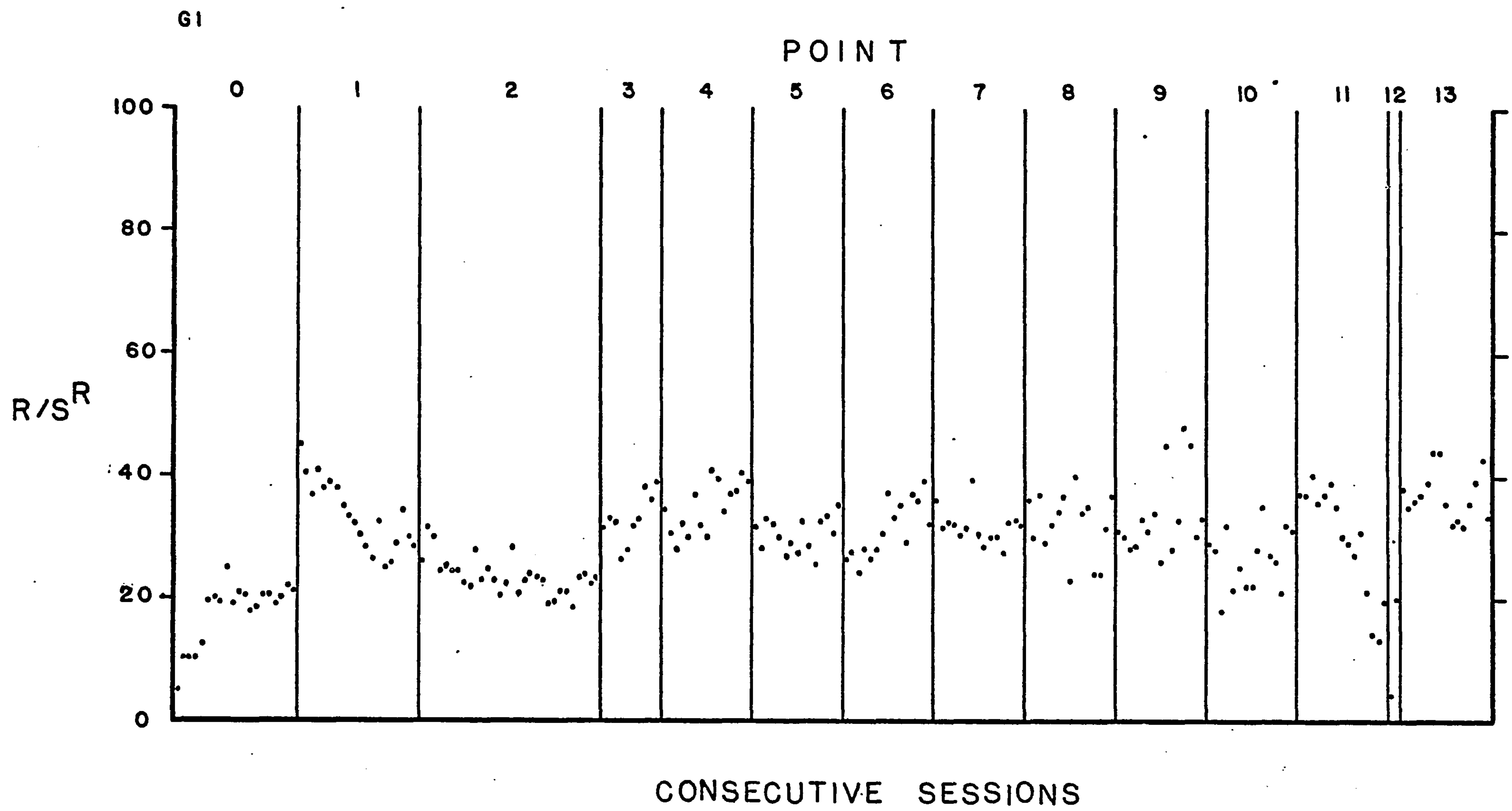

G1
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
13
100
80
60
40
20
0
R/S^R
CONSECUTIVE SESSIONS

Figure 41. Mean number of responses per reinforcement for each consecutive session for Group 2. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 2.

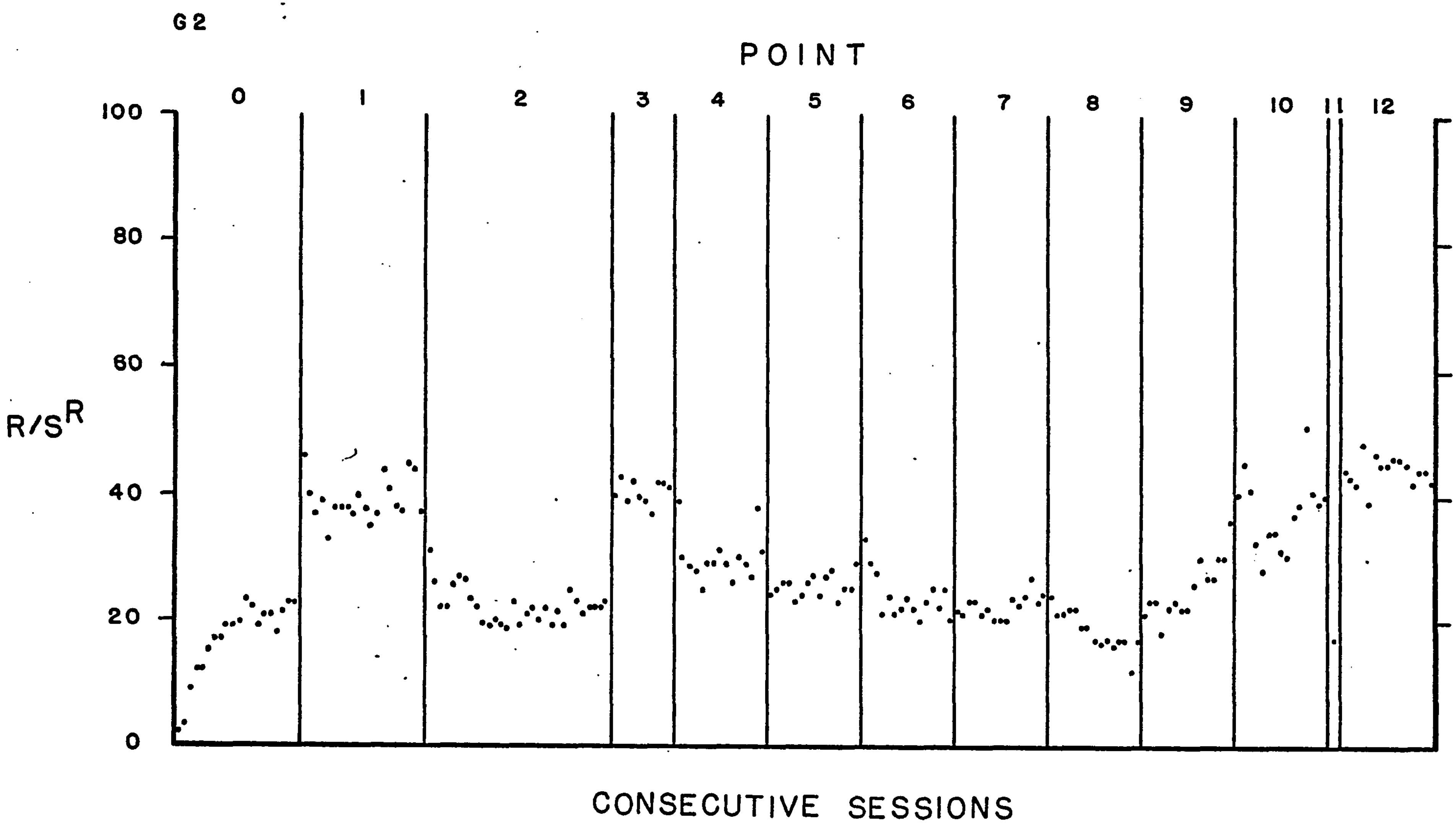

G2
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
100
80
60
40
20
0
R/S^R
CONSECUTIVE SESSIONS

Figure 42. Mean number of responses per reinforcement for each consecutive session for Group 3. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 3.

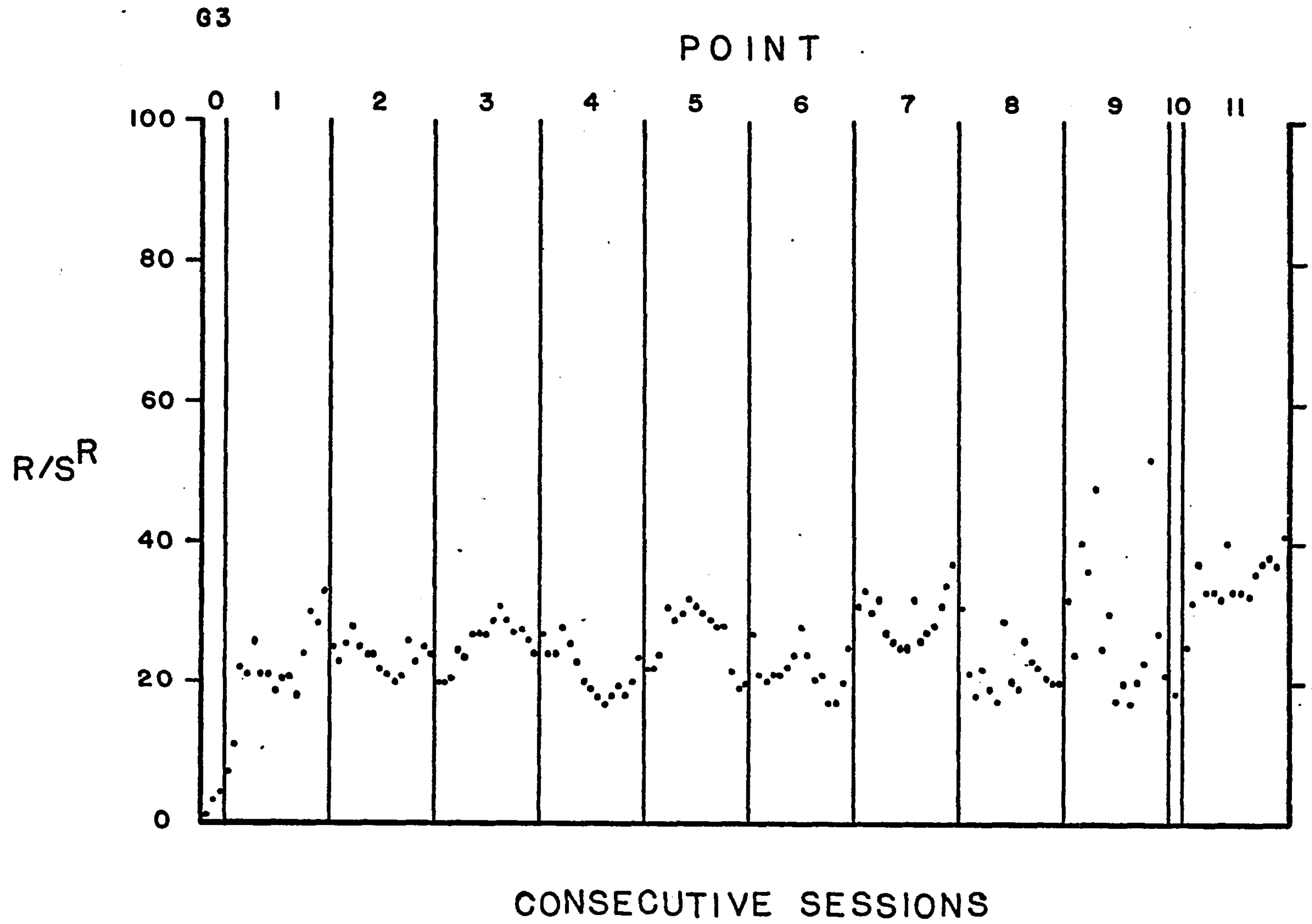
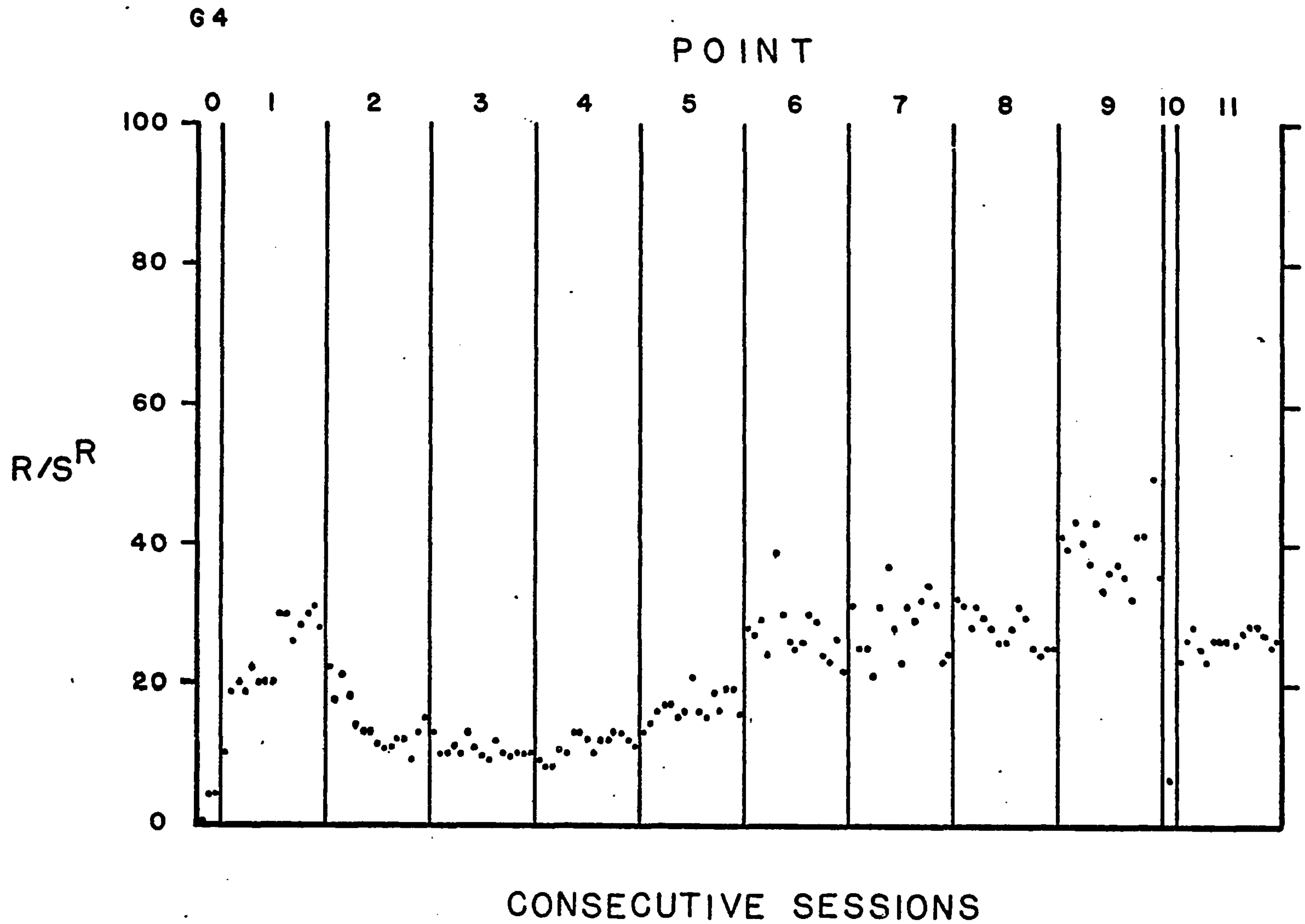

G3
POINT
0 1 2 3 4 5 6 7 8 9 10 11
100
80
60
40
20
0
R/S^R
CONSECUTIVE SESSIONS

Figure 43. Mean number of responses per reinforcement for each consecutive session for Group 4. The consecutive points are separated by vertical lines. The conditions obtaining at each point may be found in Table 4.


