

STIMULUS GENERALIZATION AND MATCHING  
IN CONCURRENT VARIABLE INTERVAL SCHEDULES

by

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B.A., State University College at Cortland, N.Y., 1976

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A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Psychology

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1982

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## ACKNOWLEDGEMENTS

It is my fine pleasure to have this opportunity to acknowledge the close supervision and extensive guidance of Dr. Charles C. Perkins, whose approach to the analysis of performance wholly enabled the analytical insights and methodological developments presented herein.

I would also like to acknowledge the extremely numerous behaviors of Debra Larsson, the extent of which limited my goals sufficiently to allow the preparation of this thesis to reach its inexorable conclusion.

And, thankfully, it is necessary to acknowledge my central model, my father, whose great diligence, dedication, and integrity define objectives which I hope one day to fulfill.

E.V.L.

### Stimulus Generalization Gradients

Stimulus generalization has been defined in a number of ways (Kalish, 1969; Heineman and Chase, 1975; Rilling, 1977; Bitterman, 1979). All seem to refer to the effect of conditioning a response to one stimulus on the tendency for this response to occur during similar stimulus conditions. A gradient of stimulus generalization is obtained when there exists a function relating the measures of performance to the stimulus dimension on which both the training and test stimuli fall. No general theory of learned behavior change can be complete without accounting for the phenomenon of stimulus generalization (Guttman, 1963; Kalish, 1969; Bitterman, 1979).

A great number of procedures have been employed to produce generalization gradients (Razran, 1949; Brown, 1965; Honig and Urcuioli, 1981) and the variations in shape of these empirical functions have been so many as to preclude concise systematization (Kalish, 1969; Honig and Urcuioli, 1981). A change in response measures, experimental procedures, or subjects changes the shape of the resulting gradients. While researchers may specify gradients empirically, no systematic description of generalization gradients is assured.

### Interval Response Scales

It is probable that the extreme variety of results from prior experimental investigations of gradients of stimulus generalization would not have been so great had more attention been paid to the nature of the scales of the response and stimulus dimensions (Bergman and Spence, 1944; Miller and Murray, 1952; Perkins and Weyant, 1958; Blough, 1965; Mackintosh, 1974). Comparisons of area, height, slope, and form of the gradient have only been meaningful when obtained under similar

procedures and contexts, within the same subject, and assessed by the same response measure. Comparisons between different procedures, measures, and subjects have only been suitable as ordinal comparisons of gradients, at best (Bergman and Spence, 1944). An ordinal scale, however, can provide no information about the shape of any gradient and the question of gradient shape has often been a crucial issue for interpretation of the research on stimulus generalization (Blough, 1965). Further, the common multiplicative transformations of relative gradients (e.g. Bitterman, 1979; Robles, Newlin, and Thomas, 1980) and algebraic comparisons of gradients (Honig and Urcuioli, 1981) require gradients whose measures have more than ordinal properties. Therefore, in order to arrive at parsimonious expressions of the gradients of stimulus generalization, meaningful scales of the strength of response tendencies which have at least interval properties are required (Perkins, 1982).

The present study employed a scale which appears to at least approximate interval properties. The method of obtaining interval measures of the strength of response tendencies is based upon the matching relationship (DeVilliers, 1977). This relationship refers to a subject matching relative rates of responses to relative rates of contingent stimuli (e.g. access to food) obtained on a concurrent variable-interval variable-interval schedule. During the concurrent variable-interval variable-interval schedule here employed, two separate response keys were simultaneously available and stimuli were independently and simultaneously programmed contingent upon the response to each key.

The probability that a contingent stimulus would become available on a certain component schedule remained approximately constant. Pecking either of two transilluminated keys provided access to grain on a con-

current variable interval (conc VI n-min VI n'-min) schedule with a change-over delay (COD) which stipulated that the first peck to a key following a peck to the other began a two-second period during which no grain was presented. This training was continued until steady-state seemed to have been approximated. The same response requirement on the two keys and the same contingent stimulus (three sec of food) was delivered on each component. The response scale, relative frequency of response, is the number of responses to one key divided by the total number of responses to both keys. The reasons for believing that this measure provides an interval scale of the strength of response tendencies will now be reviewed.

#### The Matching Relationship

While the matching relationship has been obtained with other species, contexts, numbers of alternatives, responses, and contingent stimuli (DeVilliers and Herrnstein, 1977), the following review will focus on the use of pigeons in a conventional operant chamber, pecking either of two transilluminated keys to produce access to grain. These conditions are common to the majority of studies in which VI component schedules are employed and the matching relationship obtained (DeVilliers, 1977). Here, grain presentations are made concurrently contingent upon pigeons' pecks to each of the two component schedules on the response keys. This schedule generates the matching relationship which holds when the proportion of total responding to one of the keys equals the proportion of total grain presentations yielded by pecks to that key:

$$\frac{R_1}{R_1 + R_2} = \frac{r_1}{r_1 + r_2} \quad (1)$$

(where  $R_1$  and  $R_2$  represent frequency of responding to keys 1 and 2

respectively and  $r_1$  and  $r_2$  represent frequency of grain presentations contingent upon pecks to keys 1 and 2 respectively).

Another procedural detail which is conducive to matching is the change-over delay (COD). A COD is a time interval during which responses will not produce grain following a change from one of the component schedules to the other. There is often a minimum interval for the COD which is required to provide for good matching (Brownstein and Pliskoff, 1968; Catania and Cutts, 1963). Beyond this interval (usually two to three seconds) the matching relationship has been approximated at intervals of up to 32 seconds (Stubbs and Pliskoff, 1969). When the COD is made up of a time-out period of darkness and nonfunctioning keys, however, marked deviations from matching have been obtained with COD durations above three sec (Todorov, 1971). Similarly, procedures which add a moderate response cost to the change-over response also do not provide for good matching (Baum, 1982). Therefore a standard COD of two seconds was employed.

Prolonged exposure to the final training schedule also provides for better matching. Failure to meet this condition may reduce the discrimination of the component schedule values. Trevett, Davison, and Williams (1972), for example, followed extensive conc VI FI training with a relatively brief exposure to conc VI VI schedules and failed to obtain matching. Silberberg and Fantino (1979) did not balance the order of relative schedule values between the two keys and did not obtain a straight-line function. Both of these studies could better have employed longer exposure to the schedules. Clearly, any study which does not include a rigorous criterion for steady-state performance is not likely to find matching. In most instances in which matching was not obtained,

the relative frequencies of response were closer to one-half than to the relative frequencies of grain presentations (undermatching). This seems to indicate that matching might have been obtained had prolonged training been employed (Baum, 1974). Practically perfect matching (of relative frequencies of responding to relative time spent in grain hopper) has, in fact, been obtained when these conditions are met (Keller and Gollub, 1977).

#### An Interval Scale of the Strength of Response Tendencies to Stimuli

Provided that the above conditions are met, the matching relationship seems to be closely approximated. Further, this behavior may be seen as the pigeon's equalization of responses per grain presentation between the two components:

$$\frac{R_1}{r_1} = \frac{R_2}{r_2} \quad (2)$$

(Herrnstein and Loveland, 1975). This equalization of local obtained rates of contingent stimuli indicates that the pigeon's performance is such as to equalize the strength of the response tendencies to the two component stimuli. Equation 2 thus offers a method to scale an unknown quantity (the strength of generalized response tendencies to a test stimulus) against the strength of the response tendency to a standard, comparison stimulus. In effect, in the study of stimulus generalization, fixing  $r_1$  and  $r_2$  for a training ( $S_2$ ) and a comparison ( $S_1$ ) stimulus produces  $R_1$  and  $R_2$  to satisfy equation 2. Replacing the training stimulus with a test stimulus, fixing  $r_2$  experimentally at zero, and keeping  $r_1$  constant provides for the then obtained measures of  $R_1$  and  $R_2$  to reflect the strength of generalized response tendencies to given test stimuli presented as  $S_2$  before appreciable effects of extinction occur

(equation 3).

$$r_2 = \frac{R_2}{R_1} r_1 \quad (3)$$

In this fashion, the scale of the strength of generalized response tendencies to stimuli is produced through the use of a comparison stimulus. In so far as the matching relationship holds, this procedure provides an interval scale of the strength of generalized response tendencies and thus, generalization gradients which can be compared across experimental conditions.

In the present experiment, one key stimulus (green) of the concurrent training schedule was designated the comparison stimulus and the other key stimulus (red or dark) was designated the training stimulus. During training, a baseline ratio of grain presentations was fixed by the experimenter at .80 by setting the requirement that when a grain presentation was made contingent upon the next peck to one key, the otherwise independent, VI-grain-presentation-schedule timers for both keys were halted and not restarted until that key was pecked. This manipulation has previously been shown not to interfere with the matching relationship (Stubbs and Pliskoff, 1969). The occasion for changing stimuli to allow for multiple-stimulus tests of generalization was set by imposing 15 sec blackout periods between one minute trials on the concurrent schedule. Pilot data for this study and relevant published data (Nevin, 1969) indicate that segmentation into trials does not seriously affect the matching relationship.

#### Resistance to Changes in Strength and Initial Strength of Response Tendencies

A common problem with generalization gradients reported in the literature is the use of measures which do not separate the strength of

response tendencies on the initial trials from the resistance of response tendencies to changes in strength (e.g. extinction). Such composite measures of generalization are often employed in an attempt to provide more reliable measures of the strength of generalized response tendencies. The present treatment will focus upon two separate measures because there is reason to believe that measures of initial strength of response tendencies provide flatter (broader) generalization gradients than do measures of resistance to change (Wickens, Schroder, and Snide, 1954; Jenkins and Harrison, 1960; Fleshler and Hoffman, 1961; Thomas and Barber, 1964). These studies, however, have shown a widely variable relationship across individual subjects. Further, the case can be made that some studies fail to show this trend at all (Kalish and Haber, 1963; Grant and Schiller, 1953). At present, a conclusive analysis of these extinction curves as they relate to the process of stimulus generalization awaits the use of measures of the strength of response tendencies on a scale with interval properties.

Therefore, one objective of the present experiment was to compare the decrease in strength of the response tendency to the training stimulus with the decrease in the strength of response tendencies to three test stimuli which differed from the training stimulus along the same stimulus dimension by different amounts. Responding was measured under conditions of extinction following concurrent VI VI trials with the training stimulus. One measure was obtained before appreciable decreases in the strength of response tendencies appeared; the second measure was of the successive changes in strength throughout the course of extinction.

#### The Stimulus Scale

It should be noted that development of an appropriate stimulus scale

is beyond the scope of the present paper. The present stimulus scale (light intensity) was selected for convenience. The intensities selected are assumed only to provide stimuli whose intensity values rest on one side of the training stimulus' and whose similarity to the training stimulus is a monotonic function of their distance from that stimulus. In order to recognize the complexities of using the stimulus intensity scale (Gray, 1965), the present experiment provides for a comparison of the gradient of generalization yielded when the training stimulus was at the upper end of a brightness dimension with that yielded when the training stimulus was at the lower end of the same dimension. This was accomplished by randomly assigning the 16 subjects to four major groups; two trained on the brightest stimulus and two trained on the darkest.

#### Interference by Position Cues

The final objective of the present experiment was to compare the data yielded by two procedures. A pilot experiment had indicated that, in the typical concurrent schedule, the cues which dominate the discrimination between the two components can easily be left-right side cues rather than the color cues. Therefore, in the present study, for two groups the locations of the two concurrent stimuli were interchanged between keys after varied numbers of trials, while for the other two groups the concurrent training stimuli were always at the same location. The interchange of stimulus locations for the former two groups was expected to make the position cues irrelevant to the brightness discrimination and thus control for additional contextual effects on the brightness generalization gradients.

## METHODS

### Subjects

Sixteen experimentally naive pigeons served. When necessary, each was fed after experimental sessions in order to maintain it at 75% of its free feeding weight. Each also had free access to water and grit in its individual home cage which had constant light.

### Apparatus

Two, two-key pigeon boxes of conventional design were used. Each was painted flat black inside, one wall containing the two keys and a Lehigh Valley grain hopper (centered on the wall and 4 cm from the floor). The centers of the keys were 6 cm apart and 23 cm from the floor. The key diameters were 2 cm. The dimensions of each chamber were 30 cm high by 34 cm deep by 38 cm wide. A houselight, in the center of the ceiling of each chamber, provided only a very dim illumination in the chamber (log 1.2 to log 1.5 ft. L. measured directly).

Two different types of keylight were employed. The green, comparison stimulus was illuminated by the conventional 6.3 v, 1.2 A lamp while the red, test stimulus was illuminated by a 6.5 v, 2.8 A lamp. Both were mounted in modified IEE rear projection boxes with transilluminated gels. Each stimulus could be presented on either key in Box 1, which was employed for pigeons for whom the location of the training and comparison stimuli were interchanged between keys. Box 2 was set up so that the right-hand key could be illuminated by the red stimuli and the left key by the green stimulus. The brightnesses of the red, test stimuli were adjusted to constant settings on variable resistors in the D.C. circuit. All brightnesses were set according to heterochromatic matching judgements made with a MacBeth illuminometer. The experimenter made these

measurements three times: prior to training, prior to testing, and following testing. The brightnesses prior to training were as follows: the key panels, log -2.0 ft L., each green key, log 0.0 ft L., and the four brightnesses of the red keys: log 1.0 ft L., log 0.0 ft L., log -1.0 ft L., and log -2.0 ft L. Prior to testing, unintended changes in brightnesses were judged as follows. Both of the red training stimuli in Box 1 measured log 0.9 ft L.; the left green stimulus in Box 1 was log 0.1 ft L. The test stimuli, which had never been presented, were reset to the pretraining values, but the settings of the training stimuli were not readjusted. Following testing, unintended changes in the brightnesses were as follows: in Box 1, the right green stimulus was log -0.3 ft L.; both of the red training stimuli in Box 1 were 0.8 ft L.; each of the second brightest stimuli in Box 1 were -0.3 ft L.; and in Box 2, the second brightest test stimulus was log -0.5 ft L. It is possible that these changes followed a different course for different pigeons because the various pigeons entered testing on different days.

Key pecks of a force of at least .08 N in Box 1 and between .07 and .08 N in Box 2 activated a relay behind the appropriate key to provide a feedback click and interact with the film tape readers and other electro-mechanical controlling and recording equipment. Each box was enclosed in a sound attenuating chamber. White noise and a ventilating fan provided masking noise throughout the experiment.