G4
POINT
0 1 2 3 4 5 6 7 8 9 10 11
100
80
60
40
20
0
R/S^R
CONSECUTIVE SESSIONS

Group 2 showed a sudden drop. For these two groups, however, the mean R/S^R for Point 2 is very similar (23.5 for Group 1, and 22.2 for Group 2). When each group was returned to $(0.10\overline{T}, 0''D_{mx})$ (Point 3) the original behavior of each group was recovered. Inspection of Figures 44 and 45, which give the consecutive five-session means for the individuals of each group does not suggest that the differences can be attributed to any single animal. The cause of these differences among the two groups is unknown. The remaining data for Group 2 show a slow steady decline in the number of responses per reinforcement until the beginning of Point 9 $(0.10\overline{T}, 24''D_{mx})$ after which there is a steady, relatively rapid rise in the number of responses per reinforcement until the termination of the experiment.

In the number of responses per reinforcement, Group 3 again shows periodicity (see Figure 42) as a function of consecutive sessions. The periodicity is apparently attributable to a single subject, B342 (see Figure 46). Group 4 (see Figures 43 and 47) reaches a minimum number of responses per reinforcement (10.5) at Point 3 and thereafter the number of responses per reinforcement steadily increases in both size and variability across sessions. The number of responses per reinforcement is highest (38.8 R/S^R) at Point 9 $(0.05\overline{T}, 48''D_{mx})$ for this group.

Figure 44. Mean responses per reinforcement for each individual of Group 1. Presented are consecutive five-session means. For points consisting of less than five sessions, the means are of the sessions presented. Conditions obtaining at each point may be found in Table 1.

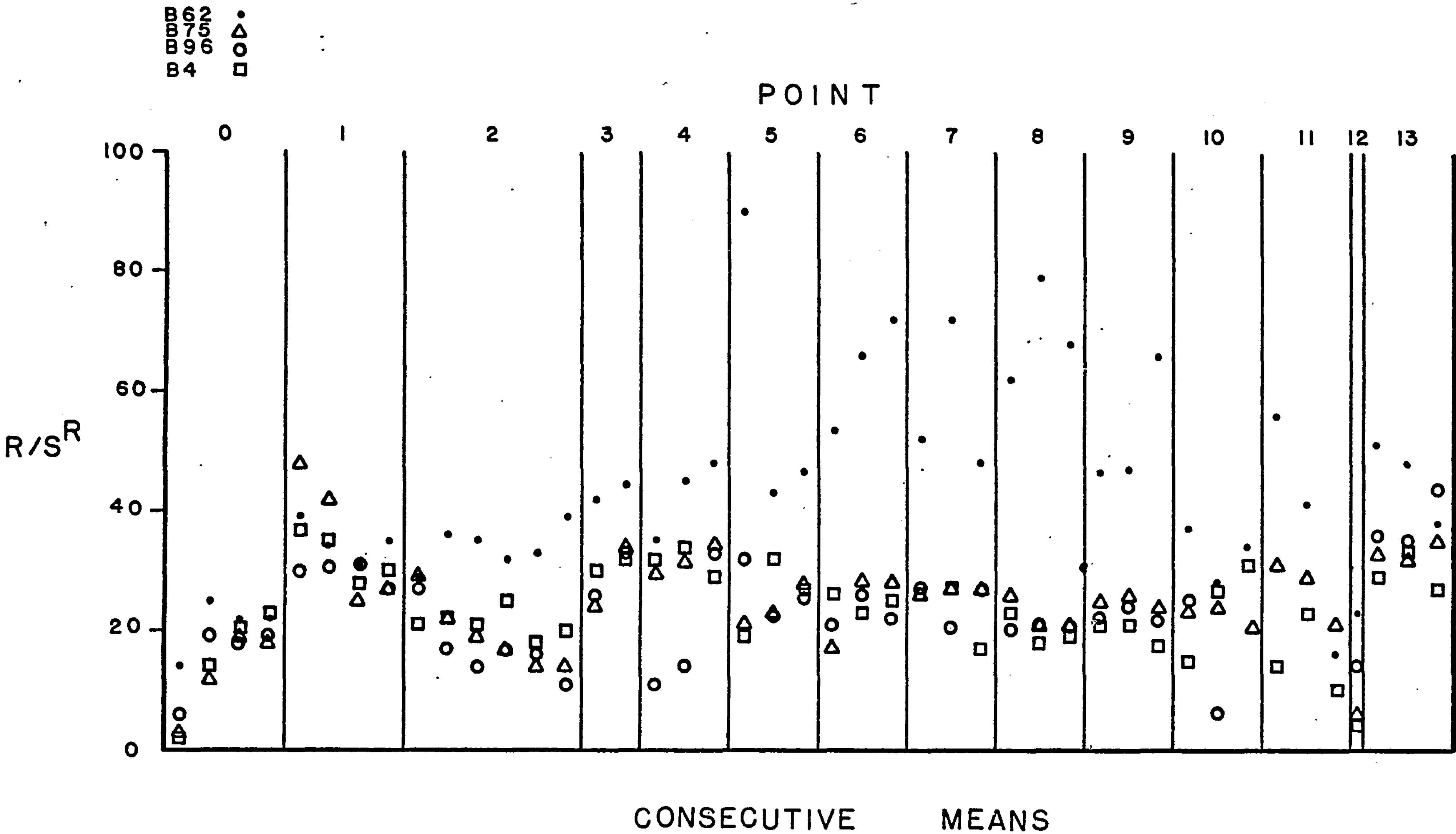

B62 •
B75 △
B96 ○
B4 □
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
13
100
80
60
40
20
0
R/S^{R}
CONSECUTIVE MEANS

Figure 45. Mean responses per reinforcement for each individual of Group 2. Presented are consecutive five-session means. For points consisting of less than five sessions, the means are of the sessions presented. Conditions obtaining at each point may be found in Table 2.

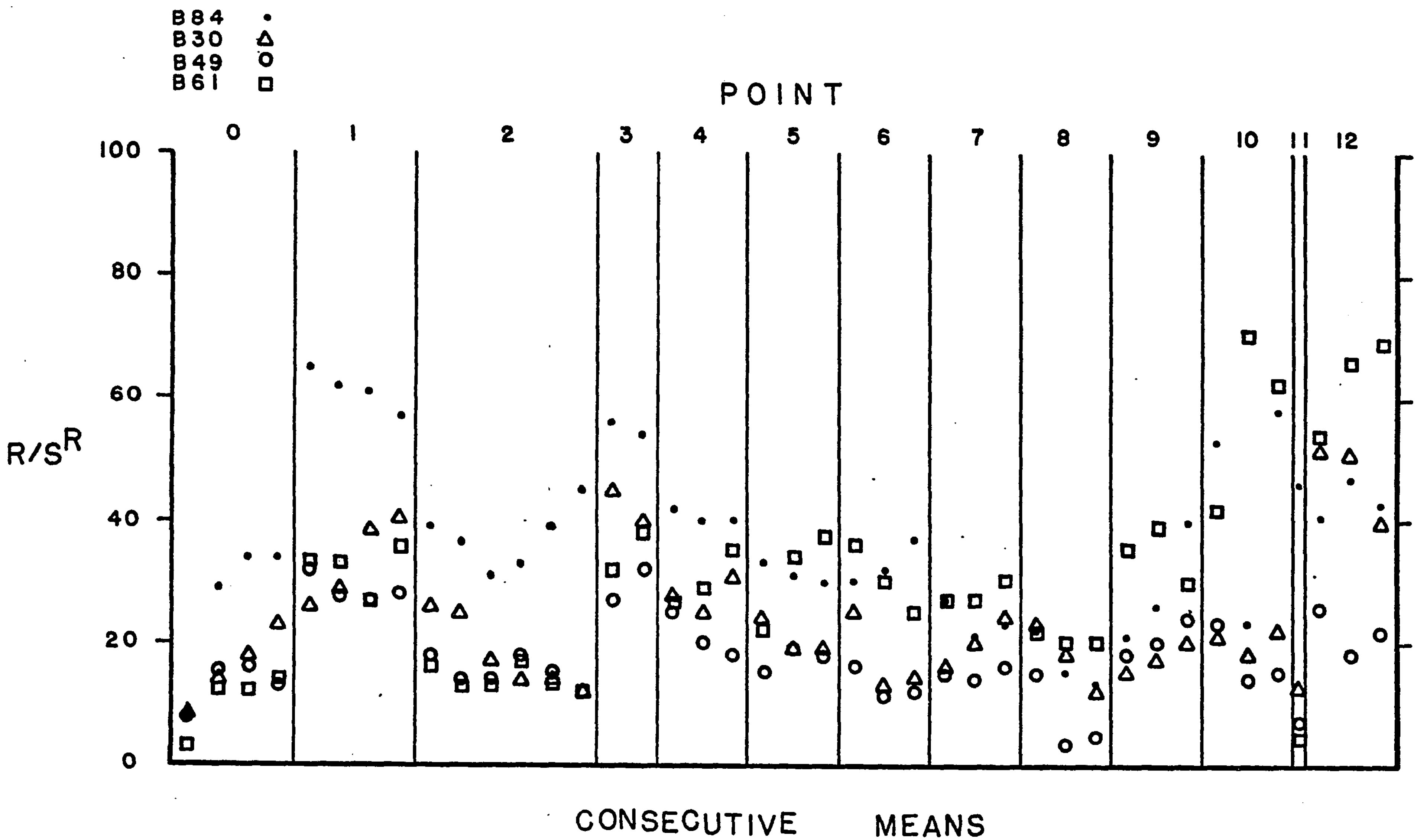

B84 •
B30 Δ
B49 O
B61 □
POINT
0
1
2
3
4
5
6
7
8
9
10
11
12
100
80
60
40
20
0
R/S^R
CONSECUTIVE MEANS

Figure 46. Mean responses per reinforcement for each individual of Group 3. Presented are consecutive five-session means. For points consisting of less than five sessions, the means are of the sessions presented. Conditions obtaining at each point may be found in Table 3.

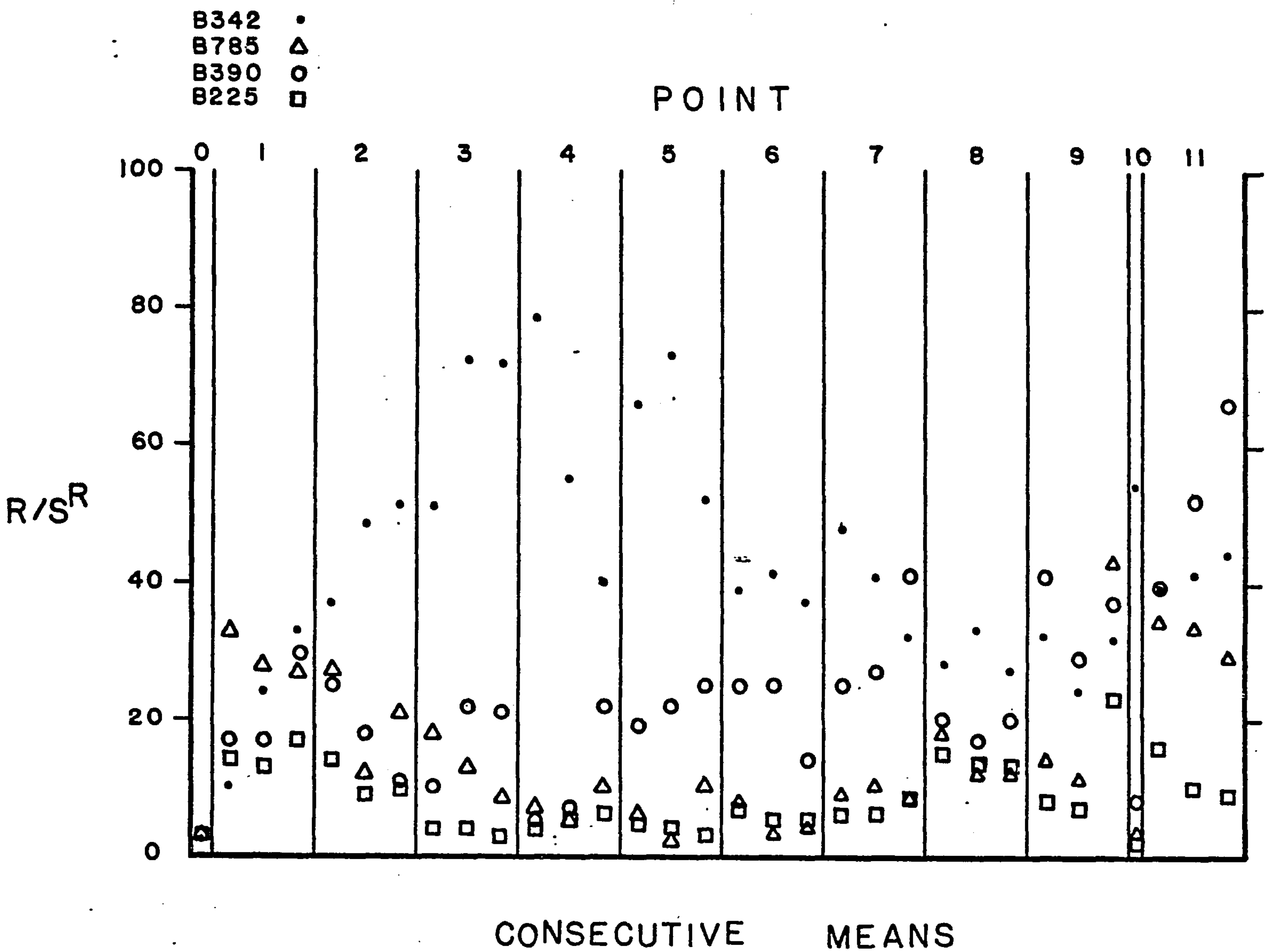
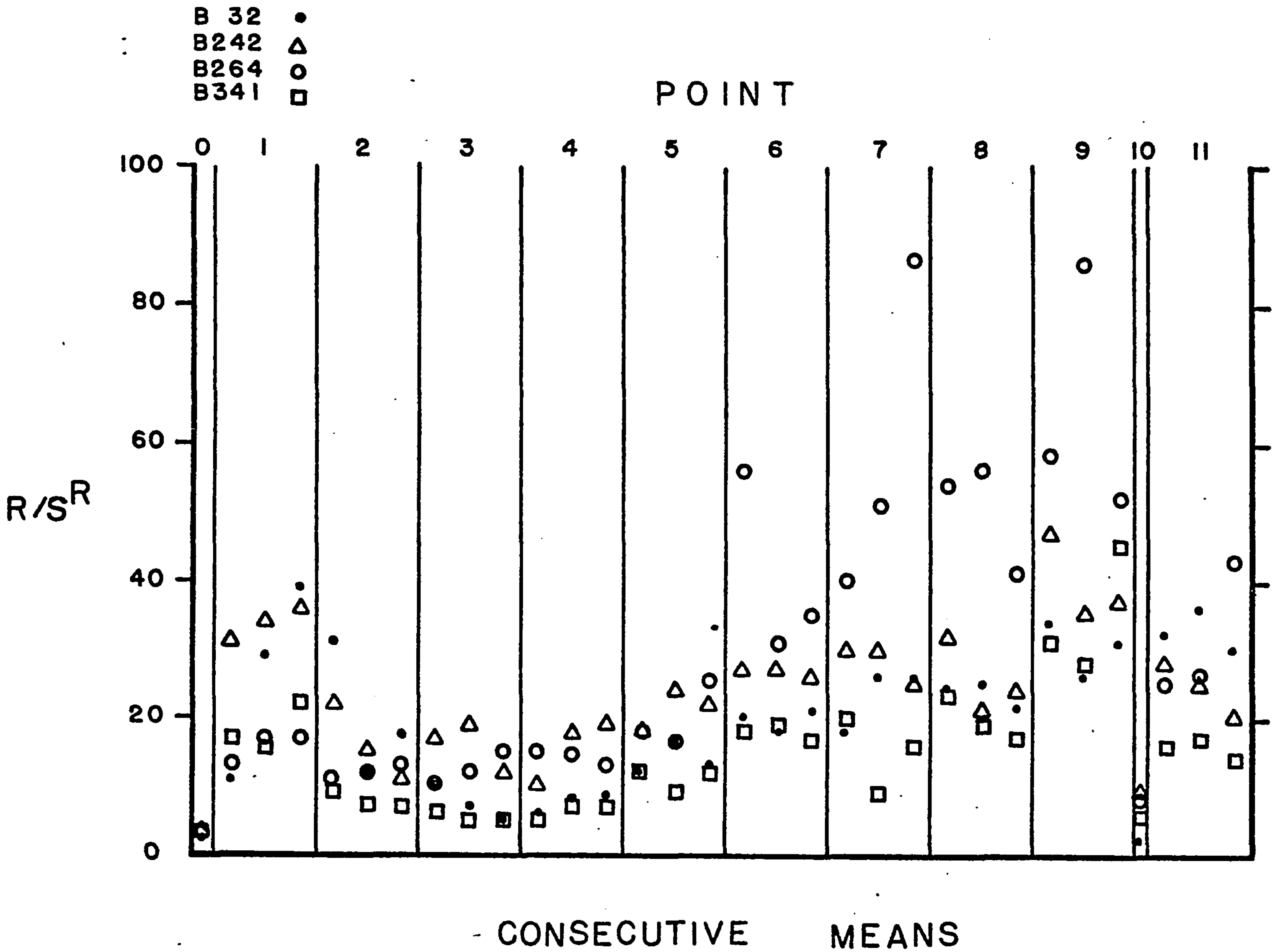

B342 •
B785 Δ
B390 o
B225 □
POINT
0
1
2
3
4
5
6
7
8
9
10
11
100
80
60
40
20
0
R/S^R
CONSECUTIVE MEANS

Figure 47. Mean responses per reinforcement for each individual of Group 4. Presented are consecutive five-session means. For points consisting of less than five sessions, the means are of the sessions presented. Conditions obtaining at each point may be found in Table 4.


B 32 •
B242 △
B264 ○
B341 □
POINT
0 1 2 3 4 5 6 7 8 9 10 11
100
80
60
40
20
0
R/S^R
CONSECUTIVE MEANS

DISCUSSION

Delay studies have in the past taken a number of forms. Renner (1964) has reviewed the delay of reinforcement studies conducted up to 1964. Most of these were studies of the effect of delayed reinforcement upon learning in descrete trial situations. Tarpy and Sawabini (1974) have reviewed the delay of reinforcement literature from 1964 to 1973. However, they limited their review to discrete trial studies which emphasized the issue of cue utilization. Reviews of free operant studies of delayed reinforcement apparently do not yet exist, possibly because of the relative dearth of such studies. A little over a score of free operant studies appear in the literature and only eight could be found which do not provide stimulus changes with the onset of the delay periods (i.e., Skinner, 1938; Dews, 1960; Azzi, Fix, Keller and Rocha e Silva, 1964; Morgan, 1970; Schoenfeld and Farmer, 1970; Schoenfeld, Cole, Lang and Mankoff, 1973; Williams, 1976; and da Silveira Dias, 1976).

In the present study, no cued delays were used because past free operant studies using "chain" schedules (Ferster and Skinner, 1957) have shown that the appearance of the stimulus associated with the second component is a secondary reinforcer for the behavior in the first component. That is, responding in the first component is reinforced by the presentation of stimulus conditions associated with a higher probability of primary reinforcement.. In a way, a chain schedule is a special kind of "multiple" schedule (Ferster and Skinner, 1957), differing from the usual multiple schedule only in that each component is associated with a different class of reinforcer. Thus, as in multiple schedules, the behavior patterns developed in the cued components of a chain schedule independently depend on the reinforcement schedules in the separate components, and in addition depend on the class of reinforcing stimulus. When a response is followed by a primary reinforcing stimulus after a cued delay, the schedule is, in Ferster and Skinner's terminology, a chain schedule. When the delay time is uncued, however, the schedule is characterized as "tandem" by Ferster and Skinner rather than "chain", and the behavior patterns in each component are dependent on their temporal relationships to the reinforcer and to their inductive relationship with other behaviors which have different temporal relationships with reinforcing stimuli.

The reinforcement schedule in the second component of either chain or tandem schedules may be a "fixed time" or "FT" schedule (Zeiler, 1968), or a "variable time" or "VT" schedule, as when responses during this component have no influence on S^R probability, or it may be a "DRO" schedule (Reynolds, 1961) in which responses will temporarily reduce S^R probability to zero. Fixed delay experiments, in which the behavior immediately before a reinforcer consists of an R followed by t-seconds of behaviors which do not include an R may then be characterized as either chain or tandem FR1, DRO-t. Variable delay studies have been of two types. First, there was the variable delay experiment in which the behavior immediately before a reinforcer consisted of an R_i followed by t-seconds of any behavior, not excluding R. This schedule may be characterized as either chain or tandem FR1, FT-t, depending on the presence or absence of delay cueing. Second, there was the variable delay experiment in which the behavior immediately before a reinforcer consisted of t-seconds containing one or more Rs. This schedule may be characterized as a conjunctive schedule (Ferster and Skinner, 1957). Morgan (1970) characterized his variable delay schedule as "conjunctive FT31", FR1 ".

Description of the experimental manipulations of the present study within the Ferster and Skinner tradition is also possible, but soon becomes cumbersome. When t^D is equal to, or larger than, D_{mx}, the procedure seems to belong to the second variable delay schedule type described above. When t^D is very small, the procedure seems to belong to the first variable delay schedule type described above. However, when t^D is smaller than D_{mx} yet still of moderate size, the procedure has features of both the variable delay procedures described above. Manipulation of the variables $\overline{T}$ and D_{mx} allows a smooth transition from one delay schedule to another.

It is this ability to proceed simply and smoothly from one nominal class of delay of reinforcement schedule to another that makes the present system of experimental manipulations of special utility. It becomes obvious with manipulations of $\bar{T}$ and D_{mx} that both variable delay of reinforcement procedures are special cases of a more general set of procedures. In the present set of experimental manipulations, no attempt was made to demonstrate that the fixed delay of reinforcement procedure is also a special case. However, the first procedure may also be incorporated as a special case by the simple expedient of having responses in t^{Δ} decrease the probability of reinforcement at the end of t^{Δ}. Responses in t^{Δ} might thereby counteract any increase in probability of reinforcement produced by responses during the previous t^{D} period. At any chosen time, a reinforcing stimulus might be delivered or not according to the value of a probability register. If the first response in t^{D} increments the probability register by 1.00 and the first response in t^{Δ} decrements the probability register by the same amount, then the probability of reinforcement at the time the register is sampled may be zero even though t^{D} contained a response. If in t^{D} the probability register is incremented independently of responses, then it might be said that responses in t^{Δ} "avoid" the reinforcing stimulus.

In the present experiment, a contingency relationship between responses and reinforcements was always present. The results clearly demonstrate, however, that the presence of a contingency relationship *per se* is not a sufficient condition for the maintenance of a given level of R_1 frequency. Past delay of reinforcement studies did not allow this fact to clearly emerge.

For those studies in which the overall reinforcement schedule was characterized as CRF or continuous reinforcement (e.g., Skinner, 1938; Dews, 1960; Azzi et al., 1964), each increase in the reinforcement delay time produced a necessary and concommitant increase in the minimum inter-reinforcement time. Any decline in response rate could then be attributed to the prior reduction in reinforcement frequency. In those cases which did not use a CRF schedule, the contingency relationship was not clearly distinguished. Skinner (1938) also investigated the effect of fixed delays under an overall schedule of FI 5'. The delays he used were rather short (2, 4, 6, and 8 seconds), so the direct effect upon reinforcement frequency would be relatively slight.

The variable delay studies by Morgan (1970), Schoenfeld, Cole, Lang and Mankoff (1973), and Williams (1976) allowed delays between the response necessary and sufficient for reinforcement (the R_1) and the reinforcement. In the studies by Morgan, and by Schoenfeld et al., the R_1s could appear at any time between reinforcers. Should R_1s at a given temporal distance not be maintained at their initial probability of emission by their reinforcement then the lowered probability of emission should shift R_1s closer to the time of reinforcement. Since the R_is were the Rs which terminated the PS^RPs in these studies one would expect the average PS^RP to increase. Morgan found, however, that the average PS^RP under his variable delay of reinforcement schedule was not notably different from that found under a fixed interval schedule of length equal to the maximum delay of reinforcement. Schoenfeld et al. (Experiment 1) found that the mean PS^RP increased substantially. Of the three subjects tested in Experiment 1, the schedule produced PS^RPs of about 3, 5, and 12 seconds for the last five sessions with T = 6", and 10, 22, and 18 seconds for the last five sessions with T = 12". The study by Williams (1976) used a VI 2' schedule to which a delayed reinforcement condition of 3, 5, 8 or 15 seconds was added. The R_is therefore could not occur prior to satisfaction of the VT component (VT schedules considered as identical to tandem VT, FR 1 schedules). Unfortunately, neither IS^RT nor PS^RP data were reported.

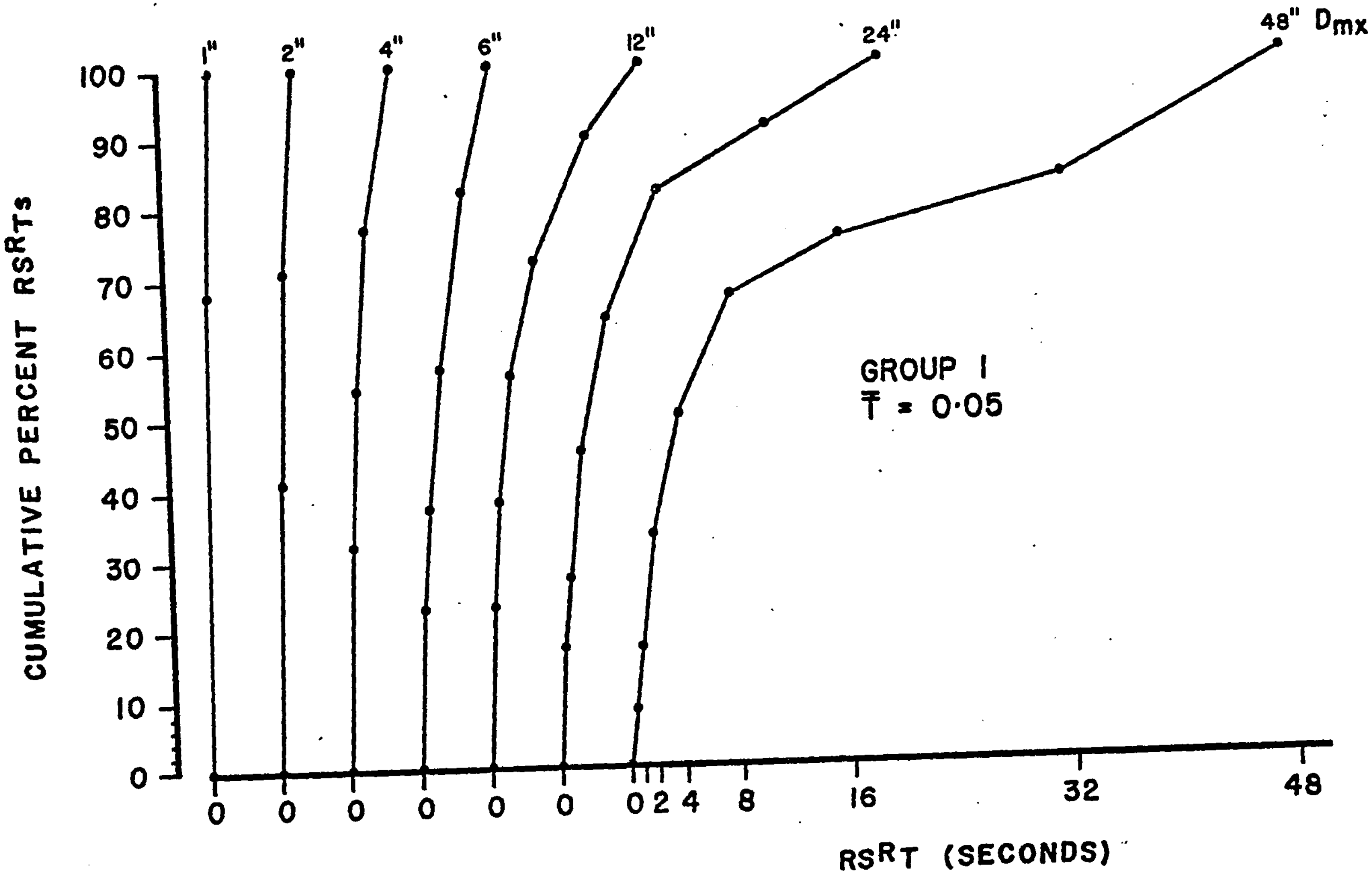
In the present experiment, reinforcement frequency was initially limited by the t-cycle to an average of one S^R per minute so that since no reinforcement delay in excess of 48 seconds was scheduled, there was presumably no necessity for reinforcement frequency to decrease. If the probability of R_i remained constant during manipulations of D_{mx} then the probability of reinforcement would also be constant. If, on the other hand, the probability of R_i decreased, either because of an interaction with an overall lowering of response frequency or because t^D sampled a smaller or different portion of the cumulative response curve after reinforcement, then the probability of reinforcement would also decrease. If the overall level of reinforcement frequency is influential in maintaining a given overall level of responding one might then expect a negative growth process to begin. That is, the schedule manipulation first forces a decrease in R_i probability, the decrease in R_i probability causes a decrease in reinforcement frequency, the decrease in reinforcement frequency then causes a further decrease in response frequency, etc. This negative growth process need not continue indefinitely, however, because the effect need not be linear. A new point of equilibrium may be reached before the probability of R_is falls completely to zero.

The results of the present experiment demonstrate that the strength of the response class upon which reinforcement was contingent (i.e., dependent) is apparently independent of this contingency relationship. That is, the probability of R_is is not maintained by their contingency relationship with S^Rs. Far more important appears to be the contiguity or delay relationship a response class has with reinforcement. Apparently, concingency serves only to maintain a degree of contiguity between Rs and S^Rs, contiguity directly affecting response probability.

As Tables 5 and 6 show, the corrected response rates and running response rates are generally highest during those subintervals most closely followed by reinforcement. The only exceptions to this general finding are produced by Group 3 for Points 4, 5, 6 and 7 (vectors ($0.80\overline{T}$, $24''D_{mx}$), ($0.80\overline{T}$, $48''D_{mx}$), ($0.40\overline{T}$, $48''D_{mx}$), and ($0.20\overline{T}$, $48''D_{mx}$), respectively). This finding does not, however, support the view that contingency is of direct importance in behavior control since the peak corrected response rate appeared in the sixth subinterval after reinforcement, independently of t^D loci, and thereafter slowly fell. It was informally observed that after reinforcement the birds would first emit the interim behaviors as described by Staddon and Simmelhag (1971), then begin key-pecking. As time progressed in the t-cycle, some of the birds would begin to emit the stereotyped kind of behavior observed by Skinner in 1948. For the other subjects of this same group, this kind of stereotyped terminal behavior was not evident even though the rate of key-pecking showed the same temporal pattern.

The function of contingency in maintaining contiguity between responses and subsequent reinforcers is demonstrated in Figures 48 through 51. The figures present data concerning the degrees of contiguity maintained between R_us (the ultimate response before a reinforcer) and S^Rs by each maximum delay contingency. The maximum delays as specified by D_{mx} ensure that all RS^RTs are less than or equal to these values but the medians and even the third quartiles are typically much less than D_{mx} (see Table 7). The maximum RS^RTs in the above mentioned figures were limited by the value of D_{mx} so the cumulative percent RS^RTs always reached one hundred at or before the RS^RT value that was equal to D_{mx}. Table 7 presents the first, second, and third quartile values as a function of each of the D_{mx} values investigated. These quartiles were calculated using the average distributions from all points, regardless of group or $\overline{T}$ value, having in common the same value of D_{mx}. These data, in conjunction with the data on response rates, indicate that even a few reinforcements of a key-peck followed by other behaviors during the remaining time to reinforcement will increase the frequency of that response pattern.

Figure 48. Cumulative RS^RTs as a function of RS^RT class for Group 1. For clarity, each curve is displaced five units to the left of the curve immediately to its right. Point 2 for this group (vector ($0.10\overline{T}$, $6''D_{mx}$)) is not displayed.



1"
2"
4"
6"
12"
24"
48" Dmx
CUMULATIVE PERCENT RSRTs
0
10
20
30
40
50
60
70
80
90
100
0
0
0
0
0
0
0
2
4
8
16
32
48
RSRT (SECONDS)
GROUP I
T̄ = 0·05

Figure 49. Cumulative RS^RTs as a function of RS^RT class for Group 2. For clarity, each curve is displaced five units to the left of the curve immediately to its right. Point 2 for this group (vector ($0.10\overline{T}$, $6"D_{mx}$)) is not displayed.