### Procedure

Design. The general design (as set out in Table 1) provided for four groups of four pigeons each, two groups with keys on which the red (training) and green (comparison) stimuli appeared irregularly interchanging between keys (as described below) and the other two with a

Table 1. Design of the experiment.

Groups	ID	IR	CD	CR
Training Stimulus	dark	red	dark	red
Location of stimuli	interchanged	interchanged	constant	constant
Schedule	<u>conc</u> VI 1-min (red or dark) VI 4-min (green); 2.0 sec COD; 15 sec ITI; 60 sec trials.			

constant location for stimuli. Further, two groups (one of each of the above types) were trained with the brightest value of red and two with the dimmest value (no illumination). The four groups of pigeons were designated: ID (interchanged locations - dark stimulus), IR (interchanged locations - red stimulus), CD (constant locations - dark stimulus), and CR (constant locations - red stimulus). For simplicity of exposition, both the bright red and dark keys will be described as "red."

Pretraining. On Session 1 each pigeon was placed in its experimental chamber for 30 minutes with the houselight on and the keys covered with black tape. On Session 2 each pigeon was given multiple grain presentations until it regularly ate from the hopper within 1 sec of grain presentation; each 3-sec grain presentation was accompanied by the noise of the hopper presentation, illumination of the hopper, and darkening of the houselight. On the next two days, the pigeons were first shaped to peck one green key, while the second key was covered with black tape, and then trained to peck the second key (also transilluminated green) while the first key was covered with black tape. This procedure was the same for every pigeon.

On the following day, the session began with a 5-minute period of no lights or operable features of any kind in the chamber in order to allow for dark adaptation (Blough, 1956). Such dark adaptation periods also preceded all subsequent sessions. Following adaptation, both the training and the comparison stimuli were presented simultaneously and VI 30-sec schedules of grain presentation were programmed on each key until alternations between keys occurred after every three to ten pecks. The onset of each programmed grain-presentation contingency halted both VI tape readers until that grain presentation had been obtained by a

peck to the appropriate key. A change-over delay (COD) was added on the next session. The first COD duration, timed from the first peck after switching keys, was .03 sec (the programmed duration of each peck) which had the effect only of preventing food for the change-over peck.

When responding was reliable, the mean size of the VI intervals was gradually increased across one or two days until a conc VI 1-min VI 1-min schedule was in effect. This did not require the same amount of time for each pigeon. All VI's in the experiment were generated by Fleshler and Hoffman's (1962) progression.

All subsequent training sessions terminated after the collection of 50 grain presentations. After two of the above sessions a conc VI 2-min (green) VI 1-min (red) schedule came in force for two sessions, with the COD increased to .3 sec for the second session. On the fifth session following the original introduction of the conc VI 1-min VI 1-min schedule, 15-sec blackouts were alternated with trials on the concurrent schedule. Trials lasted until one minute after the first peck of that trial except that timing was interrupted upon grain presentation and not reinstituted until the first key peck after retraction of the feeder. Also at this point in training, for pigeons in Groups ID and IR, the trial-by-trial location of the training and comparison stimuli and attendant schedules was randomly interchanged between the two keys with the provision that no stimulus (and schedule) remained on the same key for more than four consecutive trials. Within each subsequent session, red was on the right for half of the trials.

On the next session the schedule was a conc VI 4-min (green) VI 1-min (red) with a .5 sec COD. From this point on, with the stipulation that any programmed grain presentation halted both VI tape readers and

with the preset number of grain presentations per session, a fixed grain presentation ratio of .80 ( $\frac{r_r}{r_r + r_g}$ ) was programmed for each pigeon. Each day thereafter the only scheduled change in procedure was to increase the COD in each successive session to .75, 1.0, and 2.0 sec. The first day of the 2.0 sec COD began the final training procedure. Early in training the grain presentation ratios were not consistently .80 due to occasional apparatus malfunction.

Training Procedure. Peck ratios during the final training procedure were assessed for session to session stability. The stability criterion required a minimum of five training sessions, after which a second block of five consecutive sessions contained relative peck ratios which neither varied more than .04 from any other of those five sessions nor showed any consistent upwards or downwards trend. The day after a pigeon reached this criterion it received its first test session.

The above description is of the training procedure planned, but the results obtained dictated the following changes. After about five sessions of the final training procedure, it became apparent that the time required for Groups ID and IR to complete their sessions was twice as long as was the time for Groups CD and CR. Observation indicated that most of the pigeons in Groups ID and IR were pecking one of the two keys almost exclusively. Nevertheless, they collected all of the grain presentations and completed the session. The random interchanging of the location of stimuli and schedules on the keys made switching keys unnecessary. In order to change this pattern of responding to one of approximately equal responding to each key, the schedule on the preferred key was changed to extinction and each pigeon was manually

shaped, by the method of successive approximations, to peck the other key consistently and then the final training schedule was faded in during that same session. The above procedure transferred the key preference to the other key for most of the pigeons.

On subsequent sessions the procedure was modified so that whenever a grain presentation was scheduled for the next peck to a given component, the location of the components on the keys remained the same until the end of the trial in which the grain presentation had been collected. In this fashion, the pigeons were required to alternate between keys in order to collect all of the grain presentations and complete each session. This procedure was effective in ending the side preferences and thus was maintained for all subsequent sessions for Groups ID and IR.

Test Procedure. The schedule in effect during testing was a con VI 4-min (green) EXT (red) with the same 2.0 sec COD, 15 sec ITI, and (60+ sec) trial durations as in training. The red key was changed as follows. Each of the four brightnesses was presented once in each block of four trials in random sequence. The counterbalancing sequence followed for the next four trials (e.g. 32100123, where each digit stands for a 60 sec trial at one each of the four brightness levels). This sequence of eight trials constituted a test cycle. One pigeon in each group had one of the four different brightnesses as the first test stimulus. All brightnesses were presented equally often in each of the trials in the first test cycle according to a latin square design. Sessions proceeded through five randomly sequenced groups of these test cycles for a total of 40 trials (see Appendix A for a list of the actual sequence of trials for each pigeon). Note that the

length of a test session did not exceed the typical duration of a training session. Because preliminary data had indicated that four such sessions should be sufficient for extinction to run its course each pigeon received only five test sessions.

## RESULTS

Individual pigeon's peck ( $\frac{R_r}{R_r + R_g}$ ) and grain delivery ( $\frac{r_r}{r_r + r_g}$ ) ratios during training are shown for a different group in each of Figures 1 through 4. The data are plotted from the first day of the final training schedule until training ended after at least ten sessions and achievement of the stability criterion (peck ratios on the last five consecutive sessions varying no more than .04 and not arrayed in any consistent trend).

The mean ratio for the last five sessions (the sum of the five sessions' total responses to red divided by the sum of the five sessions' total responses to red plus the sum of the five sessions' total responses to green) for pigeons 1 through 4 (Group ID) was .78, .71, .78, and .74 respectively. The mean response ratio for pigeons 5 through 8 (Group IR) was .75, .79, .76, and .71 respectively. The mean response ratio for pigeons 9 through 12 (Group CD) was .83, .81, .64, and .64 respectively. The mean response ratio for pigeons 13 through 16 (Group CR) was .89, .80, .81, and .71 respectively. There do not appear to be any systematic differences between groups in final training mean response ratio.

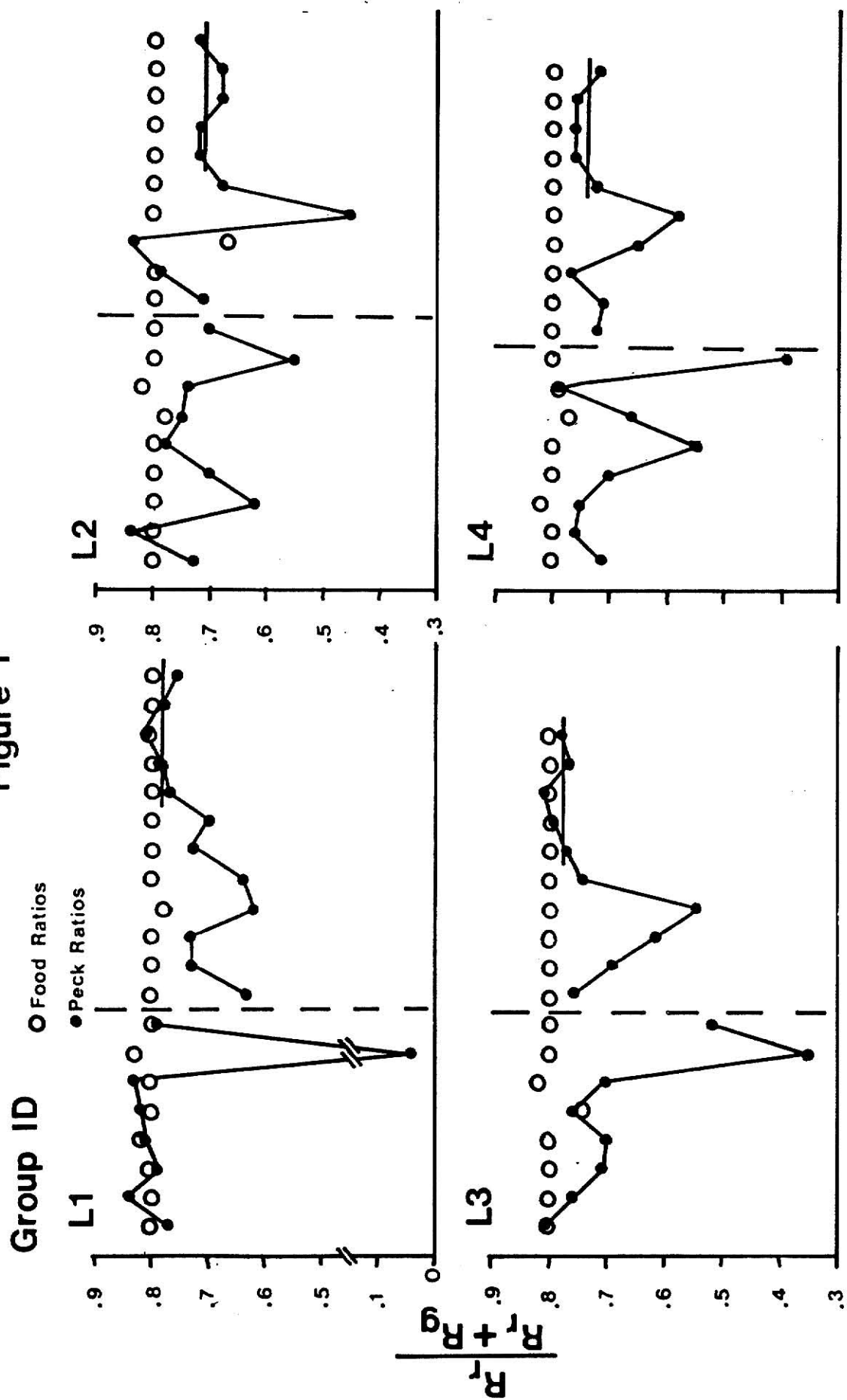
In Figures 1 and 2 the vertical dashed line indicates the point at which the modified final-training phase necessitated by the side preferences of Groups ID and IR began. Side preference ratios during the five sessions at which the stability criterion was met varied between .51 and .61 ( $\bar{X}=.575$ ) indicating little side preference.

Figure 5 presents the relative rate of responding on the first two trials to each test stimulus for each pigeon and the mean gradient for each group. In Figure 5, the left-most stimulus on each graph is the

## Figure Caption

Figure 1. Final training performance by session for each pigeon in Group ID. The open circles represent the ratio of actual grain presentations and the closed circles represent the ratio of responses ( $\frac{R_r}{R_r + R_g}$ ). The dashed vertical lines represent the beginning of the modification in training used to force the pigeons to end their side preferences. The horizontal lines for the last five sessions indicate the mean response ratio for those five sessions.

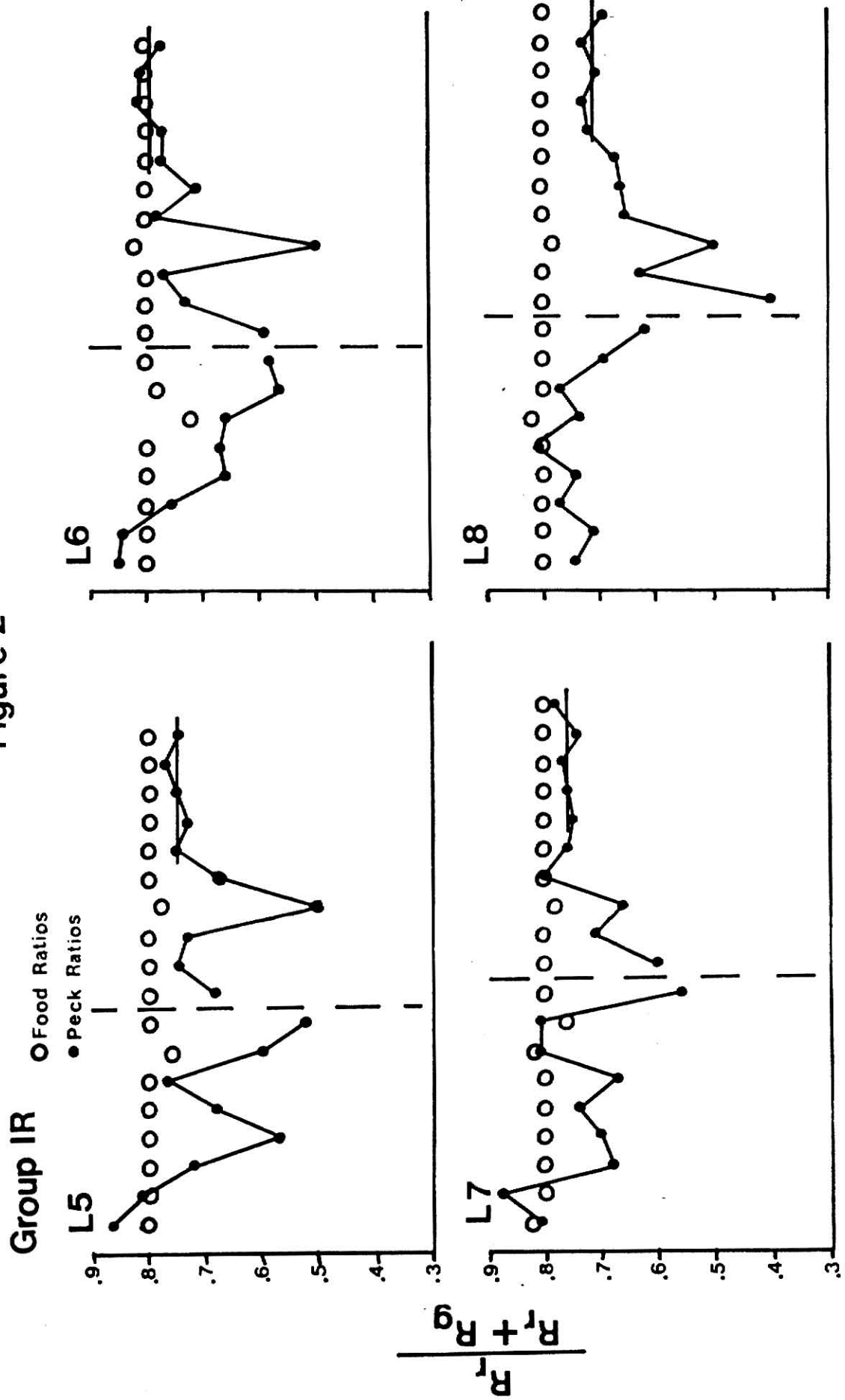
Figure 1



### Figure Caption

Figure 2. Final training performance by session for each pigeon in Group IR. The open circles represent the ratio of actual grain presentations and the closed circles represent the beginning of the modification in training used to force the pigeons to end their side preferences. The horizontal lines for the last five sessions indicate the mean response ratio for those five sessions.