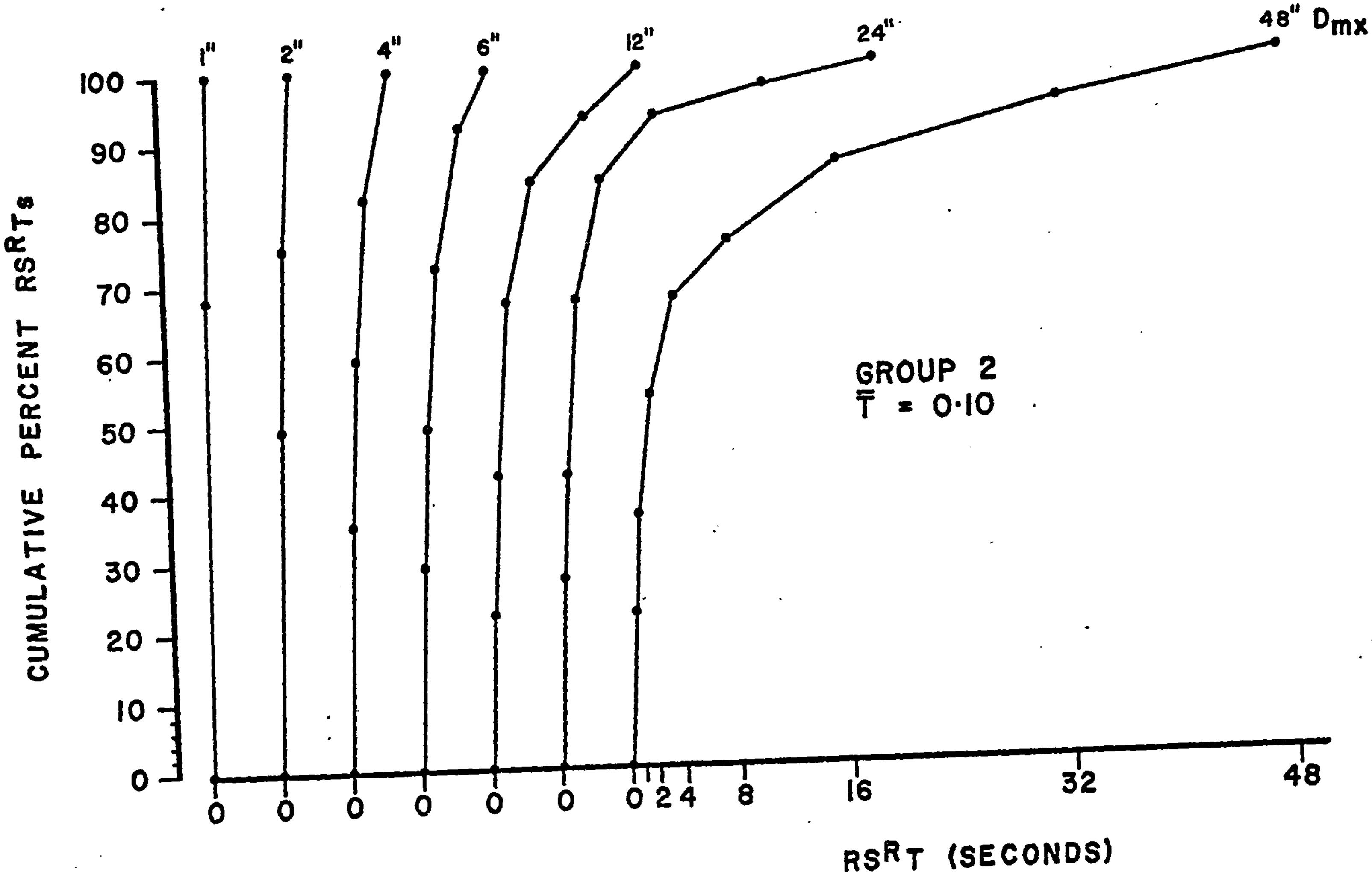
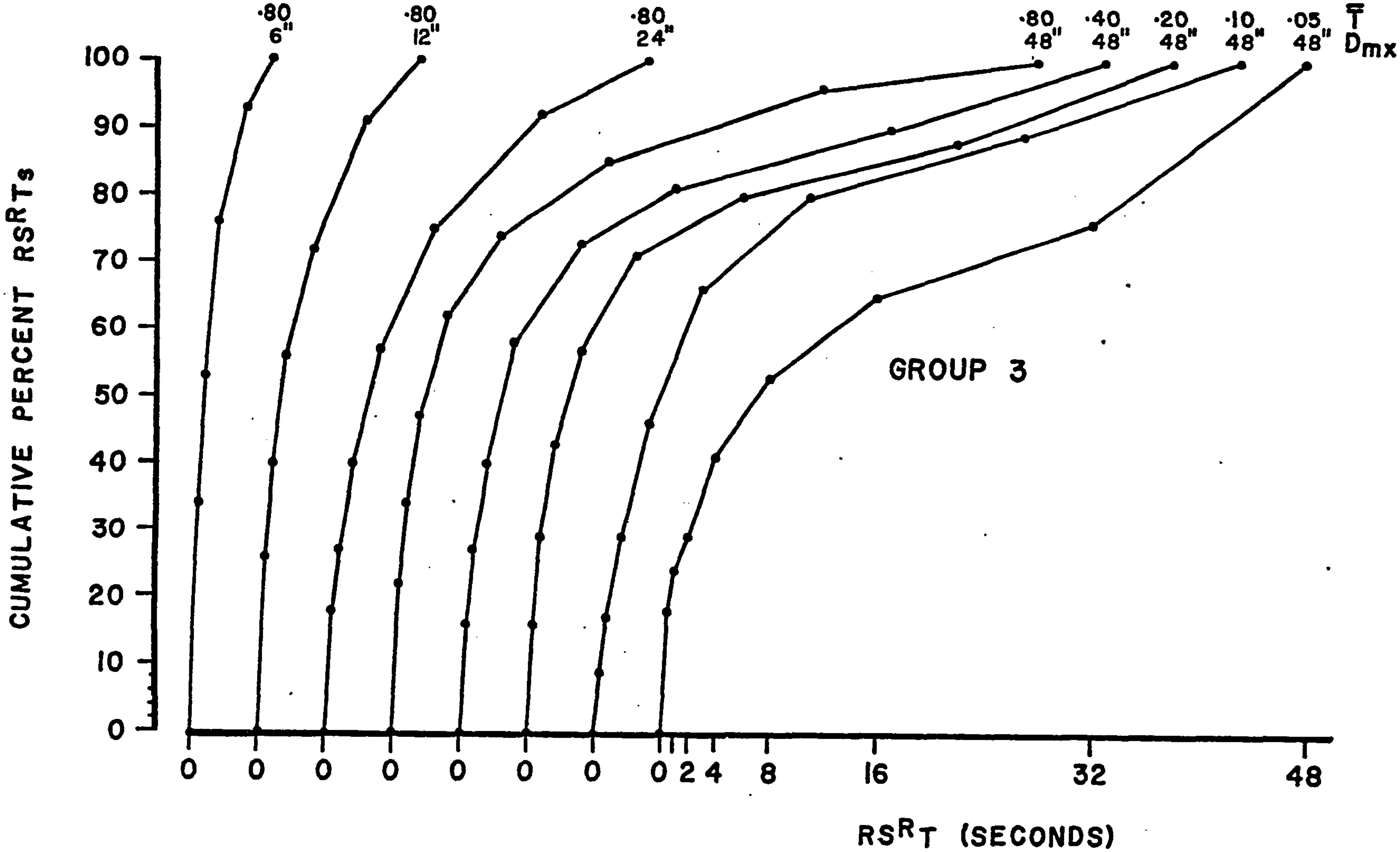
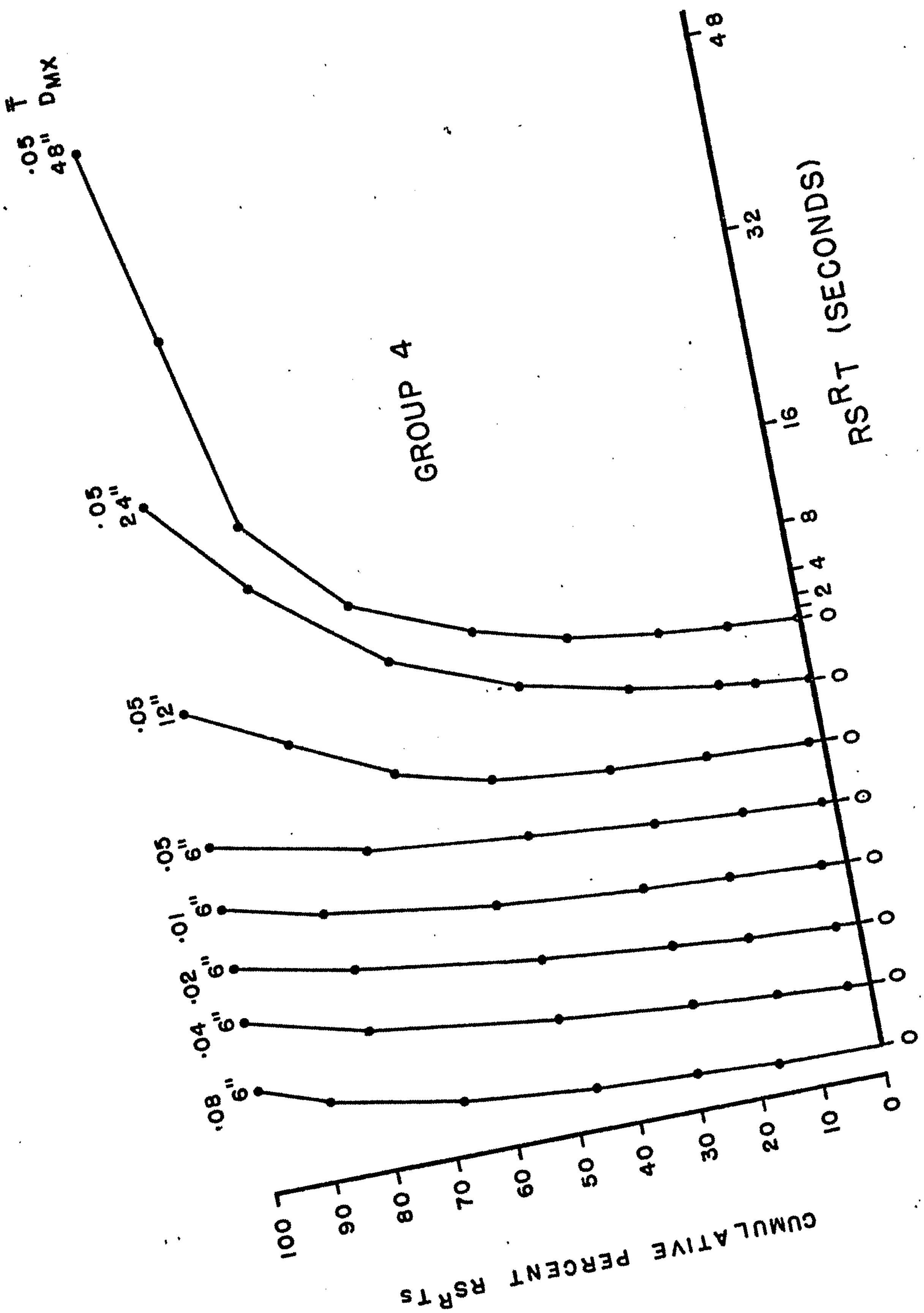

1"
2"
4"
6"
12"
24"
48" Dmx
CUMULATIVE PERCENT RSRTs
100
90
80
70
60
50
40
30
20
10
0
0 0 0 0 0 0 0 2 4 8 16 32 48
RSRT (SECONDS)
GROUP 2
T̄ = 0·10

Figure 50. Cumulative RS^RTs as a function of RS^RT class for Group 3. For clarity, each curve is displaced five units to the left of the curve immediately to its right.



·80 6"
·80 12"
·80 24"
·80 48"
·40 48"
·20 48"
·10 48"
·05 48"
T̄
Dmx
100
90
80
70
60
50
40
30
20
10
0
CUMULATIVE PERCENT RSRTs
GROUP 3
0 0 0 0 0 0 0 0 2 4 8 16 32 48
RSRT (SECONDS)

Figure 51. Cumulative $RS^{R}Ts$ as a function of $RS^{R}T$ class for Group 4. For clarity each curve is displaced five units to the left to the curve immediately to its right.


GROUP 4
RS^R T (SECONDS)
CUMULATIVE PERCENT RS^R Ts
.05 48"
.05 24"
.05 12"
.05 6"
.01 6"
.02 6"
.04 6"
.08 6"
0
2
4
8
16
32
48
100
90
80
70
60
50
40
30
20
10
0

APPENDIX A

Pretraining and Reshaping

The aim of the shaping procedures was simply to get the subjects responding in a typical fixed interval reinforcement pattern as quickly as possible. Since response patterns are strongly affected by reinforcement patterns, the pattern of reinforcement during initial training was made to resemble the expected pattern that would obtain once reinforcers were 100% response contingent. Following exposure to reinforcement schedule matrix values that produced in many subjects a cessation in responding, and prior to exposure to the final schedule value of the experiment, all subjects were exposed to the second key-peck shaping procedure described below.

Method

The first shaping procedure exposed eight subjects (Groups 1 and 2) to between 50 and 150 30-second t-cycles per session. Initially the number of t-cycles varied among subjects because of the variability in the times subjects took to first consume grain from the grain feeder. The white center-key light was turned on at the start of each t^D and was turned off with reinforcement. If a response was made to the lighted center-key within the t^D period, reinforcement was delivered immediately; if no response was made in t^D, the reinforcer was delivered

Table 7

Quartile $RS^{R}Ts$ (in seconds) for each distribution of $RS^{R}Ts$ for each D_{mx}.

D_{mx}	Q_3	Q_2	Q_1
1	0.59	0.31	0.09
2	1.08	0.59	0.25
4	1.76	0.85	0.37
6	3.03	1.39	0.51
12	4.58	1.71	0.59
24	7.09	2.55	0.86
48	13.08	3.59	1.04

automatically at the end of t^D. During reinforcement the repeating time cycle and the cumulative recorder were halted. The houselight was turned off during reinforcement during the first session only; thereafter it remained on continuously during the sessions. It was observed that many of the birds would tuck in their heads and crouch when a reinforcer was delivered, instead of eating from the hopper, and after a few reinforcer presentations would take up this stance as far as possible from the feeder. Since sudden novel changes in stimulation may produce this response in birds, efforts were then made to reduce such changes in stimulus intensities. Changes in auditory stimulation were reduced by putting more padding on the grain feeder where it struck the access hole in the intelligence panel and the white noise was introduced into the chamber to partially mask the feeder presentation sound as well as to mask extra-chamber noises.

The reinforcer presentation time depended on the feeding behavior of the individual subject. Initially the feeder was presented for as much as 18 seconds. However, the presentation was always terminated within 3 seconds after eating began. Only two birds were responding by the end of the first session. Beginning with the second session, those birds that were quickly eating from the feeder upon its presentation, but not yet pecking the center key received 3 seconds feeder presentation time for successive approximations to key-pecking during t^D periods.

During the second session, three of the eight birds made no responses. Session four was the first session in which all birds responded.

As the birds came to respond quickly to the lighted key, attempts were made to fade in the condition of continuous key-light during the t-cycle by turning on the key-light some seconds before the onset of t^D. The length of t^D continued to be 6 seconds. At first many of the birds ceased responding after only a few unreinforced pecks on the lighted center-key, even though they responded with short latencies to key-light onset. It seems that it was the key-light onset rather than the key-light *per se* that had become the discriminative stimulus for responding. Not until the sixth session (Session 006) did all birds receive continuous key-light during the t-cycles. From Session 007 through Session 020, the subjects from Groups 1 and 2 received 50 t-cycles per session (see Table A1).

The information provided by the results from the first shaping procedure was used to design the second shaping procedure. The first and second sessions were 50 t-cycles long. For the remainder of the experiment, the sessions were 25 t-cycles long. The remaining eight birds (Groups 3 and 4) were exposed to the second shaping procedure (see Table A2). Sharp changes in stimulus intensities were reduced as before by leaving the houselight on throughout the sessions and by introduction of the white noise. The feeder also remained padded. A

Table A1

Pretraining and Reshaping Schedules

Group 1: B62, B75, B96, B04.

Session	T	$\overline{T}$	D_{mx}	S^D	Cycles
001- 006	30	0.20	*	Normal	50-150
007- 020	30	0.20	0	Normal	50
1201-1202	60	0.10	**	Gold	25

Group 2: B84, B30, B49, B61.

Session	T	$\overline{T}$	D_{mx}	S^D	Cycles
001- 006	30	0.20	*	Normal	50-150
007- 020	30	0.20	0	Normal	50
1101	60	0.10	**	Gold	25

Note: A D_{mx} of "*" means that the first autoshaping procedure was being used and the maximum time between an S^R and the previous R was unlimited although the first R in t^D would produce an immediate S^R. A D_{mx} of "**" means that the second autoshaping procedure was used.

Table A2

Pretraining and Reshaping Schedules

Group 3: B342, B375, B390, B225.

Session	T	$\bar{T}$	D_{mx}	S^D	Cycles
001- 002	60	0.10	**	Gold	50
003	60	0.20	**	Gold	25
1001	60	0.10	**	Gold	25

Group 4: B32, B242, B264, B341.

Session	T	$\bar{T}$	D_{mx}	S^D	Cycles
001- 002	60	0.10	**	Gold	50
003	60	0.20	**	Gold	25
1001	60	0.10	**	Gold	25

Note: A D_{mx} of "**" means that the second autoshaping procedure was used and the maximum time between an S^R and the previous R was unlimited although the first R in t^D would produce an immediate S^R.

translucent gold cover was also placed over the houselight instead of the regular cover, but it is uncertain that this had any effect. In addition to reducing sharp changes in the intensity of ambient stimulation, changes were also decreased in frequency by increasing the t-cycle length to 60 seconds on the assumption that the effects of sudden novel changes in stimulation are non-cumulative if the changes are spaced sufficiently far apart. The center key was lighted during the 6-second t^D period and if no response was made in t^D, reinforcement was presented automatically at the end of t^D and the key light went off. Reinforcement presentation time was constant at 3 seconds even if the birds did not eat. If a response was made during t^D, reinforcement was delivered immediately. The key light went off during reinforcement as before, but came on again for the remainder of t^D as soon as reinforcement presentation terminated. This served presumably to remove the discriminative stimulus function of key-light onset. Exactly one S^R was given in each t-cycle.

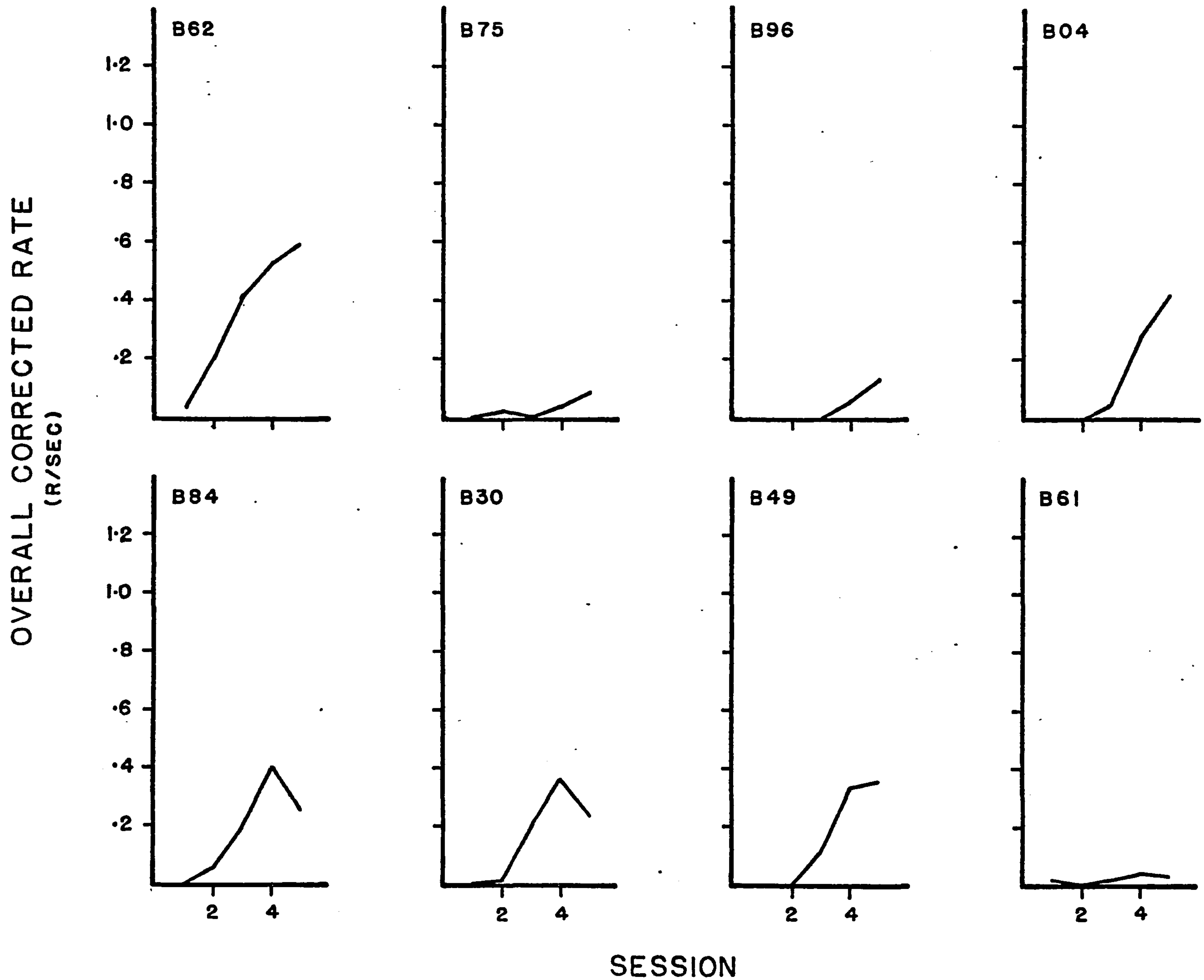
By the end of the first 50 minute session, although no prior adaptation to the chamber, no magazine training and no reinforcement of successive approximations to key pecking was given, six of the eight birds were responding whenever the key light was on, both before and after reinforcement. By the end of the second 50 minute session, all birds were responding. Most birds made few or no responses while the key light was off. On the third day the session was shortened to 25 time cycles, and the key light (and t^D) lengthened to 12 seconds after onset of the cycle. After the third session of pretraining Groups 3 and 4, they were shifted into the first phase of the main experiment.

Results

The effects of pretraining were measured in the following terms: 1) overall corrected rate of responding per session — corrected rate of responding was calculated according to the formula $R/(T_t - T_{(S^R)})$ where R is the number of key-pecks recorded, T_t is the total session time, and $T_{(S^R)}$ is the total reinforcement access time; 2) local corrected rate of responding — each t-cycle was divided into six-second subintervals and the average corrected rate of key-pecking was separately calculated for each subinterval of the t-cycle; 3) overall running rate of responding per session — running rate of responding was calculated according to the formula $R/(T_t - T_{(S^R)} - T_{PS^RP)})$, where R, T_t, and $T_{(S^R)}$ are defined as before, and $T_{(PS^RP)}$ is the total post-reinforcement pause time per session; 4) mean PS^RP; and 5) mean responses per contingent S^R.

Figure A1 presents the overall corrected rates for the first five sessions of Point 0 for the individual subjects of Groups 1 and 2. The acquisition of key-pecking was quite irregular. Four of the eight birds showed rate reversals across

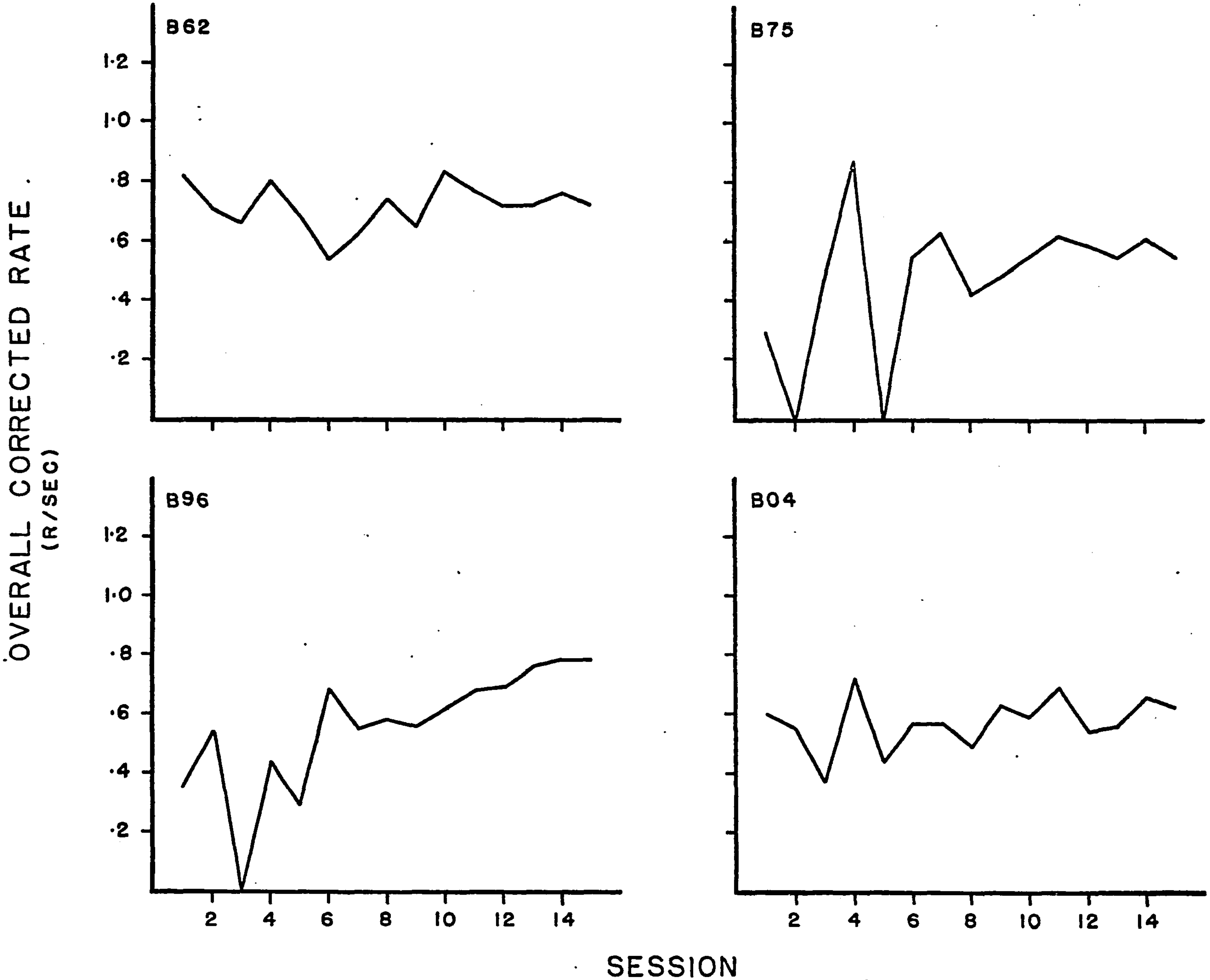
Figure A1. Overall corrected rates of responding for the first five sessions of Point O, shaping procedure number one, for the individuals of Groups 1 and 2.


OVERALL CORRECTED RATE
(R/SEC)
B62
B75
B96
B04
B84
B30
B49
B61
1·2
1·0
·8
·6
·4
·2
2
4
SESSION

the five sessions. The highest response rate, 0.59 responses per second, was given by B62 on the fifth session. The subject B61 never gave over 0.04 responses per second per session. Overall corrected rates for the last fifteen sessions of Point O are shown in Figures A2 and A3. Three of the eight subjects (B75, B96, and B61) made no responses during one or more of these fifteen sessions. There was no apparent reason for these lapses in responding. By the end of the last fifteen sessions of Point O, the subjects were responding at rates between 0.25 and 1.30 responses per second.

The local corrected rates of responding for the individuals of Groups 1 and 2 are presented in Figures A4 and A5. The response rates (means of 1.27 and 1.30 R/sec respectively for Groups 1 and 2, computed over the last five sessions of Point O) in the fifth and last subinterval of the 30-second t-cycle are generally higher than the corrected response rates computed for the remaining subintervals. Only the fourth subinterval occasionally had higher response rates. The third or middle subinterval showed a response rate of about half that found in the fifth subinterval. The second subinterval showed a response rate of about a third of that found in the third subinterval. The first subinterval had rates approximately equal to that of the second subinterval, but had much less variability among sessions than did any of the other subintervals. For three of the eight birds (B96, B84, and B30) the terminal (fourth and

Figure A2. Overall corrected rates of responding for the last fifteen sessions of Point 0 (vector value (30"T, $0.20\overline{T}$, $0''D_{mx}$)), for the individuals of Group 1.



OVERALL CORRECTED RATE
(R/SEC)
B62
B75
B96
B04
1·2
1·0
·8
·6
·4
·2
2
4
6
8
10
12
14
SESSION

Figure A3. Overall corrected rates of responding for the last fifteen sessions of Point O (vector value (30"T, 0.20$\overline{\mathrm{T}}$, 0"D_{mx})), for the individuals of Group 2.

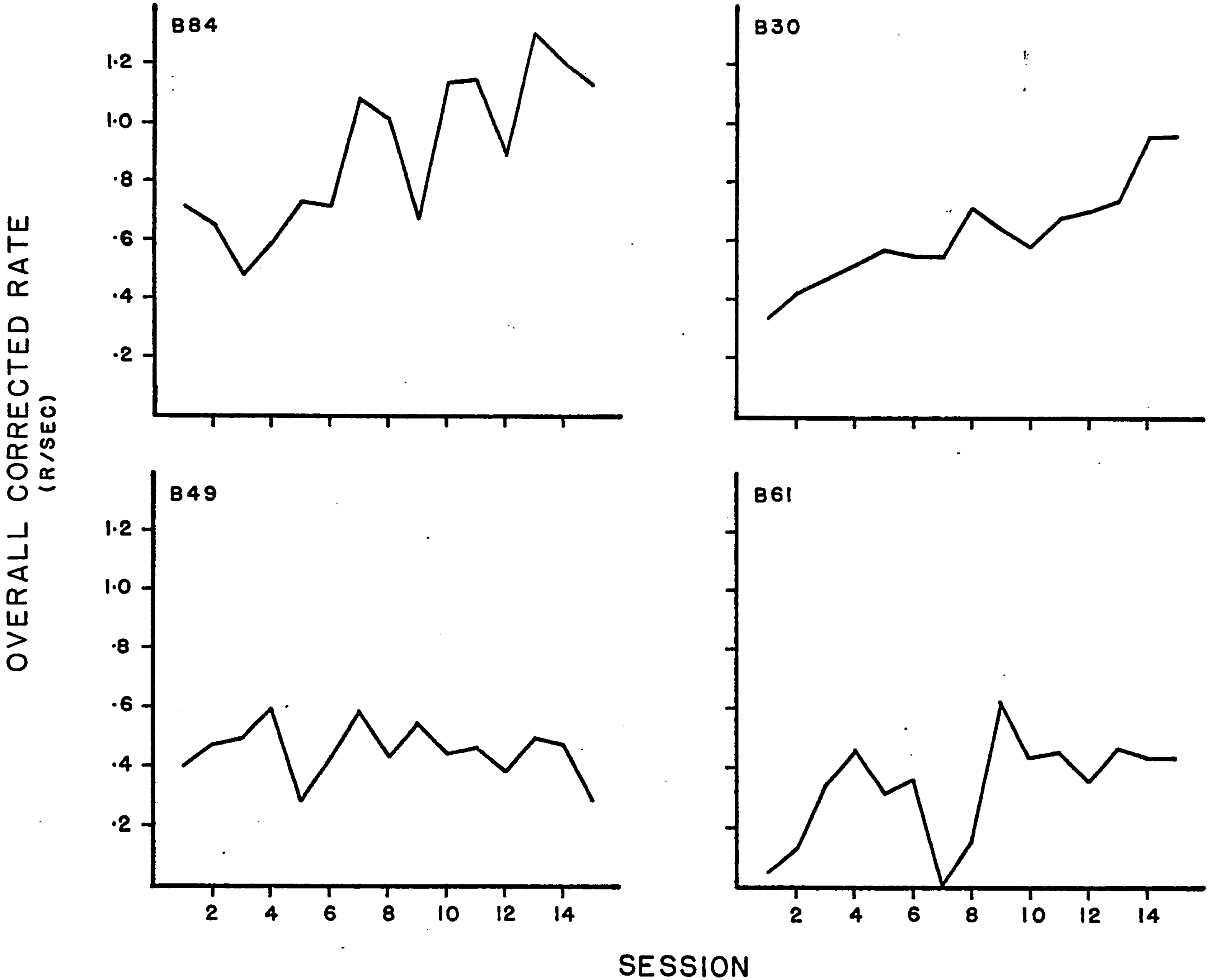

OVERALL CORRECTED RATE
(R/SEC)
B84
B30
B49
B61
·2
·4
·6
·8
1·0
1·2
2
4
6
8
10
12
14
SESSION

Figure A4. Local corrected rates of responding for the individuals of Group 1 during the last fifteen sessions of Point 0 (vector value (30"T, 0.20$\overline{T}$, 0"D_{mx})). Each line represents the mean corrected rate during one of the five six-second subintervals of the t-cycle. See text for further description.