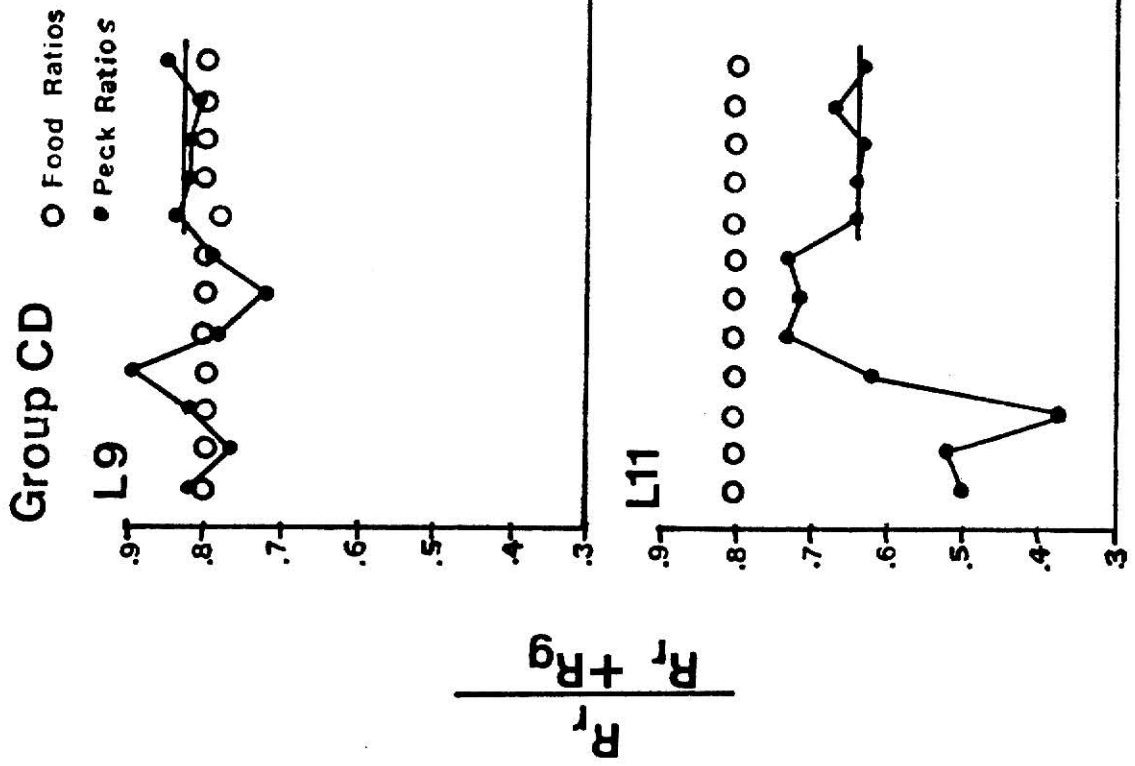
Figure 2



## Figure Caption

Figure 3. Final training performance by session for each pigeon in Group CD. The open circles represent the ratio of actual grain presentation and the closed circles represent the ratio of responses ( $\frac{R_r}{R_r + R_g}$ ). The horizontal lines for the last five sessions indicate the mean response ratio for those five sessions.

Figure 3



## Figure Caption

Figure 4. Final training performance by session for each pigeon in Group CR. The open circles represent the ratio of actual grain presentations and the closed circles represent the ratio of responses ( $\frac{R_r}{R_r + R_g}$ ). The horizontal lines for the last five sessions indicate the mean response ratio for those five sessions.

Figure 4

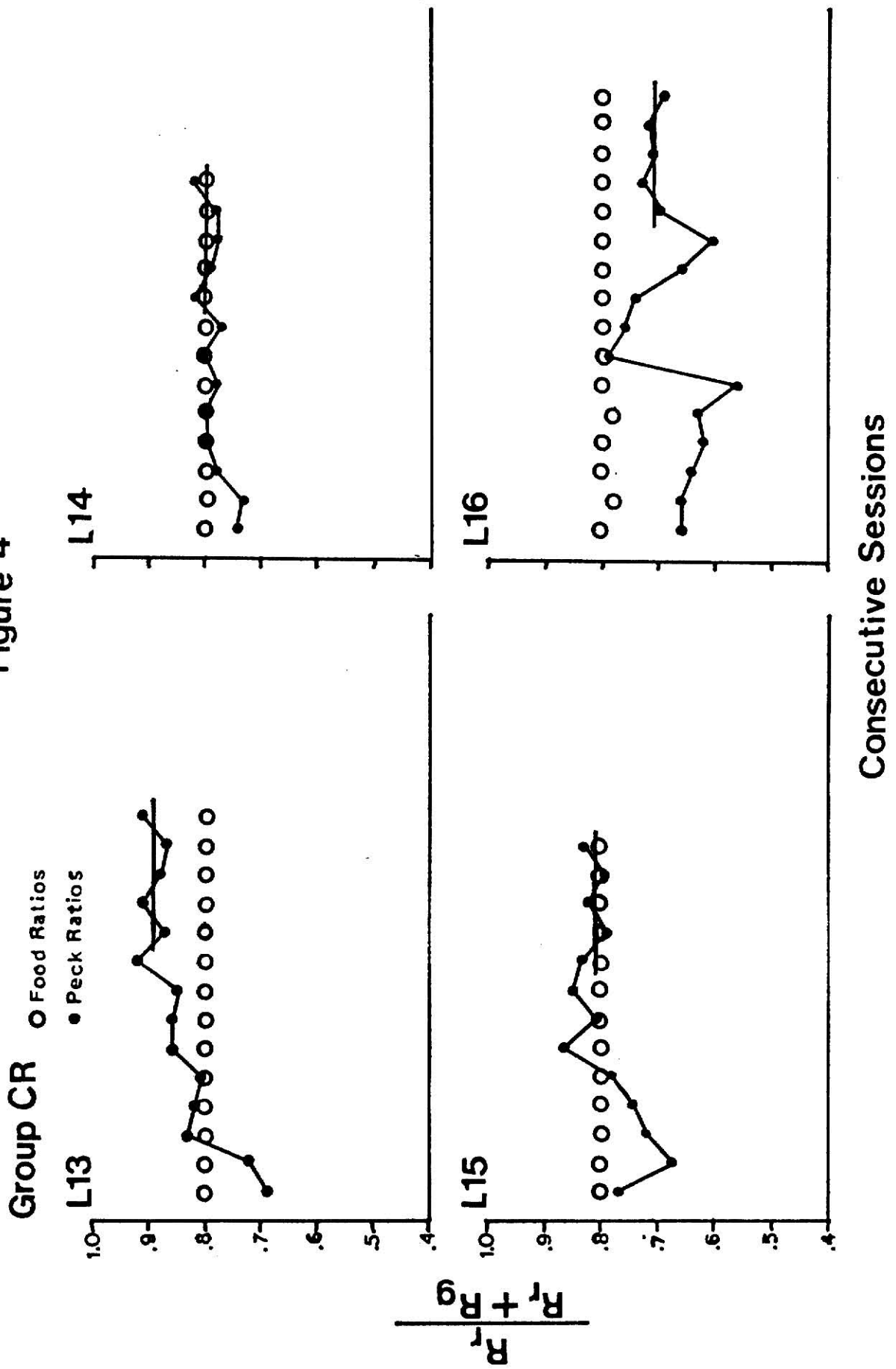


Figure Caption

Figure 5. Initial generalization gradients for each pigeon and Group means. The original training stimulus is the left hand data point in each graph: log 1.0 ft L. for Groups IR and CR and log -2.0 ft L. for Groups ID and CD. These data are collapsed from the first two trials of each stimulus.

Figure 5a

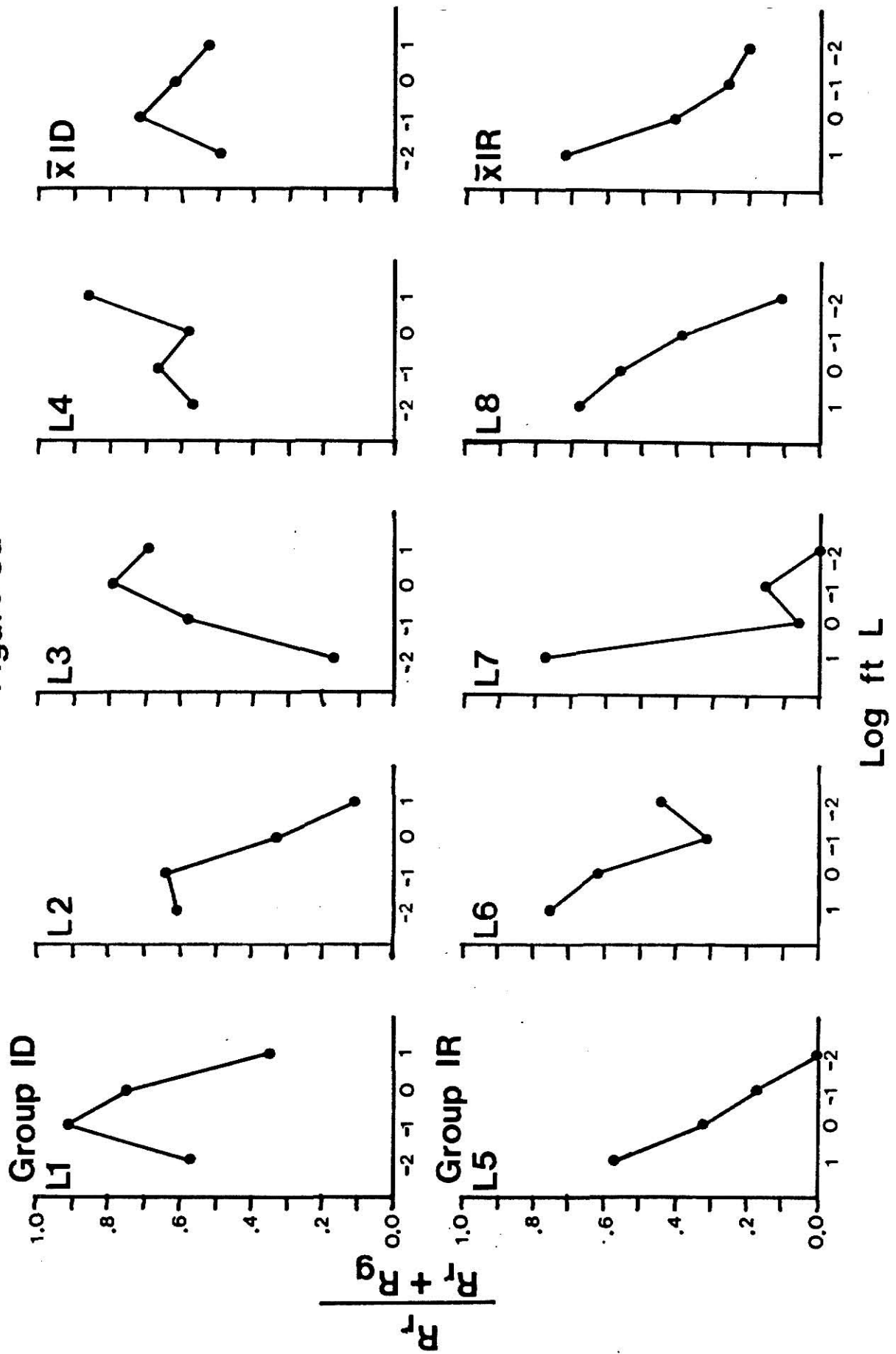
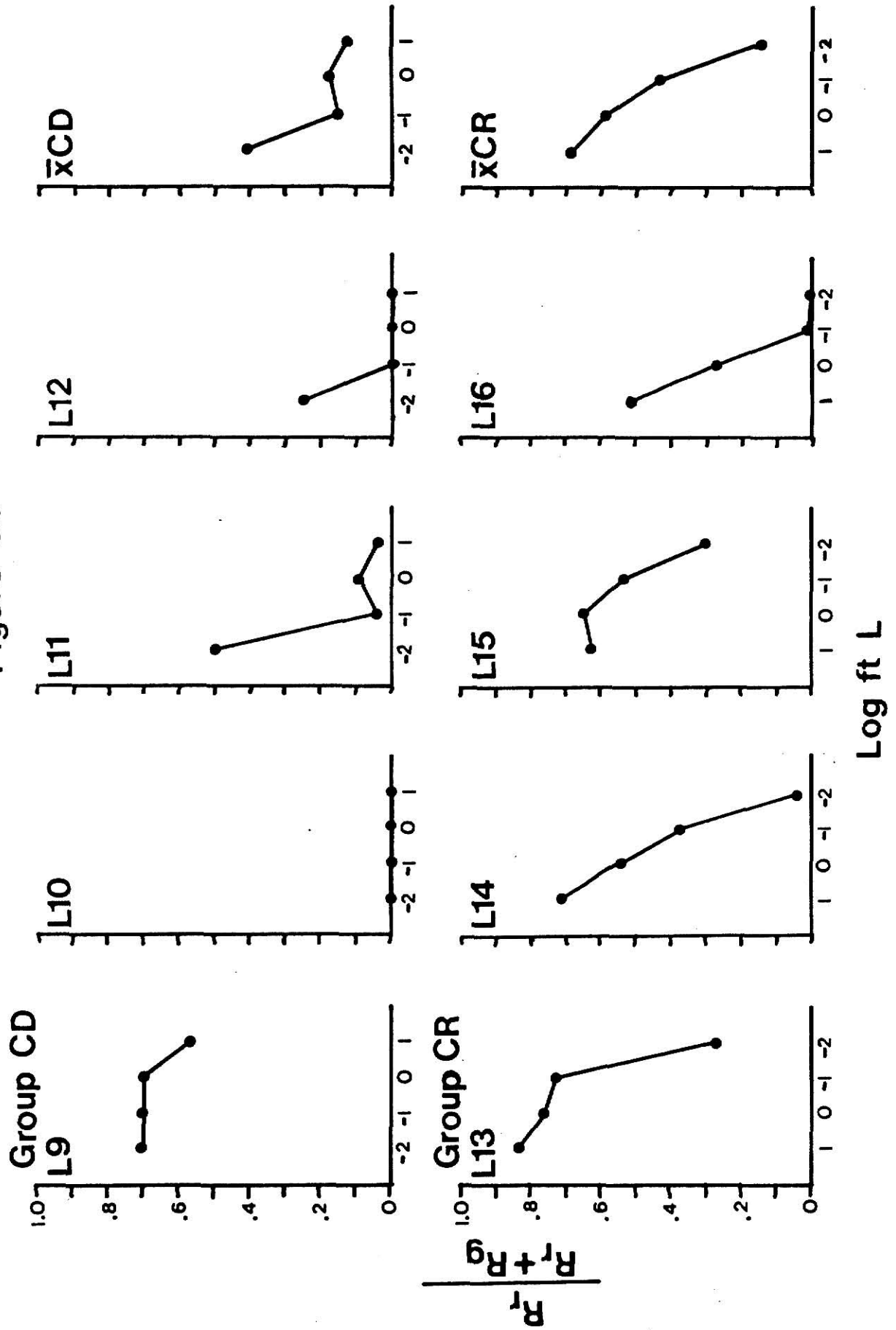