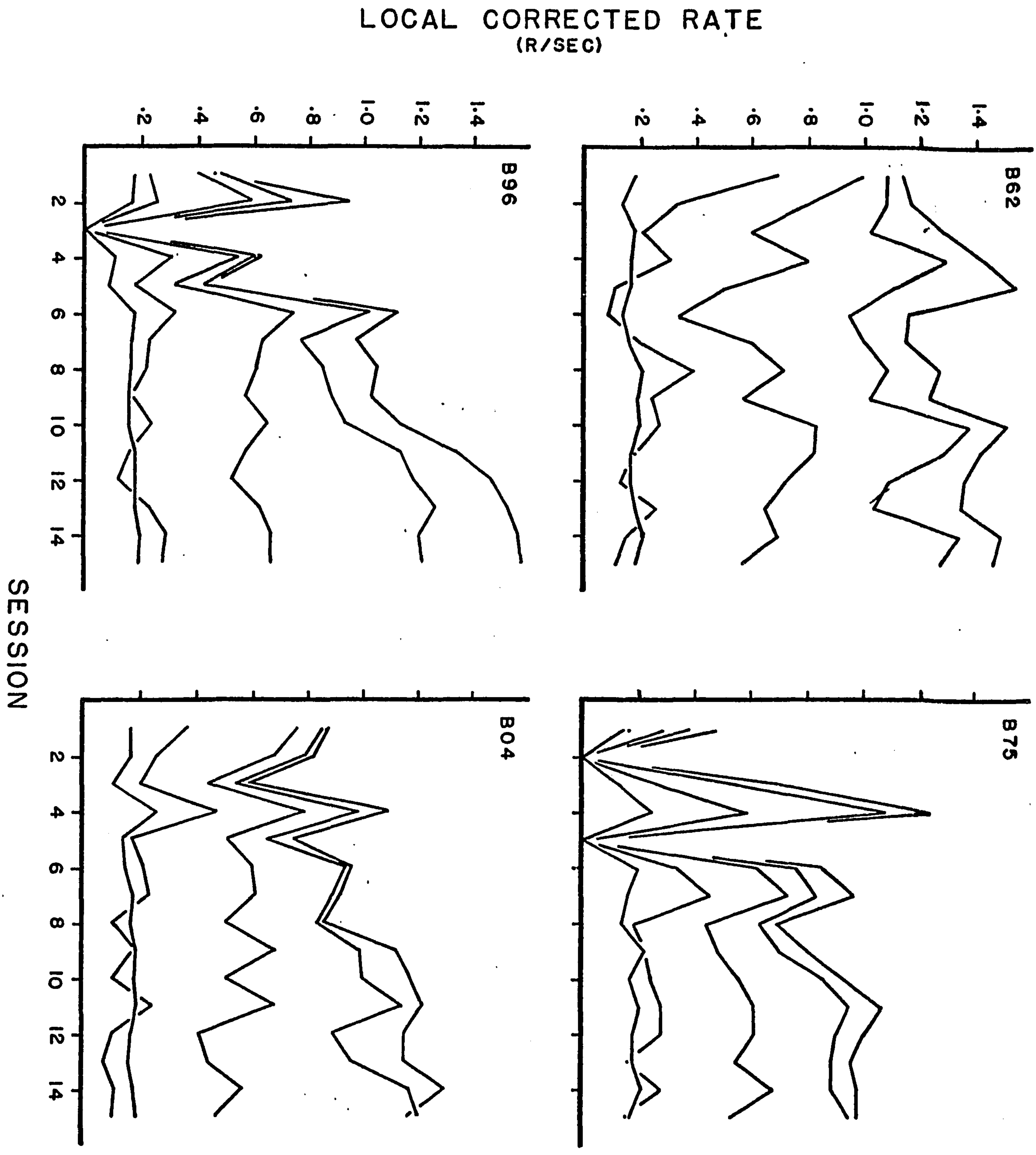
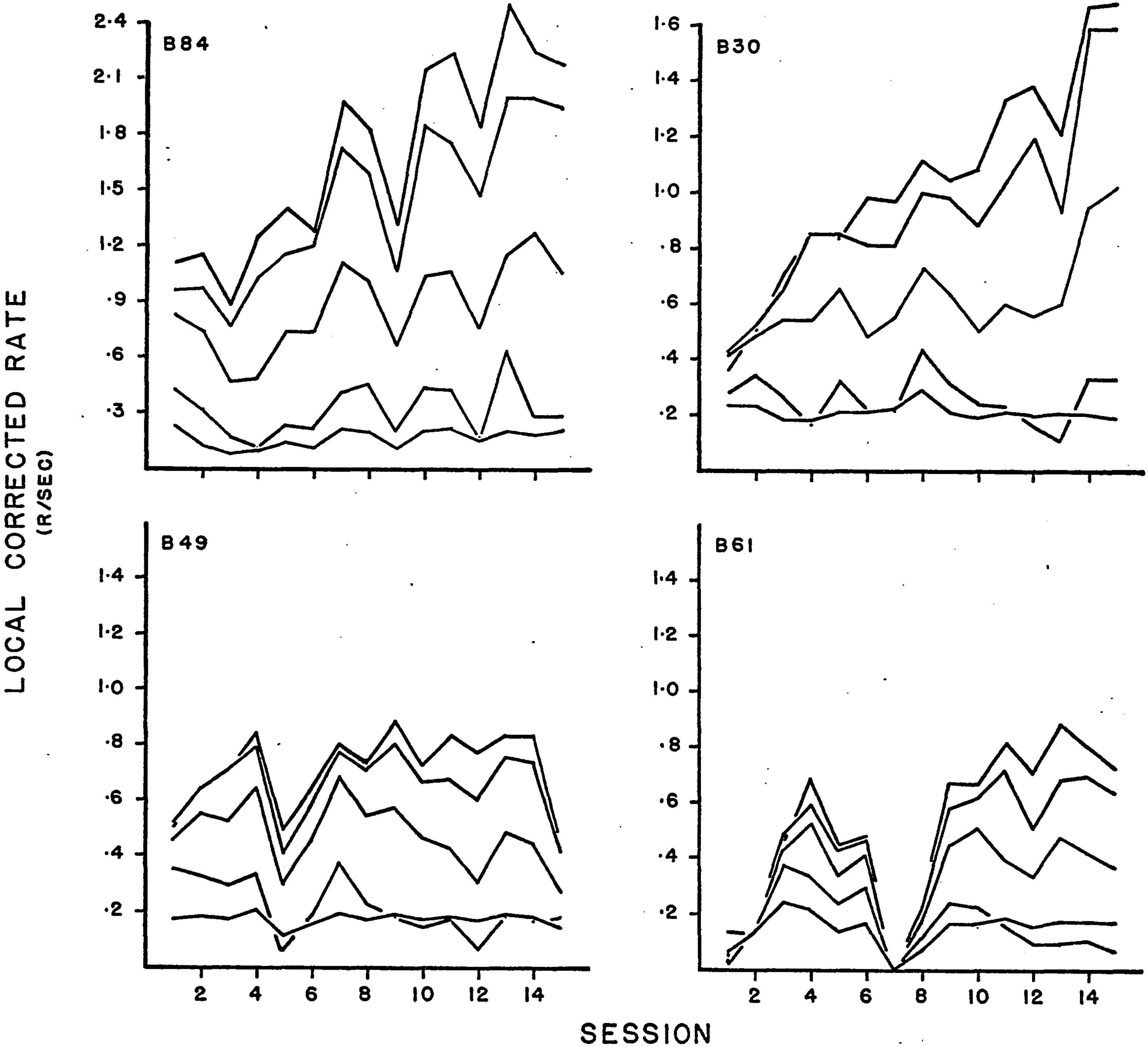

LOCAL CORRECTED RATE
(R/SEC)
B62
B75
B96
B04
SESSION

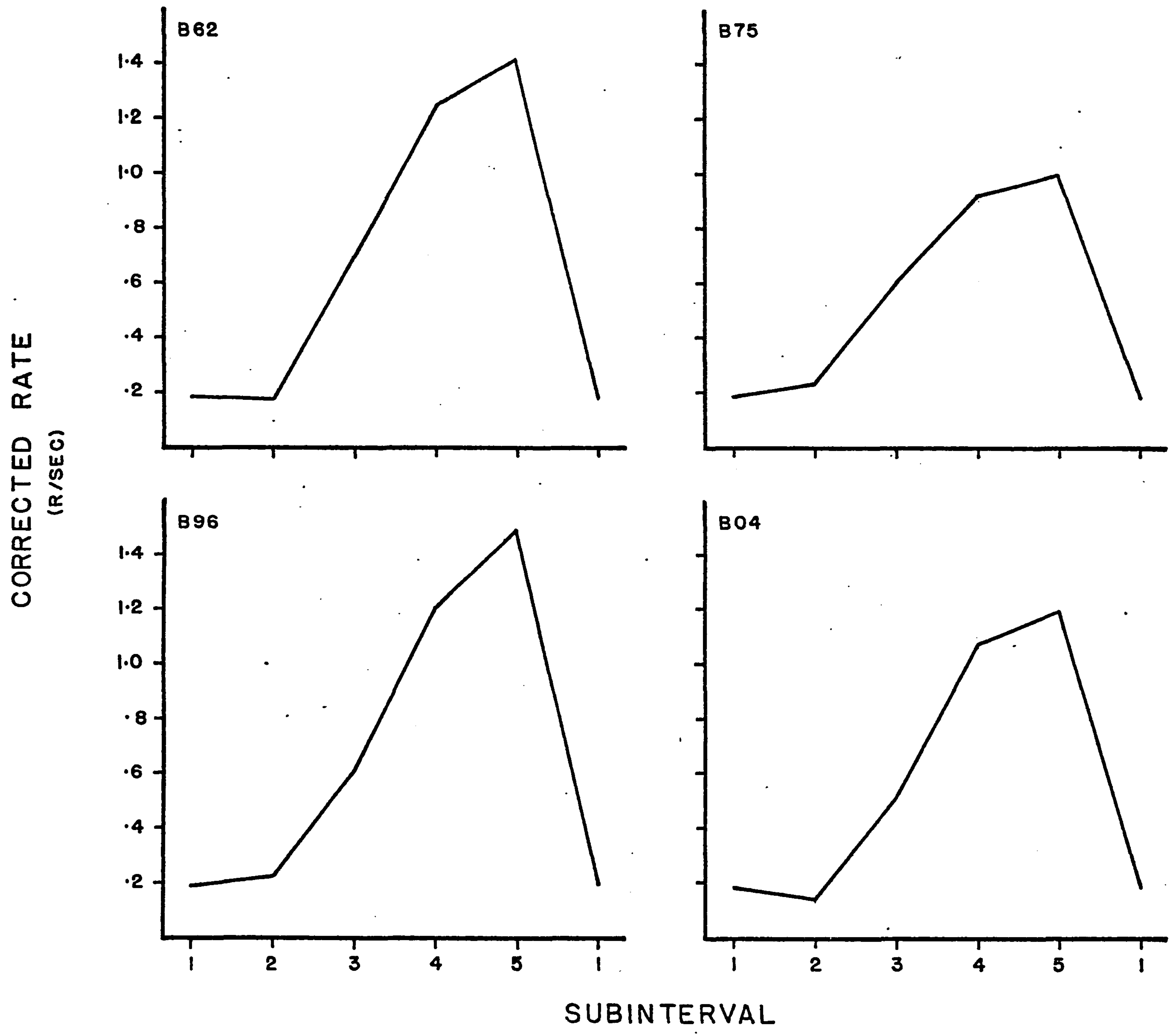
Figure A5. Local corrected rates of responding for the individuals of Group 2 during the last fifteen sessions of Point 0 (vector value (30"T, 0.20$\overline{T}$, 0"D_{mx})). Each line represents the mean corrected rate during one of the five six-second subintervals of the t-cycle. See text for further description.


LOCAL CORRECTED RATE
(R/SEC)
B84
B30
B49
B61
2·4
2·1
1·8
1·5
1·2
·9
·6
·3
1·6
1·4
1·2
1·0
·8
·6
·4
·2
2
4
6
8
10
12
14
SESSION

fifth subintervals) response rates were still increasing when the pretraining point (Point 0) was terminated. The plan of the experiment did not however call for prolongation of Point 0. For the remainder of the subjects and subintervals, response rates were showing no marked increases when Point 0 was terminated and Point 1 (the first experimental point) begun. It would seem that response rates level off more quickly for the first subintervals of the t-cycle. The mean corrected rates per subinterval are summarized in Figures A6 and A7 for the last five sessions of Point 0. The full cycle, from Subinterval 1 to Subinterval 1, is shown to emphasize the depressant effect of reinforcement as well as to show the acceleration in corrected rates after reinforcement.

The overall running rates of responding per session were quite similar in form, though not in overall height, to the overall corrected rates of responding (compare Figures A8 and A9 with Figures A2 and A3). The overall running rates shown in Figures A8 and A9 frequently exceeded the corresponding corrected rates in the terminal subinterval of the t-cycle (see Figure A4 and A5). This is evidence that most of the "scallop" in the corrected rates of responding per subinterval is due to the variability in pause size after reinforcement rather than to a steady decrease in IRT (inter-response time) size as time after reinforcement increases. The cumulative records support this judgment.

Figure A6. Mean corrected response rates per t-cycle subinterval for the last five sessions of Point 0, for the individuals of Group 1.



CORRECTED RATE
(R/SEC)
B62
B75
B96
B04
·2
·4
·6
·8
1·0
1·2
1·4
1
2
3
4
5
1
SUBINTERVAL

Figure A7. Mean corrected response rates per t-cycle subinterval for the last five sessions of Point 0, for the individuals of Group 2.