Figure 5b



training stimulus and the test stimuli are ordered in graphically equal steps differing from the training stimulus. The response measure was based on the first test cycle (the first two trials to each test stimulus for each pigeon) because at most there was only a suggestion of any decrement in responding to test stimuli during this test cycle. While there may have been some extinction, its effect on these measures appears to be negligible. There is no guarantee of a complete absence of extinction effects even if only the first sequence of four trials was used because even this sequence covered more than four minutes of responding during which the extinction procedure was in effect. The response ratios during testing for each test cycle are presented in Appendix B.

The gradients from pigeons trained with the bright stimulus (Groups IR and CR) are quite consistent; there is no reliable difference between the two groups. On the other hand, there are great individual differences in gradients within the groups trained with the dark stimulus (Groups ID and CD), especially within Group ID. This probably results from opposition between the generalization gradient and stimulus intensity effects (Gray, 1965). Individual differences in the relative importance of these two factors could presumably produce variability in the gradients. Group CD's data seem more clearly to indicate a monotonically decreasing gradient but the slopes of CD gradients are much less than those of Group CR, again suggesting the opposing influences of stimulus intensity effects and generalized response tendencies.

In Appendix C, Figures 13 through 17 present the simple course of extinction of responding to the test stimuli (including the training brightness value). Each data point is plotted as the number of responses during a session to a red stimulus divided by the total number of responses in the session during trials in which the given red stimulus was presented.

While these Figures (13 through 17) allow for a comparison between the slopes of extinction of responding to the four test stimuli to be determined, Figures 6 through 10 were constructed to allow an immediate comparison of the forms and relative slopes of the same extinction curves. Presentation of the course of extinction in this manner is consistent with the model of response strength advocated by Rescorla and Wagner (1972) where changes in strength are best considered as proportional to the prior composite strength of the response tendencies. Figures 6 through 10 are plots of the course of extinction of responding relative to the initial response ratio to each stimulus. Each data point is plotted as the relative frequency of responding (the number of responses during a session to a red stimulus divided by the total number of responses in the session during trials in which that red stimulus was presented) divided by the initial session's relative frequency of responding to that red stimulus.

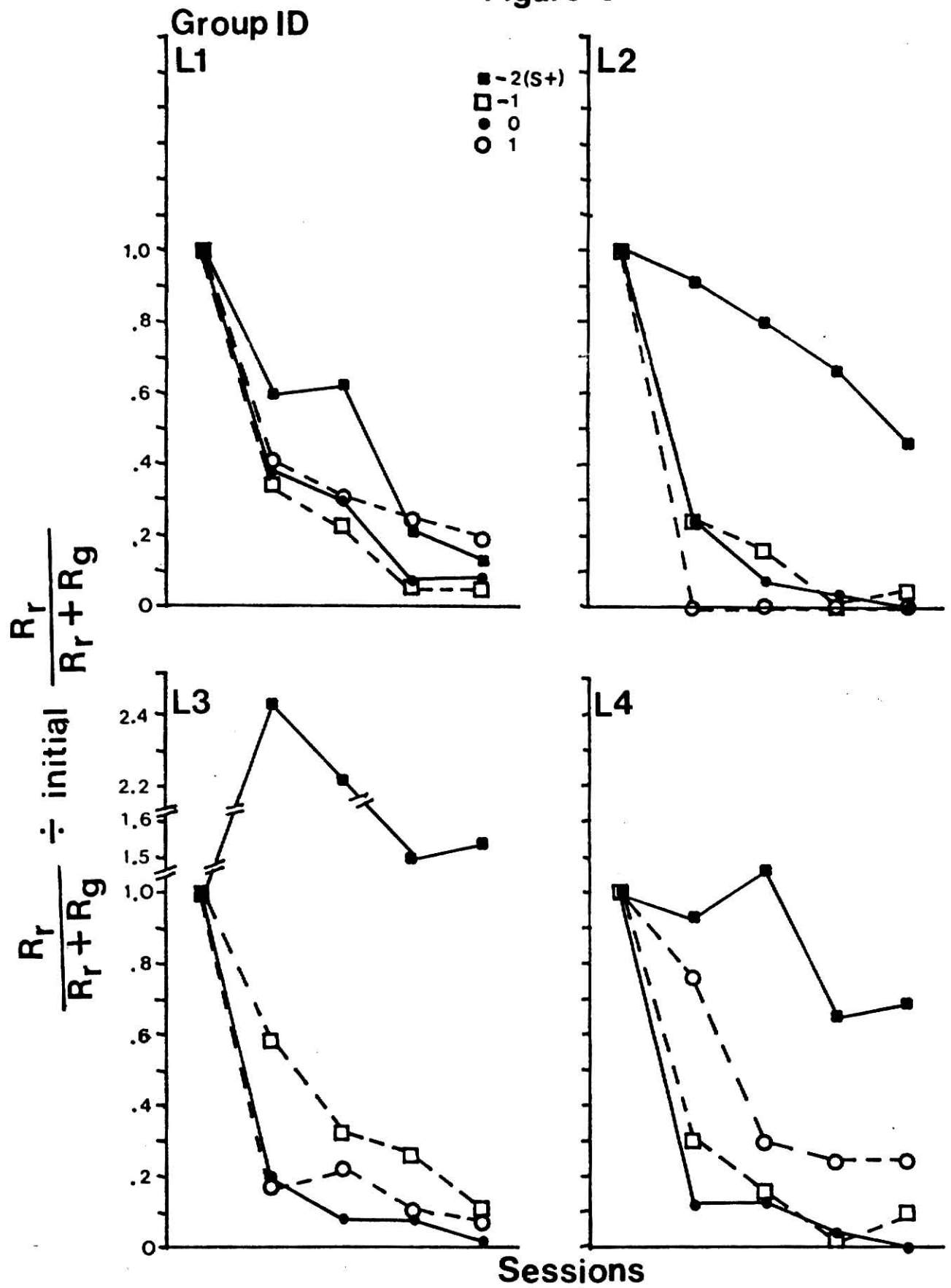
From Figures 6 through 10 it is clear that, while the response ratio to the original training stimulus was not always greater than that to the test stimuli, the course of extinction relative to the initial response ratio is slowest for the original training stimulus. Further, the slopes of the extinction curves for the three test stimuli are quite similar. Although a few inversions appear, these inversions are predominantly due to extinction curves wherein all points were close to a value of .00 and subsequent peck ratios were large by comparison even though the subsequent absolute number of pecks was extremely low.

Figure 11 presents the mean extinction curves for all pigeons in Groups ID and CD and for all pigeons in Groups IR and CR. Similarly, Figure 12 presents the mean relative extinction curves for all pigeons in Groups ID and CD and for all pigeons in Groups IR and CR.

### Figure Caption

Figure 6. The course of extinction of responding to each stimulus relative to the original rate of response for each stimulus. Each graph represents the results for a single bird. Extinction is plotted separately for each stimulus and averaged within each stimulus for each session.

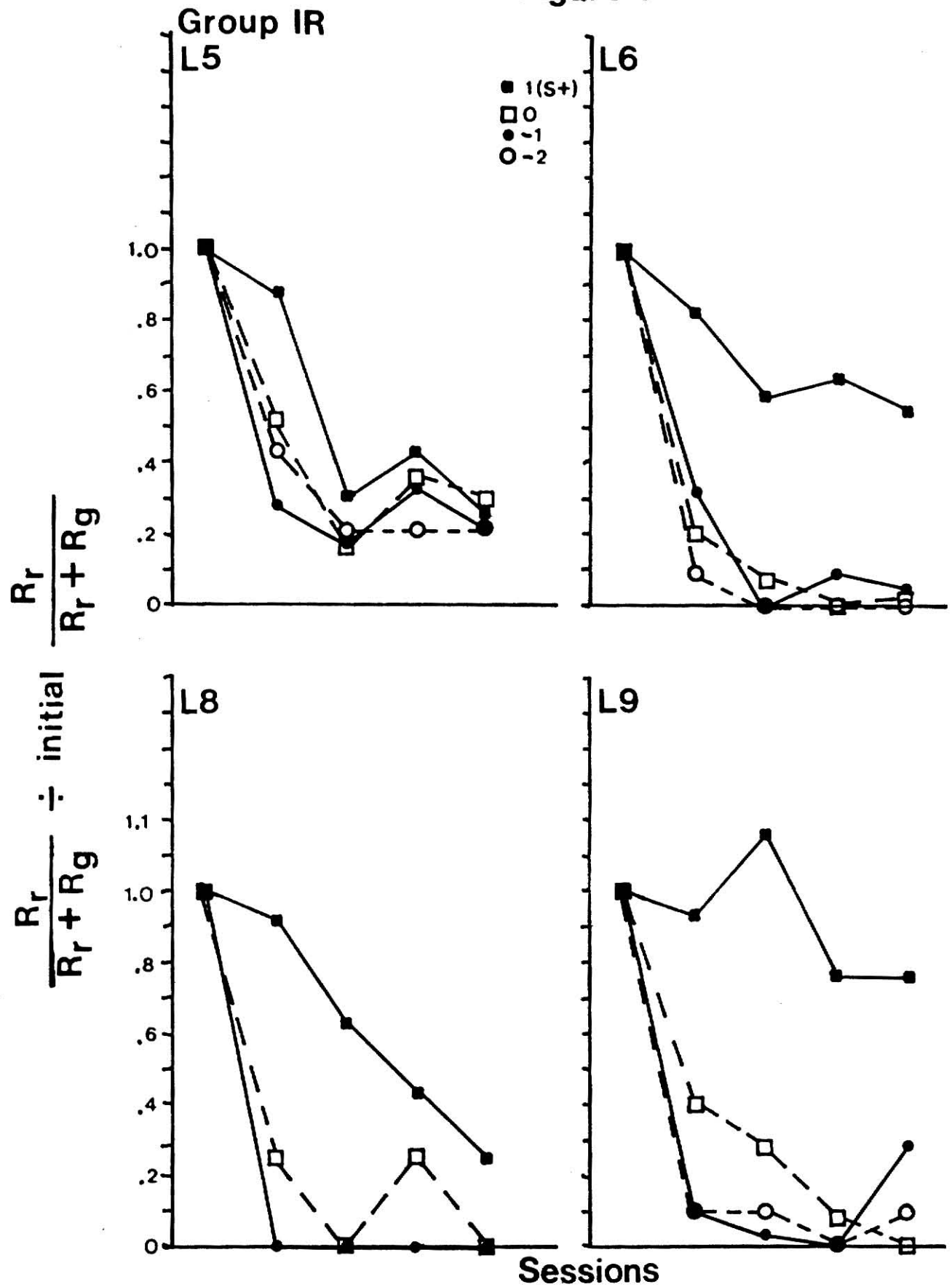
Figure 6



### Figure Caption

Figure 7. The course of extinction of responding to each stimulus relative to the original rate of response for each stimulus. Each graph represents the results for a single bird. Extinction is plotted separately for each stimulus and averaged within each stimulus for each session. Data points for stimulus -2 for Pigeon L7 is missing due to the original rate of response being 0 (relative ratios =  $\infty$ ).