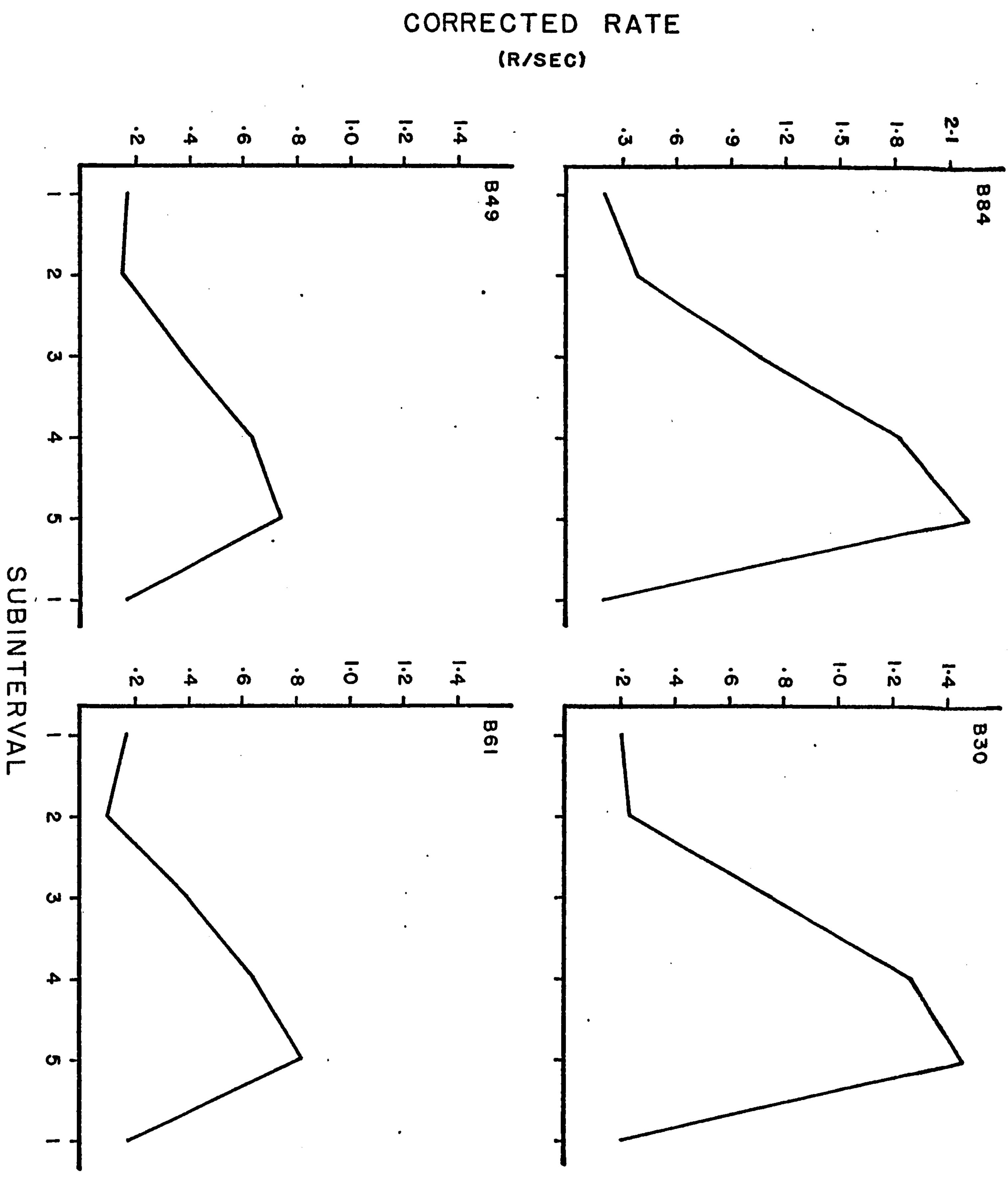

CORRECTED RATE
(R/SEC)
SUBINTERVAL
B84
B30
B49
B61

Figure A8. Overall running rates of responding per session for the individuals of Group 1 during the last fifteen sessions of Point O.

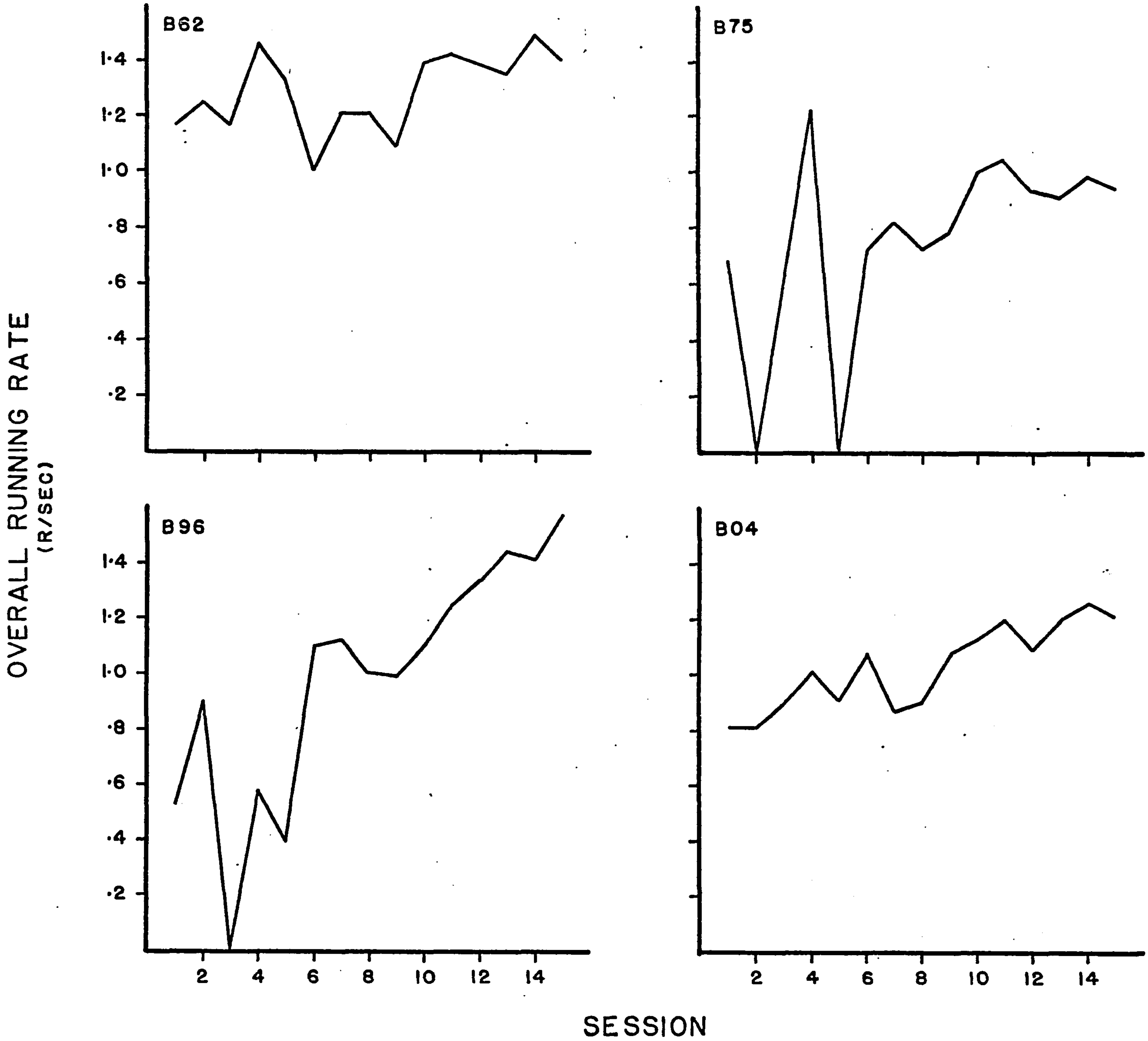
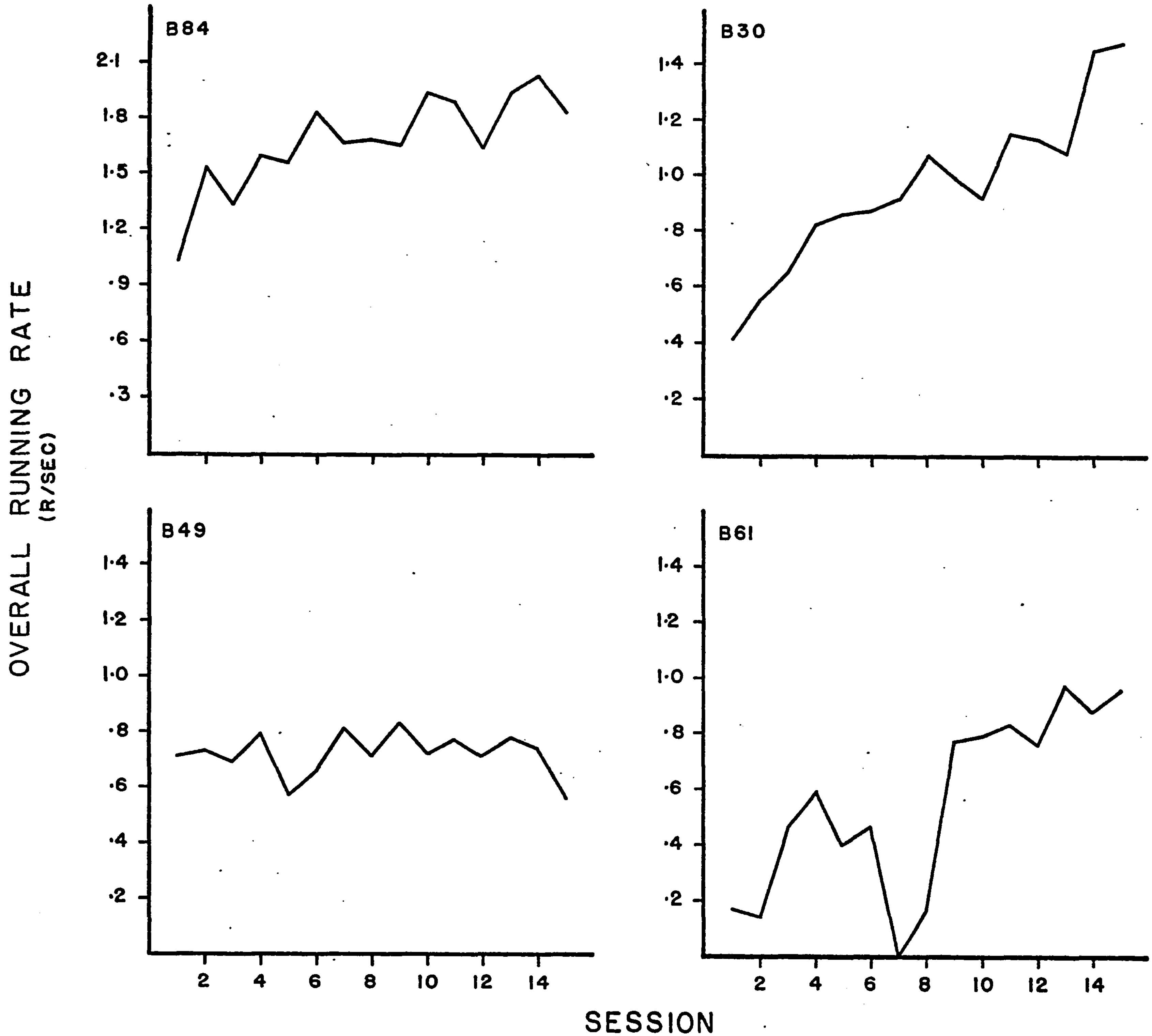

OVERALL RUNNING RATE
(R/SEC)
B62
B75
B96
B04
·2
·4
·6
·8
1·0
1·2
1·4
2
4
6
8
10
12
14
SESSION

Figure A9. Overall running rates of responding per session for the individuals of Group 2 during the last fifteen sessions of Point O. Note the change in scale of the ordinate for subject B84.


OVERALL RUNNING RATE
(R/SEC)
B84
2·1
1·8
1·5
1·2
·9
·6
·3
B30
1·4
1·2
1·0
·8
·6
·4
·2
B49
1·4
1·2
1·0
·8
·6
·4
·2
B61
1·4
1·2
1·0
·8
·6
·4
·2
2
4
6
8
10
12
14
SESSION

The mean pause after reinforcement was quite stable for most birds. Subject B84 had pauses averaging 1.38 t-cycles on the third session of Figure A11 (Session 008) but by the tenth session of this panel (Session 015) the mean PS^RP ranged between 0.33 t-cycle and 0.50 t-cycle. During the last five sessions no individual had a mean PS^RP exceeding 0.66 t-cycle, or less than 0.33 t-cycle. The mean PS^RP for the last five sessions was 0.47 and 0.44 for Group 1 and Group 2 respectively. In Figures A10 and A11 there are gaps left in the data for B75, B96 and B61. For the sessions associated with these gaps there were no reinforcers delivered and mean PS^RPs could therefore not be computed. The gaps represent values interpolated from values at the surrounding sessions.

Finally, Figures A12 and A13 show the mean number of responses emitted per reinforcement per session. Subject B84 emitted the most responses per reinforcement (a mean of 34.3 for the last five sessions of Point 0), and B49 and B61 emitted the fewest (13.0 and 13.4 responses per reinforcement respectively). The remaining birds ranged between a mean of 18.1 and 23.4 responses per reinforcement for the last five sessions of Point 0. The mean for Group 1 was 20.5; for Group 2 it was 21.2.

Groups 3 and 4 had only three sessions of pretraining rather than the 20 sessions which Groups 1 and 2 had. As described in the method section above, the second shaping procedure was used to establish a substantial probability of key-

Figure A10. Mean post-reinforcement pause time in t-cycle units for the individuals of Group 1 for the last fifteen sessions of Point 0. The t-cycle was 30 seconds in length. Gaps in the data lines represent interpolated values of $PS^{R}P$. There were no reinforcements delivered during these sessions.

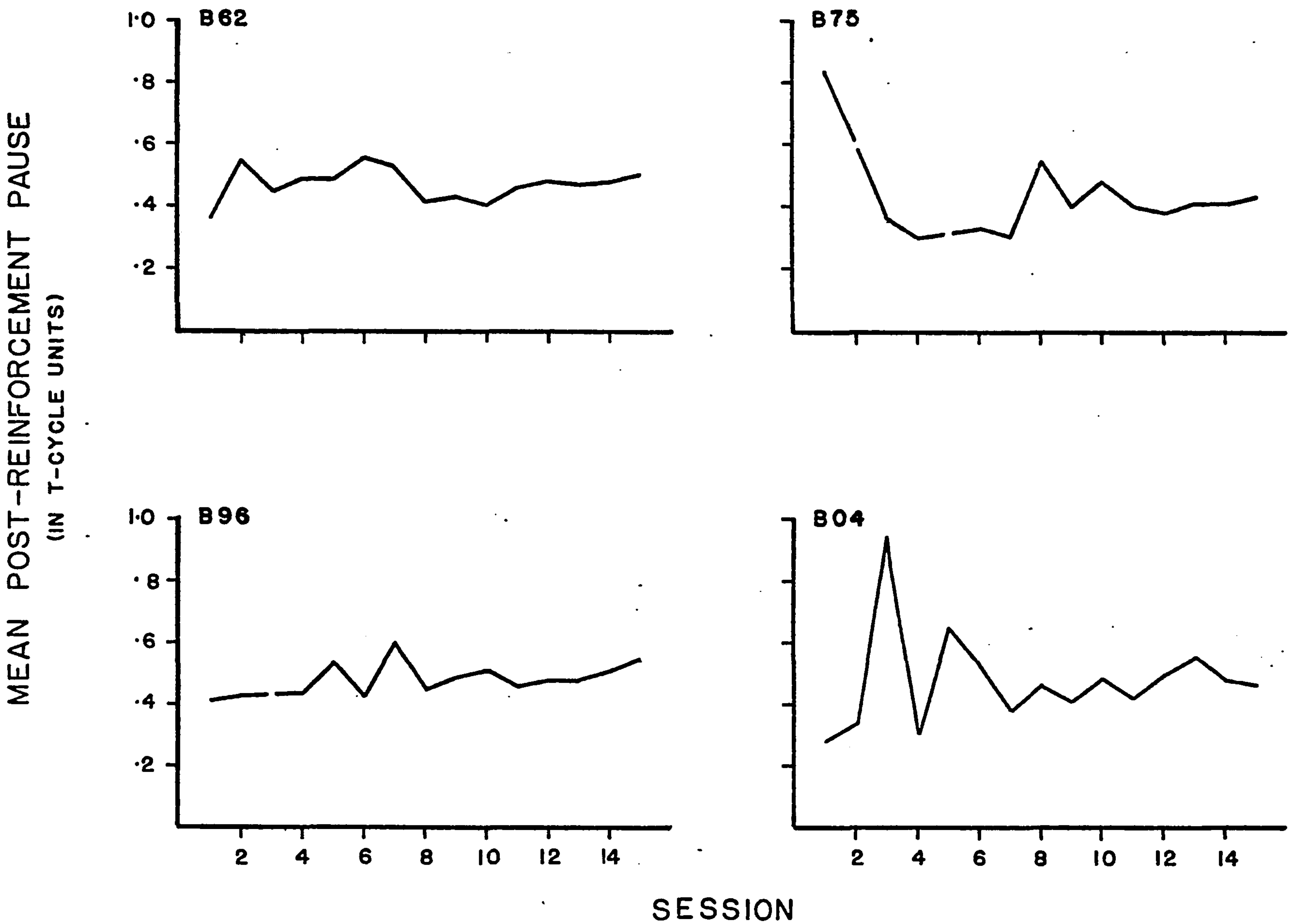
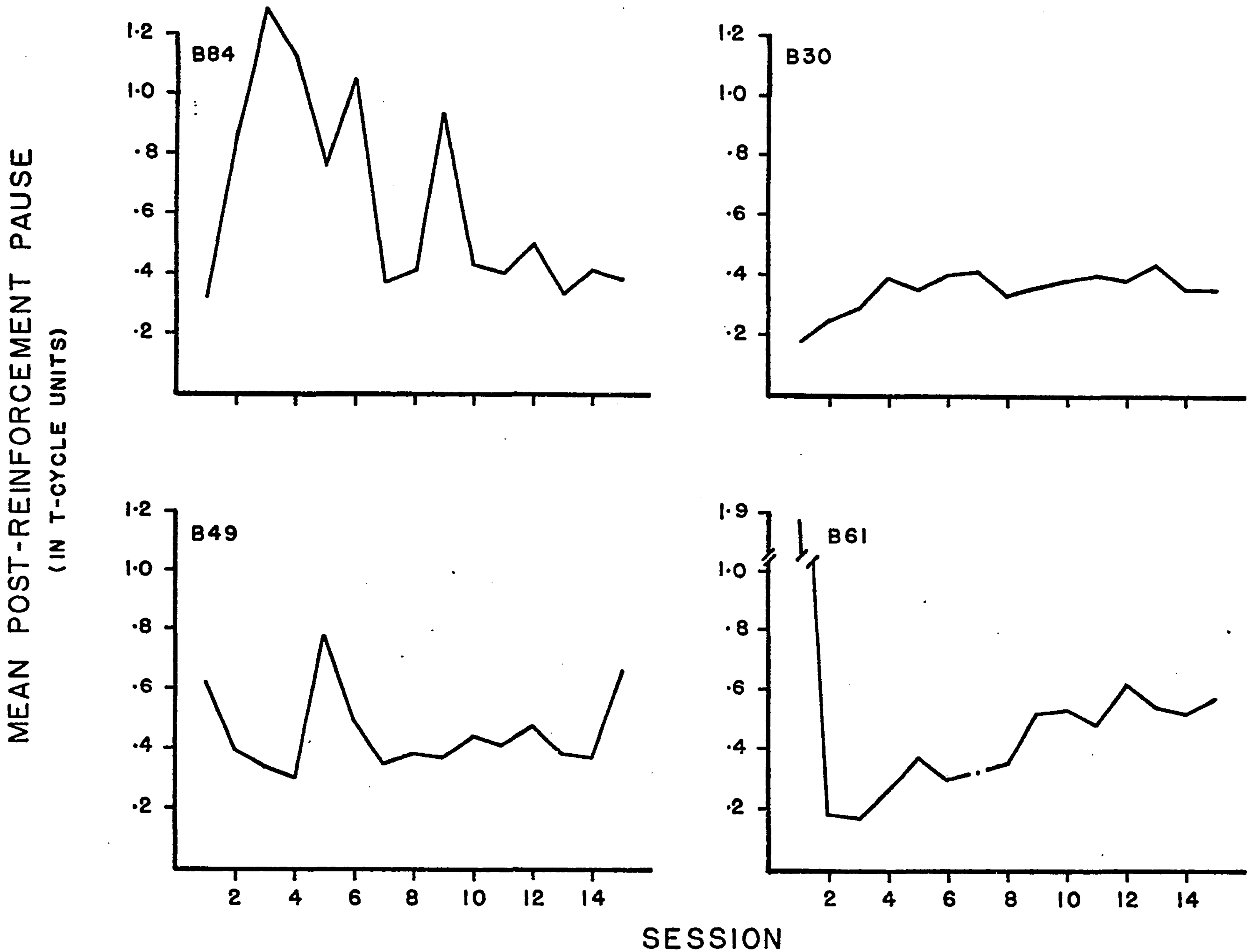

MEAN POST-REINFORCEMENT PAUSE
(IN T-CYCLE UNITS)
B62
B75
B96
B04
SESSION

Figure A11. Mean post-reinforcement pause time in t-cycle units for the individuals of Group 1 for the last fifteen sessions of Point 0. The t-cycle was 30 seconds in length. The gap in the data at the seventh session (Session 012) for subject B61 represents the interpolated value of the $PS^{R}P$. No reinforcements were delivered to this bird for this session.



MEAN POST-REINFORCEMENT PAUSE
(IN T-CYCLE UNITS)
B84
B30
B49
B61
SESSION

Figure A12. Responses per reinforcement per session during the last fifteen sessions of Point 0 for the individuals of Group 1. Gaps in the data lines of subjects B75 and B96 represent interpolated values from the surrounding sessions. No reinforcers were delivered during those sessions because of insufficient responding.

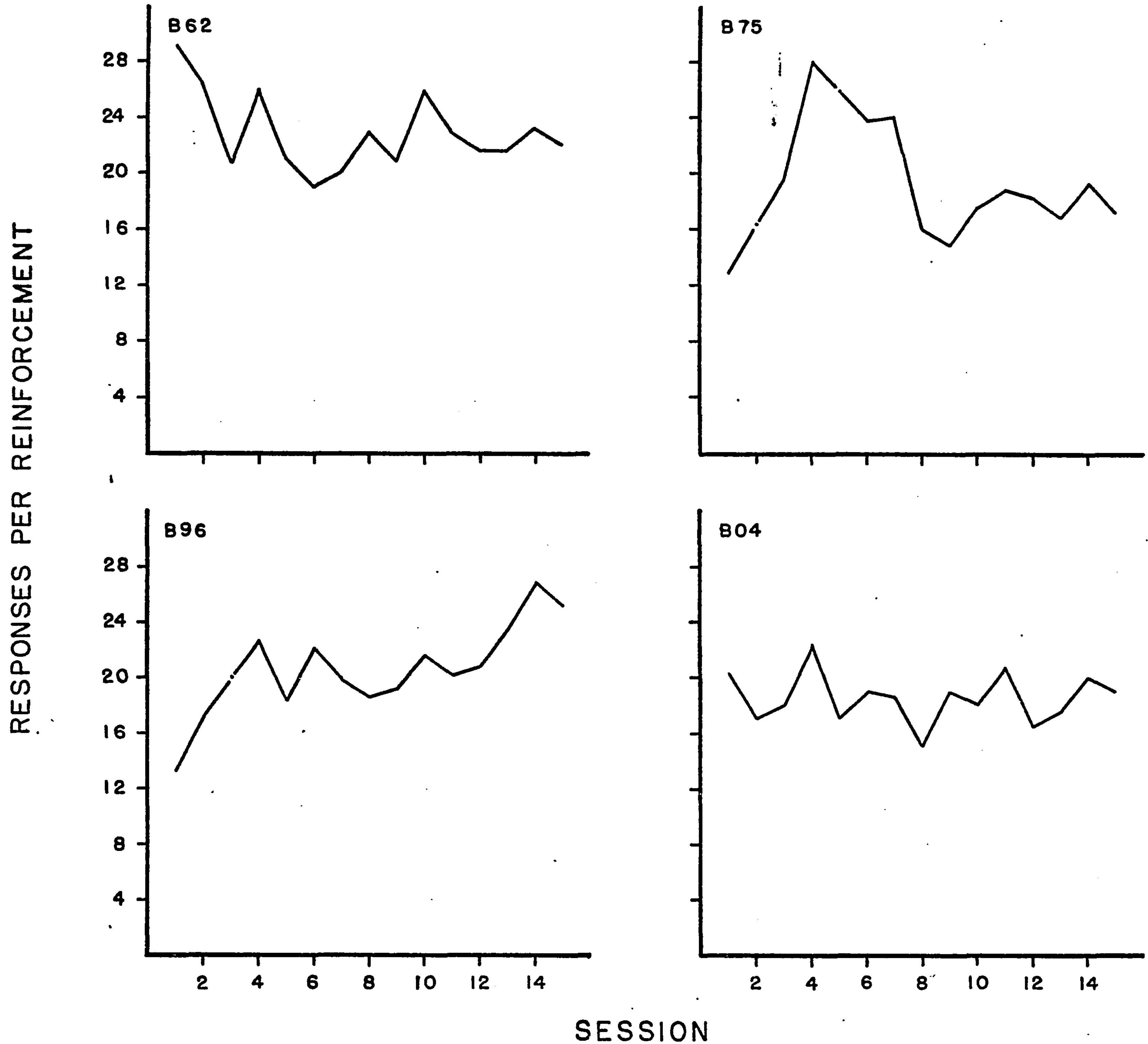
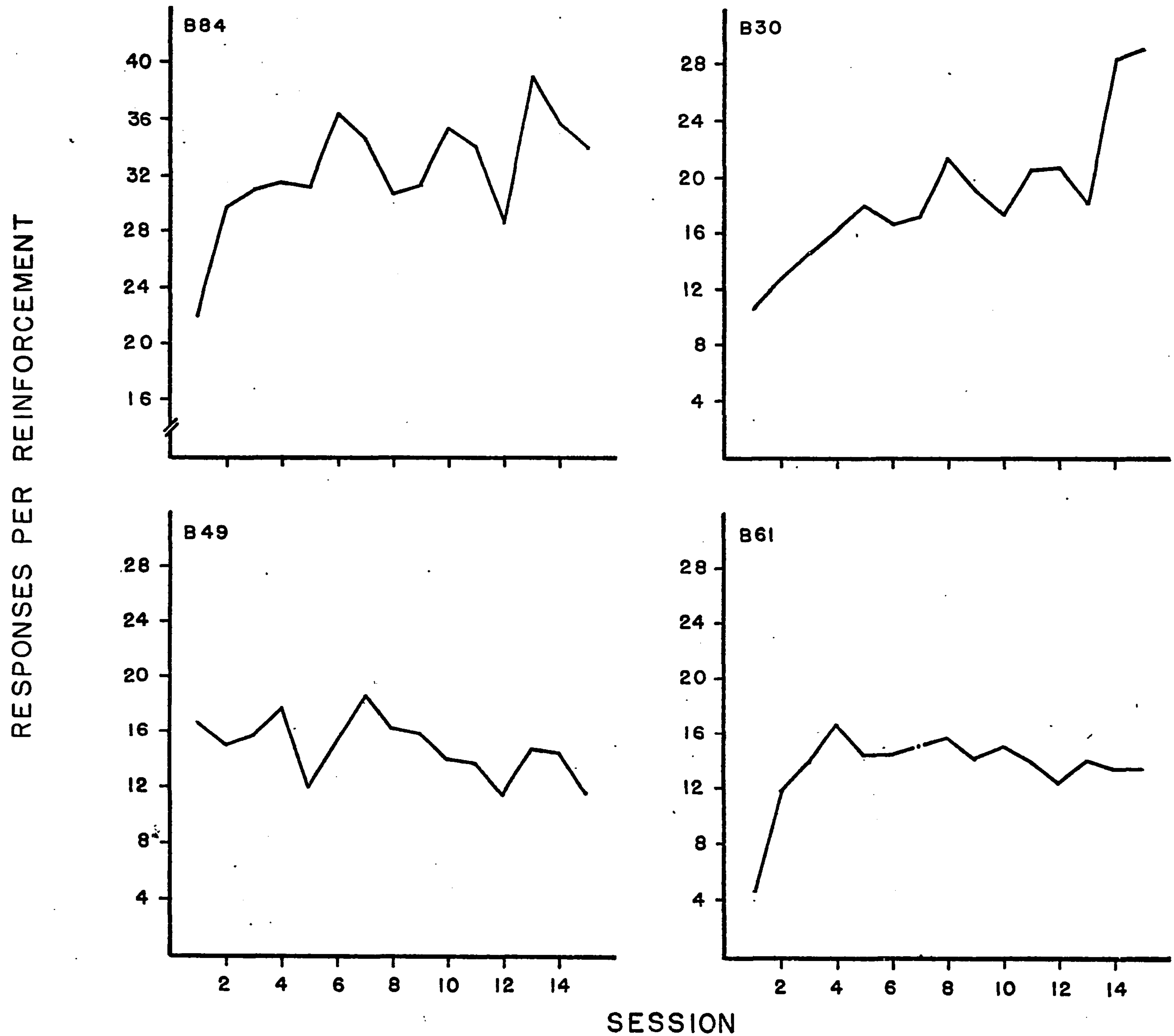

B62
B75
B96
B04
RESPONSES PER REINFORCEMENT
SESSION
28
24
20
16
12
8
4
2
4
6
8
10
12
14

Figure A13. Responses per reinforcement per session during the last fifteen sessions of Point 0 for the individuals of Group 2. The gap in the data line of B61 represents an interpolated value from the surrounding sessions. No reinforcers were delivered during that session because of insufficient responding.


RESPONSES PER REINFORCEMENT
B84
B30
B49
B61
40
36
32
28
24
20
16
12
8
4
2
6
10
14
SESSION

pecking before the first experimental point was begun. The mean proportions of contingent reinforcers for Group 3 for the first, second, and third sessions was 0.20, 0.79 and 0.98 respectively. For Group 4 the mean proportions were 0.13, 0.96, and 0.99 for the first, second, and third sessions respectively. Similarly, median values were 0.09, 0.80, and 0.98 for Group 3, and 0.09, 0.97, and 1.00 for Group 4.

The overall corrected rates of responding were quite low in comparison to those typically found in asymptotic performance under a fixed-interval one-minute schedule of contingent reinforcement. The mean responses per second were 0.01, 0.05, and 0.07 for Group 3 and 0.01, 0.07, and 0.07 for Group 4. The medians were 0.003, 0.048 and 0.062 for Group 3, and 0.003, 0.074, and 0.076 for Group 4. The response rates may be lower for two reasons. One is that subjects were initially naive to the experimental situation and naive subjects typically require several sessions before their response rates reach their maxima. The second reason is that differential response rates generally ensue when various stimulus states (such as light-on, light-off) are differentially associated with different probabilities of immediate reinforcement. The discrimination indices for the mean corrected rates of the first, second and third sessions for Groups 3 and 4 were 0.989, 0.979 and 0.995, and 0.706, 0.990 and 0.941 respectively, indicating a strong depression of response probability during t^{Δ}. The running rates were also lower than those usually found in asymptotic performance. Group 3 responded with mean rates of 0.11 0.08 and 0.11 responses per second for the first, second and third pretraining sessions respectively. Similarly, Group 4 responded with rates of 0.08, 0.09 and 0.09 respectively.

The mean pause times per reinforcement (both contingent and noncontingent) were 0.88, 0.40 and 0.38 t-cycles for the three pretraining sessions for Group 3. For Group 4 they were 0.93, 0.21 and 0.22 t-cycles. The median PS^RPs for Groups 3 and 4 for these sessions were respectively 0.99, 0.39 and 0.32, and 0.86, 0.16 and 0.16 t-cycles. Interpretation of these figures must be undertaken with caution. First, the number of reinforcements per session was an independent variable. The number was 50 in Sessions 001 and 002, and 25 in Session 003. Furthermore, the maximum pause after a given S^R was 66 seconds because pause times were not permitted to overlap. That is, pauses were terminated not only by the first response after an S^R but also by the next S^R. The maximum mean PS^RP was therefore 1.00 t-cycle. This consideration becomes less important as a higher proportion of S^Rs are response-produced. Other factors must then be considered, such as the high discrimination indices reported above. It is the belief of this author that the distribution of pause lengths was bimodal with peaks at $PS^RP < t^D$ sec, and $PS^RP \approx 60$ sec. That is, after a reinforcement the subject would often begin responding again before t^D

(and S^D) terminated, only to stop when S^Δ began. This would produce a short PS^RP of less than 6 seconds (or 12 seconds for Session 003). If no response was made before S^D termination, then the PS^RP would generally be terminated with the next t^D onset. The mean PS^RPs for the last two pretraining sessions are then basically weighted averages of these two modal values rather than representatives of values which actually occurred at a high frequency.

The mean numbers of responses per contingent reinforcer were quite low — 2.88, 3.70, and 4.02 for Sessions 001, 002 and 003 respectively for Group 3 (the mean value for Session 001 is computed using only the two subjects that obtained contingent reinforcers). For Group 4 the values were 1.97, 4.24, and 4.24 responses per contingent S^R for the first three sessions.

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