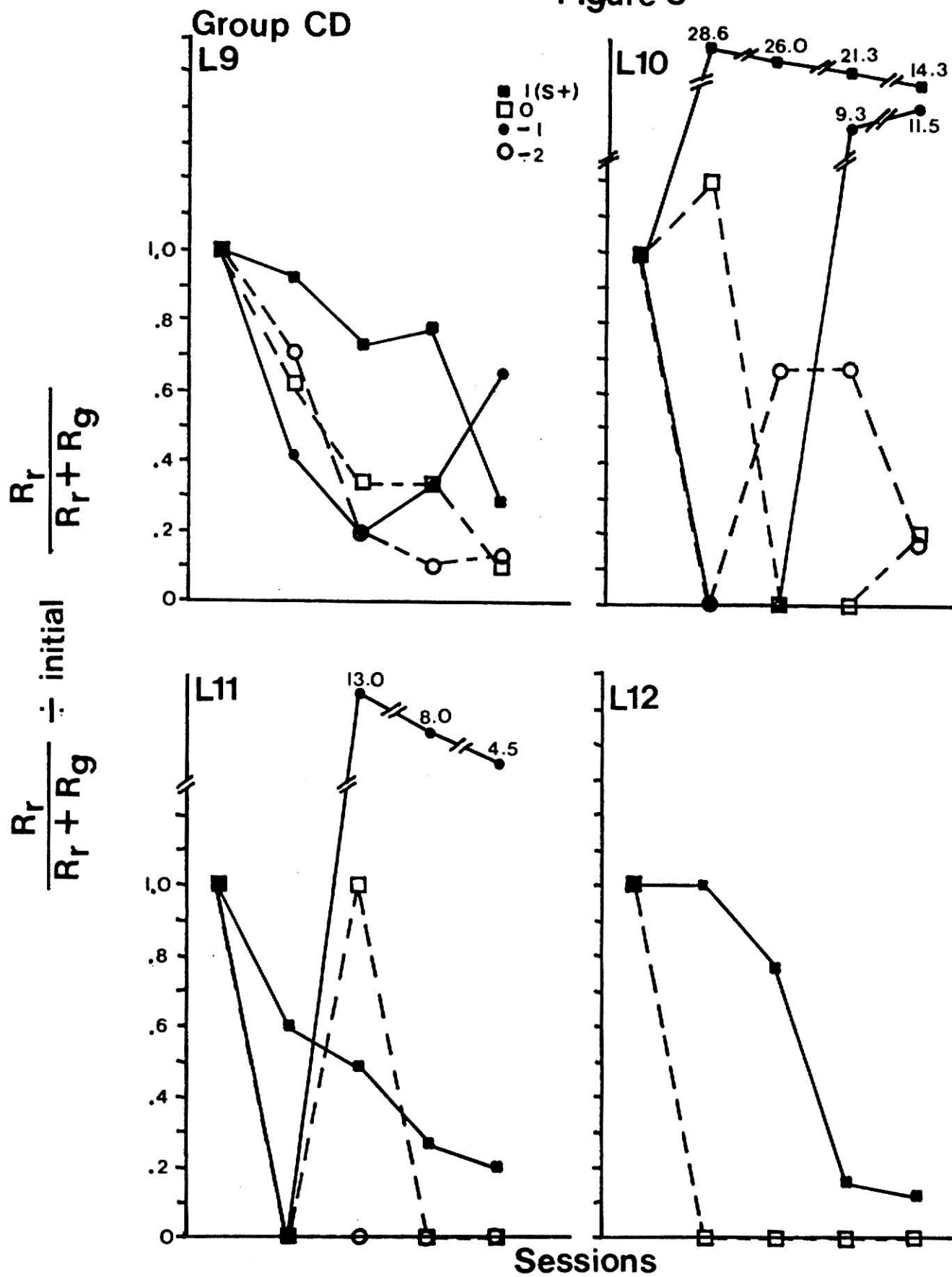
Figure 7



### Figure Caption

Figure 8. The course of extinction of responding to each stimulus relative to the original rate of response for each stimulus. Each graph represents the results for a single bird. Extinction is plotted separately for each stimulus and averaged within each stimulus for each session. Data points for stimuli -1 and -2 for Pigeon LR are missing due to the original rate of response being 0 (relative ratios =  $\infty$ ).

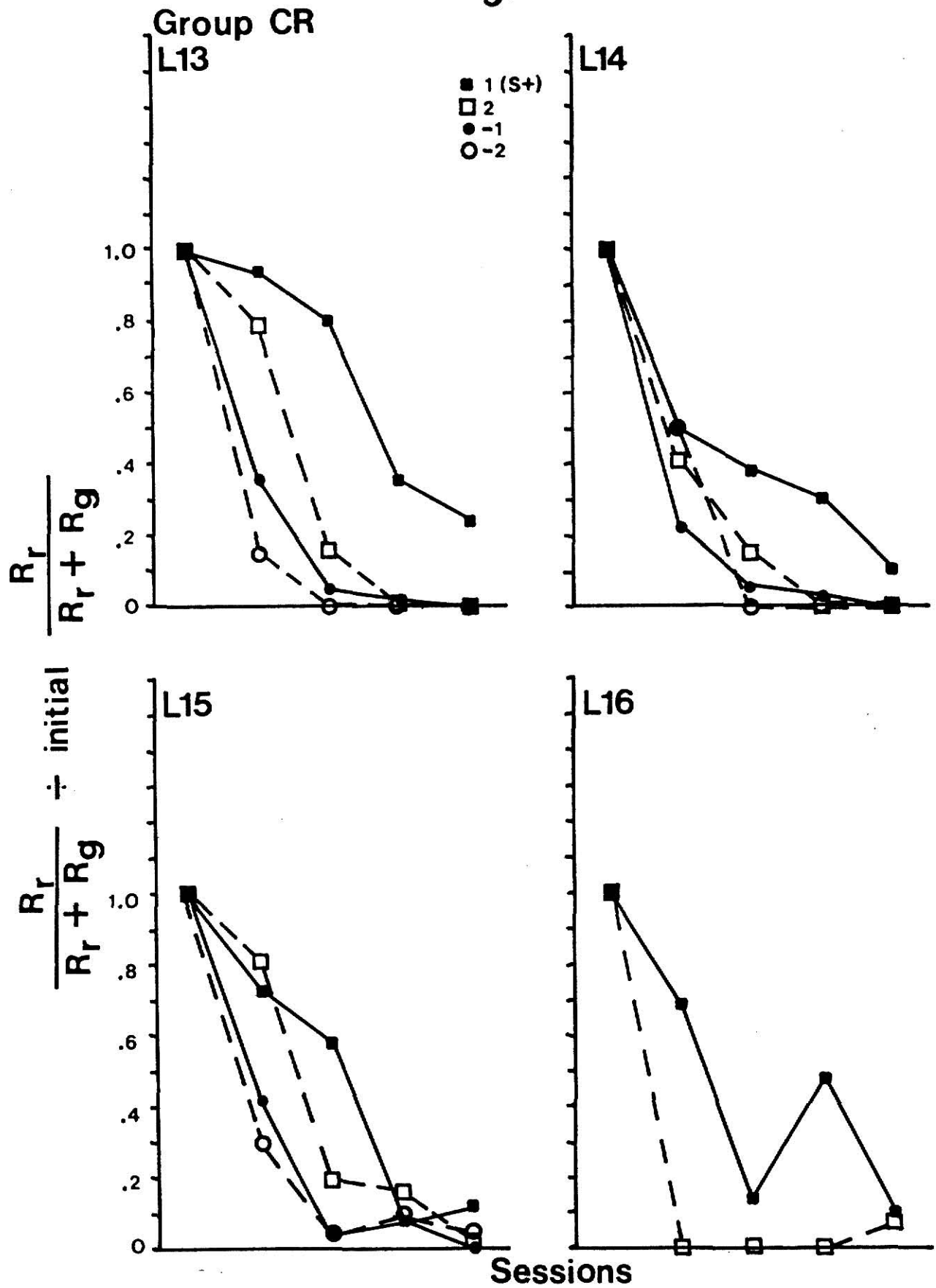
Figure 8



## Figure Caption

Figure 9. The course of extinction of responding to each stimulus relative to the original rate of response for each stimulus. Each graph represents the results for a single bird. Extinction is plotted separately for each stimulus and averaged within each stimulus for each session. Data points for stimuli 1 and 0 for Pigeon L16 are missing due to the original rate of response being 0 (relative ratios =  $\infty$ ).

Figure 9



### Figure Caption

Figure 10. The mean ratio of responding relative to the initial rate of responding for each stimulus and session per experimental group. Each graph presents the course of extinction of responding relative to the initial rate of responding averaged across the total response ratios from each individual subject within a group.

Figure 10

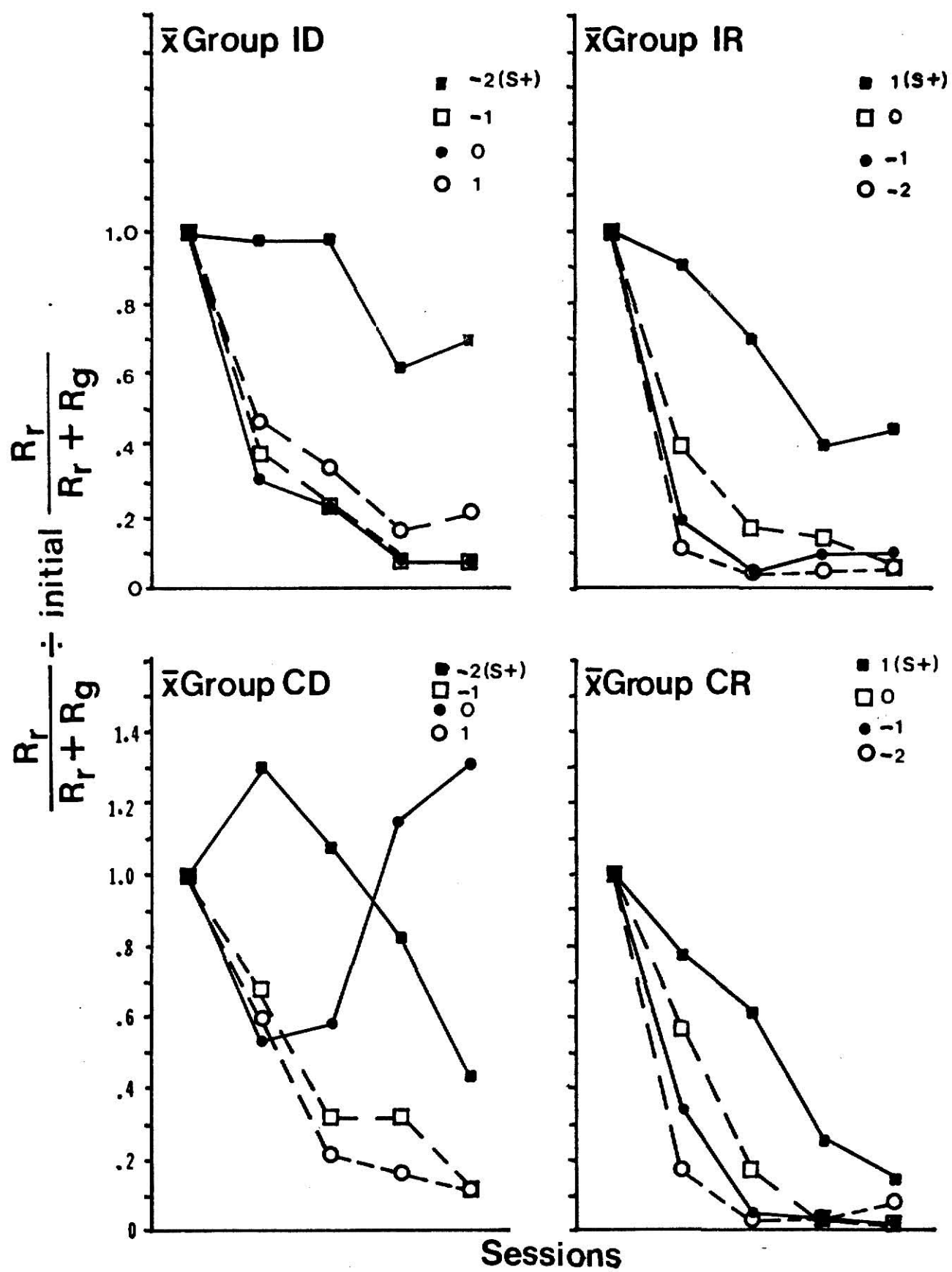


Figure Caption

Figure 11. Mean absolute extinction gradients collapsed across Groups ID and CD and across Groups IR and CR.

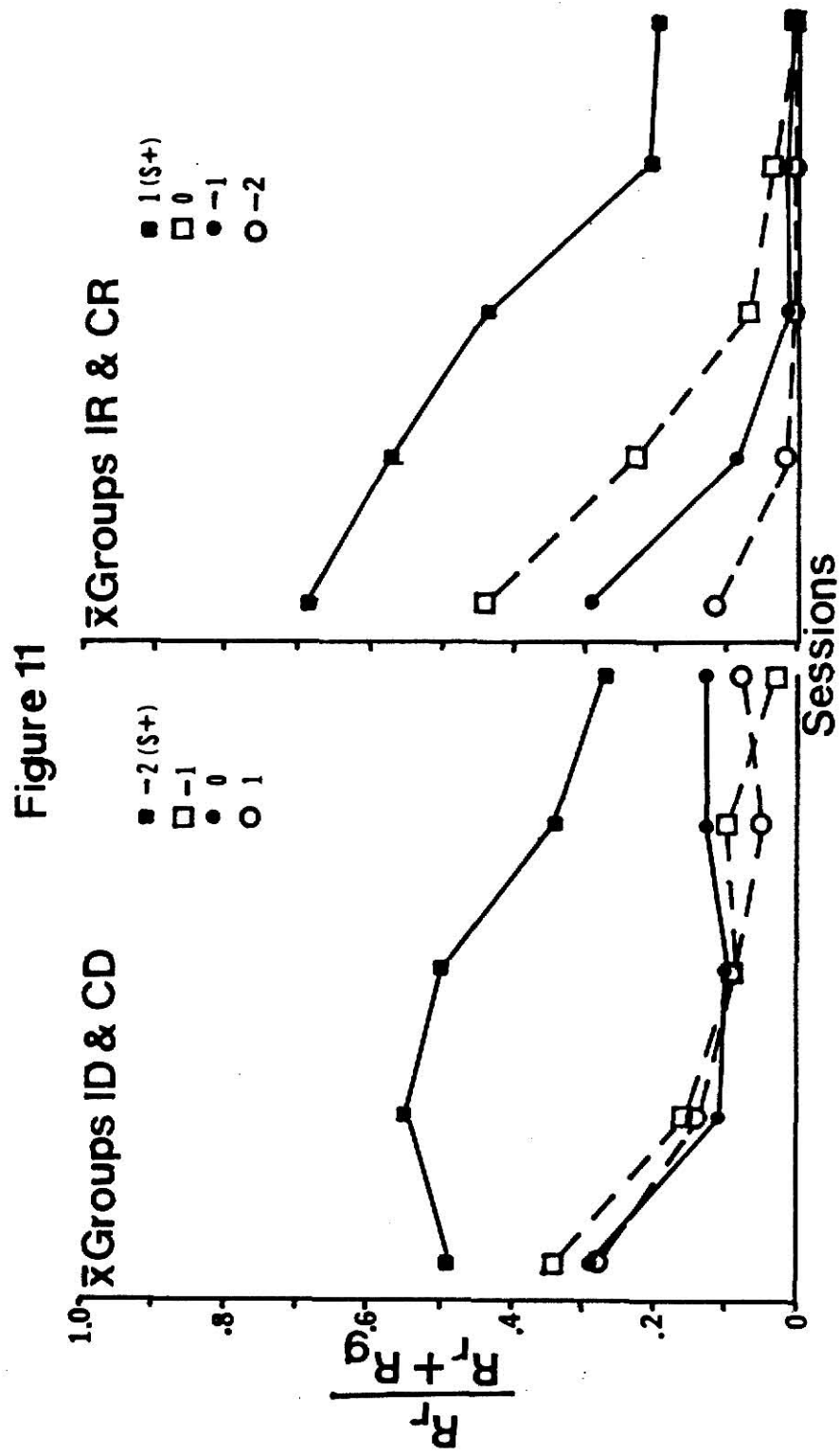
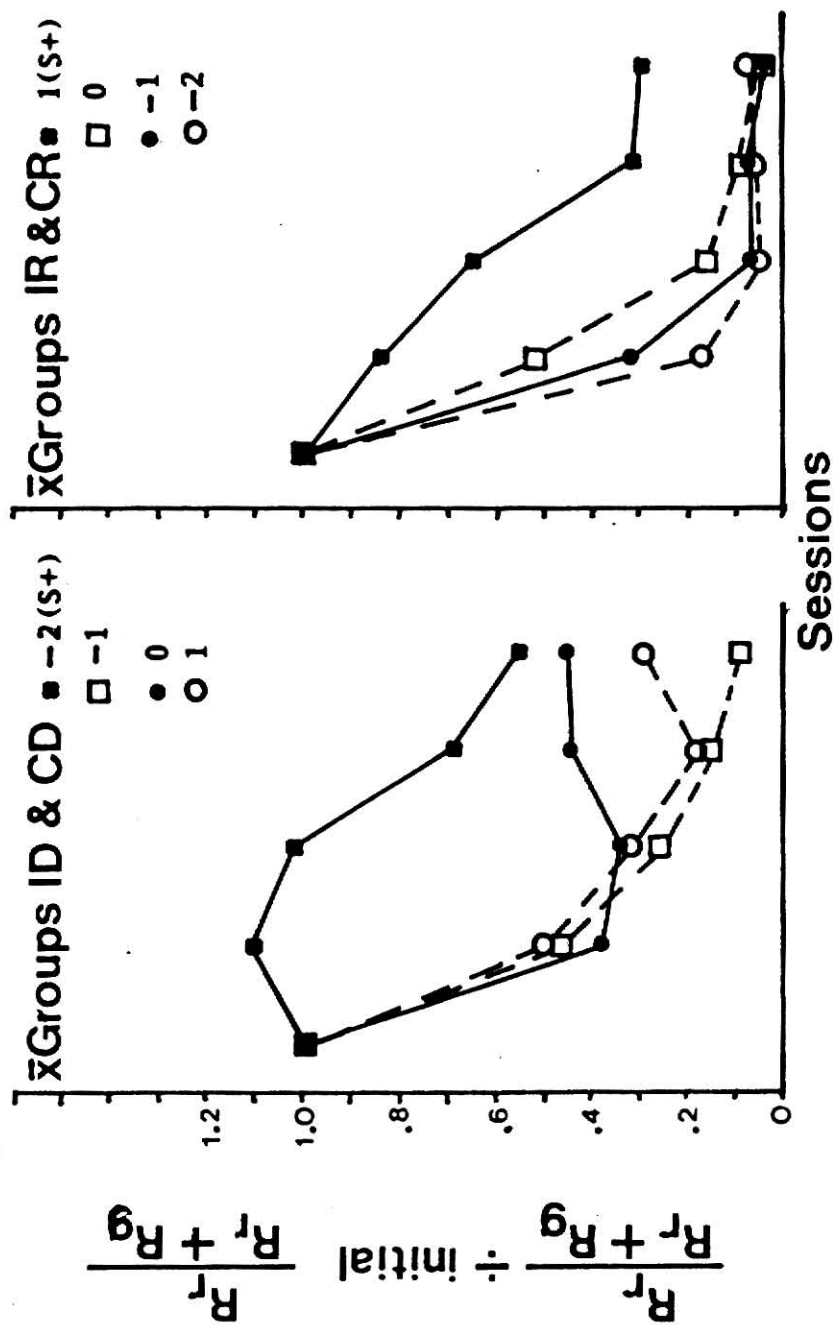


Figure Caption

Figure 12. Mean relative extinction gradients collapsed across Groups ID and CD and across Groups IR and CR.

Figure 12



## DISCUSSION

The unplanned modification in the training procedure made to counter the extreme side preferences encountered in training Groups ID and IR (the interchanging component-locations groups) complicates somewhat the comparison between Groups ID-IR and CD-CR. Nevertheless the gradients obtained from each interchanged group (ID and IR) are quite similar to those obtained from the comparable constant group (CD and CR). This similarity suggests that with an interval scale of strength of response tendencies, generalization gradients may be unaffected by the presence of irrelevant cues, i.e. variations in extraneous stimuli which are uncorrelated with outcomes.

The incidence of undermatching (the relative frequencies of response being closer to one-half than to the relative frequencies of grain presentations) at the end of training suggests two possibilities. One is that the stability criterion may not have been stringent enough for steady-state performance to have been observed. While a number of reports either did not specify or did not require a criterion (Herrnstein, 1961; Catania, 1963; Stubbs and Pliskoff, 1969), there are some reports which include more rigorous criteria than the present one (Trevett, Davison, and Williams, 1972; Davison, 1970; Silberberg and Fantino, 1970). The present study could have included a more stringent stability criterion by assessing within session variability in trial-by trial responding to each key. This would have been a more relevant measure given the importance of trial-by-trial data during testing. Possibly, if future research employs more rigorous criteria, this problem of undermatching will not occur.

Another possible factor involved in the incidence of undermatching is suggested because Figures 1 through 4 contain no indication that further training would have resulted in closer matching. It seems likely that there is a systematic deviation from matching with the procedure employed. Therefore the intervals on the scale of the strength of response tendencies employed may be only approximately equal. The possible factor which may have resulted in this deviation from matching is that the COD (two sec) may have been too low for some birds to produce matching. There is substantial evidence that given subjects require an unpredictable minimum COD value for conditions to produce matching (DeVilliers, 1977). The current COD value may not have been sufficient for all pigeons. Certainly the literature contains many studies employing similar procedures which failed to produce close matching (DeVilliers, 1977).

Figure 5 presents the initial generalization gradients obtained. Note that while the gradients of Group CR reflect a uniform decrement, the gradients of Group CD are much flatter. This is a confirmation of the stimulus intensity effects typically obtained (Gray, 1965). The flat gradients would presumably reflect a situation where the effects of increasing stimulus intensity upon the strength of response tendencies are in opposition to the effects of stimulus-distance from training.

Examination of the extinction gradients of Figures 6 through 9 provides strong evidence of differential extinction rates between the training and all other test stimuli. This is the most striking result of the present study. The final relative response ratios to the three test stimuli average .42

across all subjects with the mean difference between the two most discrepant points for each subject being 1.23. In contrast, the final relative response ratio to the training stimulus averages 1.27 across all subjects. The mean difference between these training-stimulus points and the average of the three test stimulus points for each subject is .85 (range -1.3 to 10.372). This is a clear difference for 12 of the 16 subjects. Whereas previous evidence could not provide a defensible slope for a gradient of the strength of generalized response tendencies (Wickens, Schroder, and Snide, 1954; Hoffman and Fleshler, 1961; and Thomas and Barber, 1964), the current evidence seems to be measured by a scale with approximately equal intervals of the strength of generalized response tendencies. The current data seems to be the first to provide evidence of more rapid extinction of the strength of generalized response tendencies which would still be valid after permissible transformation of the Y axis.

The use of multiple-stimulus tests may have affected the shape of the stimulus generalization gradients presently provided. Changing the number of test stimuli employed in a multiple-stimulus test has markedly affected the shape of the generalization gradient (Marsh, 1967; Thomas and Bistey, 1964). Direct comparisons of multiple- and single-stimulus test gradients have shown marked differences between the obtained gradients (Kalish and Haber, 1963). None of these studies, however, have employed the interval response scales necessary to make the appropriate comparisons in a valid manner.

The techniques employed provided easily obtained data for relating a measure of behavior change to a stimulus dimension along which both training and test stimuli fall. The principal contribution of this

study is that it indicates the feasibility of this method. If the present method provides a scale with approximately equal intervals of the strength of response tendencies, then there is promise that the difficult questions concerning stimulus generalization may be answered (Blough, 1965).

## REFERENCES

- Baum, W.M. On two types of deviation from the matching law: Bias and undermatching. Journal of the Experimental Analysis of Behavior, 1974, 22, 231-242.
- Baum, W.M. Choice, changeover, and travel. Journal of the Experimental Analysis of Behavior, 1982, 38, 35-49.
- Bergman, G. & Spence, K.W. The logic of psychophysical measurement. The Psychological Review, 1944, 51, 1-24.
- Bitterman, M.E. Generalization. In M.E. Bitterman, V.M. LoLordo, J.B. Overmeir, & M.E. Rashotte (Eds.), Animal learning: Survey and analysis. New York: Plenum Press, 1979.
- Blough, D.S. Dark adaptation in the pigeon. Journal of Comparative and Physiological Psychology, 1956, 49, 425-430.
- Blough, D.S. Definitions and measurement in generalization research. In D.I. Mostofsky (Ed.), Stimulus generalization. Stanford: Stanford University Press, 1965.
- Brown, J.S. Generalization and discrimination. In D.I. Mostofsky (Ed.), Stimulus generalization. Stanford: Stanford University Press, 1965.
- Brownstein, A.J. & Pliskoff, S.S. Some effects of relative reinforcement rate and changeover delay in response independent concurrent schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1968, 11, 683-688.
- Catania, A.C. Concurrent performances: Reinforcement interaction and response independence. Journal of the Experimental Analysis of Behavior, 1963, 6, 253-264.
- Catania, A.C. & Cutts, D. Experimental control of superstitious responding in humans. Journal of the Experimental Analysis of Behavior, 1963, 6, 203-208.

- Davison, M.C. A choice technique to assess the effects of selective punishment on fixed-ratio performance. Journal of the Experimental Analysis of Behavior, 1970, 13, 57-64.
- DeVilliers, P. Choice in concurrent schedules and a quantitative formulation of the law of effect. In W.K. Honig & J.E.R. Staddon, (Eds.), Handbook of operant behavior. Englewood Cliffs, N.J.: Prentice-Hall, 1977.
- DeVilliers, P.A. & Herrnstein, R.J. Toward a law of response strength. Psychological Bulletin, 1977, 74, 1131-1153.
- Fleshler, M. & Hoffman, H.S. Stimulus generalization of conditioned suppression. Science, 1961, 133, 753-755.
- Fleshler, M., & Hoffman, H.S. A progression for generating variable-interval schedules. Journal of the Experimental Analysis of Behavior, 1962, 5, 529-530.
- Ganz, L. Hue generalization and hue discrimination in Macaca Mulatta. Journal of Experimental Psychology, 1962, 64, 142-150.
- Grant, D.A. & Schiller, J.J. Generalization of the conditioned galvanic skin response to visual stimuli. Journal of Experimental Psychology, 1953, 46, 309-313.
- Gray, J.A. Stimulus intensity dynamism. Psychological Bulletin, 1965, 63, 180-196.
- Guttman, N. Laws of behavior and facts of perception. In S. Koch (Ed.), Psychology: A study of a science (Vol. 5). New York: McGraw-Hill, 1963.
- Heineman E.G., & Chase, S. Stimulus generalization. In W.K. Estes (Ed.) Handbook of learning and cognitive processes (Vol. 2). Hillsdale, N.J.: Lawrence Erlbaum Associates, 1975.

- Herrnstein, R.J. Relative and absolute strength of response as a function of frequency of reinforcement. Journal of the Experimental Analysis of Behavior, 1961, 4, 267-272.
- Herrnstein, R.J. & Loveland, D.H. Maximizing and matching on concurrent ratio schedules. Journal of the Experimental Analysis of Behavior, 1975, 24, 107-116.
- Honig, W.K., & Urcuioli, P.J. The legacy of Guttman and Kalish (1956): Twenty-five years of research on stimulus generalization. Journal of the Experimental Analysis of Behavior, 1981, 36, 405-445.
- Jenkins, H.M., & Harrison, R.H. Effect of discrimination training on auditory generalization. Journal of Experimental Psychology, 1960, 59, 246-253.
- Kalish, H.I. Stimulus generalization. In M.H. Marx (Ed.), Learning Processes, London: The Macmillan Company, 1969.
- Kalish, H.I., & Haber, A. Generalization: I. Generalization gradients from single and multiple stimulus points. II. Generalization of inhibition. Journal of Experimental Psychology, 1963, 65, 176-181.
- Keller, J.V., & Gollub, L.R. Duration and rate of reinforcement as determinants of concurrent responding. Journal of the Experimental Analysis of Behavior, 1977, 28, 145-153.
- MacKintosh, N.J. The psychology of animal learning. New York: Academic Press, 1974.
- Marsh, G.D. The inverse relationship between discriminability and stimulus generalization as a function of the number of test stimuli. Journal of Comparative and Physiological Psychology, 1967, 64, 284-289.

- Miller, N.E. & Murray, E.J. Displacement and conflict: Learnable drive as a basis for the steeper gradient of avoidance than of approach. Journal of Experimental Psychology, 1952, 43, 227-231.
- Nevin, J.A. Interval reinforcement of choice behavior in discrete trials. Journal of the Experimental Analysis of Behavior, 1969, 12, 875-885.
- Perkins, C.C. The analysis of performance. In M.D. Zeiler & P. Harzem (Eds.), Advances in the analysis of behaviour (Vol. 3). Biological factors in learning. Chichester, U.K. and New York: Wiley & Sons, in press.
- Perkins, C.C. & Weyant, R.G. The interval between training and test trials as a determiner of the slope of generalization gradients. Journal of Comparative and Physiological Psychology, 1958, 51, 596-600.
- Razran, G. Stimulus generalization of conditioned responses. Psychological Bulletin, 1949, 46, 337-365.
- Rescorla, R.A., & Wagner, A.R. A theory of pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A.H. Black & W.F. Prokasy (Eds.), Classical conditioning II: Current research and theory. New York: Appleton-Century-Crofts, 1972.
- Rilling, M. Stimulus control and inhibitory processes. In W.K. Honig & J.E.R. Staddon (Eds.), Handbook of operant behavior. Englewood Cliffs, N.J.: Prentice-Hall, 1977.
- Robles, L.C., Newlin, R., & Thomas, D.R. Potentiation of attentional enhancement in the pigeon produced by a "blocking" stimulus. Animal Learning and Behavior, 1980, 8, 31-36.
- Silberberg, A., & Fantino, E. Choice, rate of reinforcement, and the changeover delay. Journal of the Experimental Analysis of Behavior, 1970, 13, 187-198.
- Stubbs, D.A. & Pliskoff, S.S. Concurrent responding with fixed relative rate of reinforcement. Journal of the Experimental Analysis of Behavior,

1969, 12, 887-895.

Thomas, D.R. & Barber, E.G. The effects of extinction and "central tendency" on stimulus generalization in pigeons. Psychonomic Science, 1964, 1, 119-120.

Thomas, D.R. & Bistey, G. Stimulus generalization as a function of the number and range of generalization test stimuli. Journal of Experimental Psychology, 1964, 68, 599-602.

Todorov, J.C. Concurrent performances: Effect of punishment contingent on the switching response. Journal of the Experimental Analysis of Behavior, 1971, 16, 51-62.

Trevett, A.J., Davison, M.C., & Williams, R.J. Performance in concurrent interval schedules. Journal of the Experimental Analysis of Behavior, 1972, 17, 369-374.

Wickens, D.D., Schroder, H.M., & Snide, J.D. Primary stimulus generalization of the GSR under two conditions. Journal of Experimental Psychology, 1954, 47, 52-56.

#### Appendix A.

The Sequence of Test Cycles of Test Stimulus Presentation.

Table A. Sequence of test cycles of test stimulus presentation.

3 (brightest) = log 1.0 ft L.; 2 = log 0.0 ft L.; 1 = log -1.0 ft L.,

0 (dimpest) = log -2.0 ft L. The right hand column lists the group and number of the pigeons which were first presented with a given test cycle. The sequence of test cycles of trials for each pigeon then followed in the numerical order of test cycle until the end of testing.

Test Cycle #	Test Cycle	First for Pigeon #	
1	3 2 1 0 0 1 2 3	IR-5	CR-13
2	2 1 0 3 3 0 1 2	IR-6	CR-14
3	1 0 3 2 2 3 0 1	IR-7	CR-15
4	0 3 2 1 1 2 3 0	IR-8	CR-16
5	3 1 0 2 2 0 1 3		
6	2 0 3 1 1 3 0 2		
7	1 3 2 0 0 2 3 1		
8	0 2 1 3 3 1 2 0		
9	3 0 2 1 1 2 0 3		
10	2 3 1 0 0 1 3 2		
11	1 2 0 3 3 0 2 1		
12	0 1 3 2 2 3 1 0		
13	3 2 0 1 1 0 2 3		
14	2 1 3 0 0 3 1 2		
15	1 0 2 3 3 2 0 1		
16	0 3 1 2 2 1 3 0		
17	3 1 2 0 0 2 1 3		
18	2 0 1 3 3 1 0 2		
19	1 3 0 2 2 0 3 1		
20	0 2 3 1 1 3 2 0		
21	3 0 1 2 2 1 0 3	ID-4	CD-12
22	2 3 0 1 1 0 3 2	ID-3	CD-11
23	1 2 3 0 0 3 2 1	ID-2	CD-10
24	0 1 2 3 3 2 1 0	ID-1	CD-9

#### APPENDIX B

Response ratios during testing for each randomized, counterbalanced test cycle of eight trials for each subject.

Table B

Session & Test Cycle	L1				L2				L3			
	1.0	0.0	-1.0	-2.0	1.0	0.0	-1.0	-2.0	1.0	0.0	-1.0	-2.0
1 1	.35	.75	.91	.57	.11	.33	.64	.61	.69	.79	.58	.17
2	.79	.62	.65	.67	.02	.42	.54	.61	.39	.45	.70	.53
3	.78	.35	.62	.57	.04	.26	.36	.48	.21	.82	.32	.11
4	.34	.51	.35	.70	.39	.07	.42	.59	.03	.46	.01	.26
5	.88	.61	.52	.56	.07	.35	.58	.48	.51	.46	.06	.12
2 1	.41	.40	.14	.54	.00	.14	.21	.39	.04	.22	.30	.66
2	.24	.17	.42	.52	.00	.08	.04	.46	.44	.16	.10	.64
3	.10	.37	.15	.11	.00	.05	.18	.50	.00	.08	.20	.56
4	.06	.05	.24	.23	.00	.06	.09	.64	.01	.06	.31	.40
5	.83	.05	.23	.22	.00	.02	.14	.59	.02	.12	.24	.61
3 1	.53	.13	.16	.49	.00	.01	.28	.60	.07	.14	.23	.67
2	.11	.11	.19	.36	.00	.06	.04	.38	.38	.03	.15	.53
3	.00	.30	.23	.46	.00	.01	.09	.36	.03	.05	.09	.53
4	.40	.11	.06	.34	.00	.09	.00	.38	.03	.02	.12	.58
5	.29	.15	.13	.26	.00	.00	.00	.52	.00	.00	.00	.25
4 1	.26	.07	.03	.24	.00	.02	.00	.27	.11	.11	.39	.40
2	.34	.06	.05	.09	.00	.03	.00	.50	.00	.05	.10	.30
3	.18	.03	.04	.06	.00	.00	.00	.41	.03	.01	.02	.43
4	.06	.01	.07	.15	.00	.00	.00	.40	.00	.00	.01	.38
5	.00	.04	.03	.04	.00	.00	.04	.23	.00	.03	.00	.34
5 1	.19	.01	.02	.06	.00	.00	.02	.17	.03	.05	.07	.53
2	.60	.11	.02	.06	.00	.00	.04	.21	.00	.01	.10	.35
3	.00	.00	.01	.04	.00	.02	.03	1.0	.04	.00	.02	.23
4	.05	.04	.04	.09	.00	.00	.00	.15	.30	.04	.01	.59
5	.00	.09	.08	.15	.00	.00	.01	.47	.00	.00	.00	.24

Table B con't

Session & Test Cycle	L4				L5				L6			
	1.0	0.0	-1.0	-2.0	1.0	0.0	-1.0	-2.0	1.0	0.0	-1.0	-2.0
1 1	.86	.58	.67	.57	.57	.32	.17	.00	.75	.62	.31	.44
2	.24	.27	.35	.73	.46	.74	.34	.16	.77	.34	.21	.25
3	.25	.65	.37	.62	.81	.37	.13	.08	.70	.56	.24	.15
4	.37	.53	.65	.65	.42	.50	.01	.35	.53	.02	.16	.01
5	.37	.76	.52	.81	.88	.37	.25	.29	.50	.40	.06	.11
2 1	.79	.10	.19	.63	.75	.08	.01	.07	.45	.43	.07	.00
2	.08	.09	.13	.59	.53	.34	.02	.13	.59	.05	.11	.06
3	.57	.03	.02	.67	.44	.06	.05	.02	.74	.00	.22	.04
4	.03	.06	.33	.67	.80	.24	.00	.00	.45	.16	.00	.00
5	.05	.03	.12	.56	.39	.36	.21	.02	.44	.01	.00	.00
3 1	.02	.46	.00	.79	.07	.00	.16	.00	.21	.02	.01	.00
2	.03	.00	.11	.80	.08	.02	.06	.00	.38	.02	.00	.00
3	.49	.01	.33	.77	.33	.28	.00	.00	.39	.00	.00	.00
4	.30	.02	.00	.70	.13	.02	.00	.03	.49	.06	.00	.00
5	.01	.00	.06	.52	.34	.05	.01	.10	.55	.02	.00	.00
4 1	.01	.00	.02	.45	.53	.49	.15	.01	.44	.01	.02	.00
2	.20	.04	.00	.56	.26	.08	.01	.01	.44	.00	.01	.00
3	.08	.06	.03	.42	.29	.16	.06	.11	.30	.00	.07	.01
4	.08	.00	.00	.46	.15	.07	.06	.01	.45	.00	.01	.00
5	.05	.00	.00	.33	.23	.04	.01	.07	.45	.00	.00	.00
5 1	.25	.00	.00	.55	.28	.08	.10	.05	.13	.00	.00	.00
2	.10	.00	.01	.50	.09	.02	.00	.00	.52	.00	.00	.00
3	.00	.00	.17	.41	.22	.05	.00	.03	.39	.02	.00	.00
4	.10	.00	.00	.42	.08	.10	.21	.03	.42	.01	.03	.00
5	.02	.00	.07	.48	.18	.10	.00	.00	.27	.00	.00	.00

Table B con't

Session & Test Cycle	L7				L8				L9			
	1.0	0.0	-1.0	-2.0	1.0	0.0	-1.0	-2.0	1.0	0.0	-1.0	-2.0
1 1	.77	.06	.15	.00	.68	.56	.39	.11	.57	.70	.70	.71
2	.67	.07	.01	.00	.57	.50	.60	.04	.87	.88	.72	.74
3	.74	.04	.00	.01	.84	.67	.45	.26	.62	.50	.60	.82
4	.81	.01	.01	.00	.75	.46	.35	.05	.50	.62	.74	.64
5	.84	.04	.00	.01	.61	.42	.29	.04	.63	.72	.80	.97
2 1	1.0	.06	.00	.00	.61	.30	.06	.01	.49	.13	.41	.69
2	.59	.02	.00	.00	.63	.05	.07	.00	.26	.40	.39	.84
3	.69	.00	.00	.01	.62	.11	.05	.06	.32	1.0	.32	.76
4	.76	.00	.00	.01	.67	.41	.00	.00	.64	.43	.63	.74
5	.53	.00	.00	.00	.61	.13	.00	.00	.51	.15	.48	.59
3 1	.44	.00	.00	.00	.78	.32	.01	.00	.20	.20	.30	.76
2	.49	.00	.00	.00	.94	.00	.03	.00	.19	.26	.35	.41
3	.52	.00	.00	.00	.68	.00	.00	.00	.09	.13	.10	.71
4	.37	.00	.00	.00	.76	.10	.00	.00	.04	.09	.11	.55
5	.58	.00	.00	.00	.81	.23	.00	.04	.03	.13	.39	.39
4 1	.36	.04	.00	.00	.42	.04	.00	.00	.02	.10	.05	.61
2	.46	.00	.00	.00	.61	.07	.00	.00	.12	.25	.20	.47
3	.29	.00	.00	.00	.70	.00	.00	.00	.03	.17	.47	.46
4	.34	.01	.00	.00	.11	.04	.00	.00	.03	.25	.31	.79
5	.21	.00	.00	.00	.47	.00	.00	.00	.08	.38	.27	.73
5 1	.34	.00	.00	.00	.32	.01	.00	.00	.02	.30	.00	.36
2	.21	.00	.00	.00	.69	.00	.03	.05	.00	.53	.08	.37
3	.22	.00	.00	.00	.61	.00	.00	.00	.11	.47	.14	.12
4	.04	.00	.00	.00	.51	.00	.00	.00	.11	.35	.12	.16
5	.12	.00	.00	.00	.39	.00	.00	.00	.13	.44	.00	.11

Table B con't

Session & Test Cycle	L10				L11				L12			
	1.0	0.0	-1.0	-2.0	1.0	0.0	-1.0	-2.0	1.0	0.0	-1.0	-2.0
1 1	.00	.00	.00	.00	.04	.09	.02	.50	.00	.00	.00	.25
2	.00	.00	.14	.00	.03	.01	.00	.53	.00	.00	.00	.42
3	.00	.00	.02	.05	.01	.02	.00	.58	.00	.00	.00	.51
4	.20	.15	.04	.10	.01	.01	.02	.65	.00	.00	.00	.63
5	.12	.03	.00	.00	.07	.01	.01	.49	.00	.00	.04	.44
2 1	.00	.02	.14	.80	.00	.00	.00	.36	.00	.00	.00	.33
2	.02	.00	.05	.91	.00	.00	.00	.35	.00	.00	.00	.37
3	.00	.00	.07	.91	.00	.00	.00	.32	.00	.00	.00	.73
4	.00	.00	.00	.87	.00	.00	.00	.30	.00	.00	.00	.57
5	.00	.00	.04	.80	.00	.00	.00	.29	.00	.00	.00	.26
3 1	.00	.00	.00	.79	.00	.23	.01	.28	.00	.26	.00	.16
2	.04	.00	.00	.87	.00	.23	.00	.22	.00	.31	.00	.40
3	.12	.00	.00	.82	.01	.29	.00	.31	.00	.19	.00	.33
4	.03	.00	.00	.75	.00	.27	.03	.21	.00	.34	.00	.46
5	.07	.00	.00	.67	.00	.29	.00	.35	.00	.21	.00	.30
4 1	.08	.07	.00	.84	.00	.17	.00	.19	.00	.11	.00	.00
2	.07	.05	.00	.61	.00	.14	.00	.04	.00	.28	.00	.16
3	.11	.70	.00	.71	.00	.11	.00	.20	.00	.04	.00	.03
4	.00	.76	.00	.58	.00	.21	.01	.14	.00	.10	.00	.03
5	.00	.34	.00	.48	.00	.19	.00	.18	.00	.05	.00	.02
5 1	.07	.58	.01	.56	.00	.20	.00	.11	.00	.09	.00	.02
2	.00	.48	.00	.46	.00	.12	.00	.12	.00	.10	.00	.01
3	.00	.37	.00	.32	.00	.07	.00	.08	.00	.02	.00	.17
4	.00	.26	.00	.42	.00	.07	.00	.05	.00	.04	.00	.11
5	.00	.40	.01	.32	.00	.07	.00	.19	.00	.01	.00	.00

Table B con't

Session & Test Cycle	L13				L14				L15			
	1.0	0.0	-1.0	-2.0	1.0	0.0	-1.0	-2.0	1.0	0.0	-1.0	-2.0
1 1	.83	.76	.73	.27	.71	.54	.37	.04	.63	.65	.53	.30
2	.88	.84	.61	.16	.84	.53	.68	.01	.78	.63	.45	.17
3	.88	.86	.77	.21	.95	.66	.36	.02	.76	.72	.58	.30
4	.93	.84	.49	.07	.89	.55	.16	.01	.77	.45	.26	.15
5	.85	.73	.49	.04	.85	.44	.42	.01	.78	.67	.61	.08
2 1	.84	.47	.09	.01	.30	.20	.15	.00	.36	.61	.08	.16
2	.79	.61	.22	.02	.55	.24	.11	.00	.62	.57	.09	.03
3	.97	.71	.32	.07	.51	.32	.06	.02	.62	.52	.21	.08
4	.76	.69	.36	.02	.42	.20	.03	.00	.55	.56	.36	.00
5	.75	.62	.15	.02	.32	.17	.03	.01	.60	.53	.29	.00
3 1	.82	.20	.02	.00	.32	.11	.07	.00	.53	.14	.06	.00
2	.77	.13	.07	.00	.41	.05	.02	.00	.40	.28	.01	.02
3	.75	.18	.06	.00	.34	.10	.01	.00	.40	.08	.01	.00
4	.49	.08	.02	.00	.28	.06	.01	.00	.46	.08	.03	.02
5	.58	.05	.01	.01	.25	.10	.01	.00	.36	.06	.01	.02
4 1	.30	.00	.01	.00	.15	.00	.02	.00	.17	.00	.01	.00
2	.25	.00	.00	.00	.25	.00	.02	.00	.00	.00	.16	.00
3	.38	.00	.00	.00	.35	.00	.00	.00	.01	.08	.00	.00
4	.17	.00	.00	.00	.32	.00	.02	.00	.02	.35	.02	.00
5	.43	.00	.02	.00	.28	.00	.00	.00	.01	.01	.01	.08
5 1	.08	.00	.00	.00	.15	.00	.00	.00	.03	.02	.00	.01
2	.10	.00	.01	.00	.10	.00	.00	.00	.09	.01	.01	.00
3	.35	.00	.00	.00	.02	.00	.00	.00	.08	.00	.00	.00
4	.16	.00	.00	.00	.05	.00	.00	.00	.09	.01	.00	.00
5	.33	.00	.00	.00	.10	.00	.00	.00	.13	.01	.02	.02

Table B con't

Session & Test Cycle		L16			
		1.0	0.0	-1.0	-2.0
1	1	.52	.27	.01	.01
	2	.52	.09	.01	.00
	3	.48	.05	.00	.00
	4	.46	.18	.00	.00
	5	.44	.07	.00	.00
2	1	.39	.00	.00	.00
	2	.34	.00	.00	.00
	3	.38	.00	.00	.00
	4	.15	.00	.00	.00
	5	.35	.00	.00	.00
3	1	.25	.00	.00	.00
	2	.21	.00	.00	.00
	3	.46	.00	.01	.00
	4	.17	.00	.00	.00
	5	.12	.00	.00	.00
4	1	.04	.00	.00	.00
	2	.03	.00	.00	.00
	3	.09	.00	.00	.00
	4	.08	.00	.00	.00
	5	.03	.00	.00	.00
5	1	.00	.00	.00	.00
	2	.13	.00	.00	.00
	3	.00	.00	.02	.00
	4	.08	.00	.00	.15
	5	.06	.03	.00	.06

## APPENDIX C

The course of extinction of responding to each stimulus averaged for each session, pigeon, and Group.

### Figure Caption

Figure 13. The course of extinction of responding averaged for each session for each pigeon in Group ID. Extinction is plotted separately for each stimulus.

Figure 13

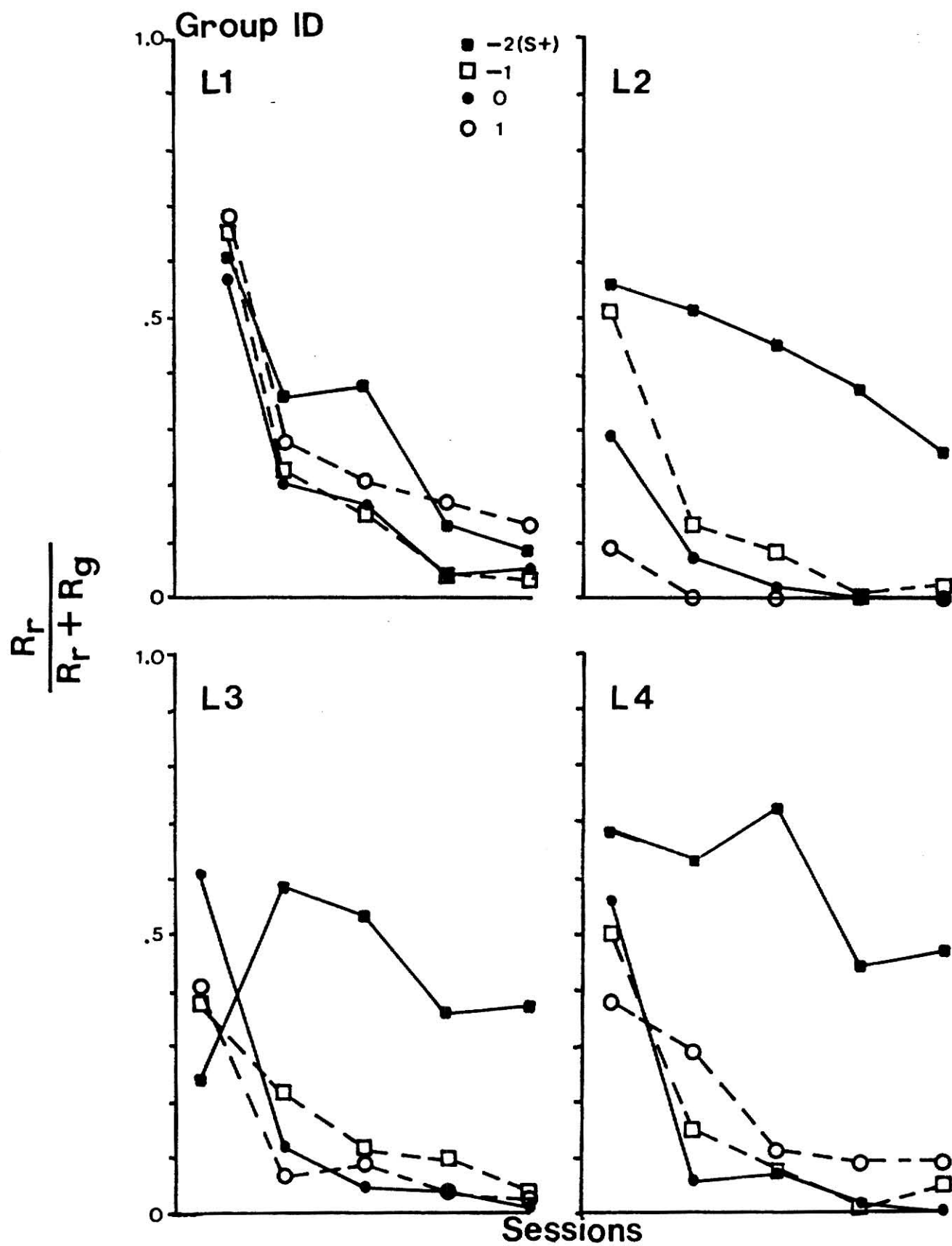


Figure Caption

Figure 14. The course of extinction of responding averaged for each session for each pigeon in Group IR. Extinction is plotted separately for each stimulus.

Figure 14

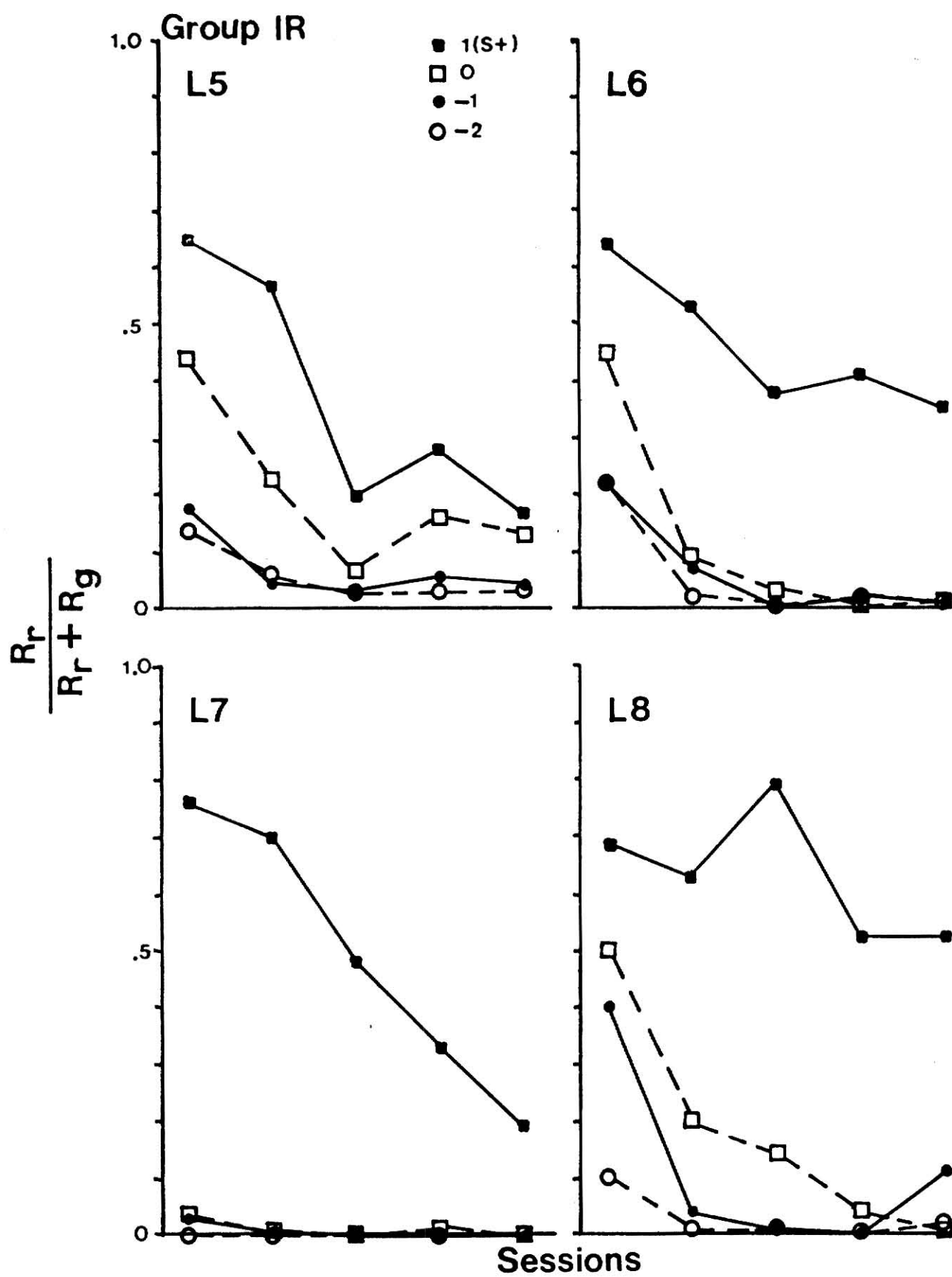


Figure Caption

Figure 15. The course of extinction of responding averaged for each session for each pigeon in Group CD. Extinction is plotted separately for each stimulus.

Figure 15

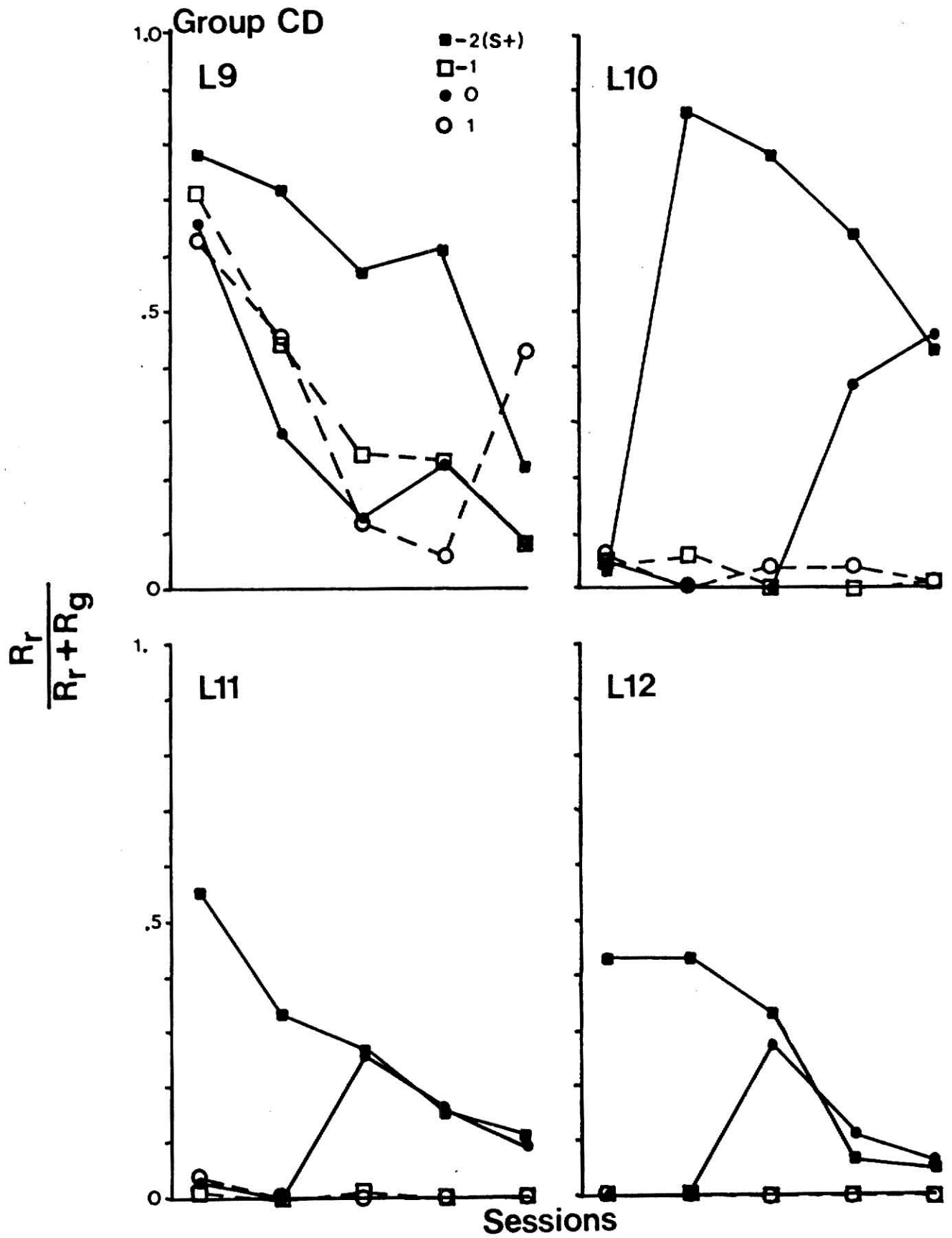


Figure Caption

Figure 16. The course of extinction of responding averaged for each session for each pigeon in Group CR. Extinction is plotted separately for each stimulus.

Figure 16

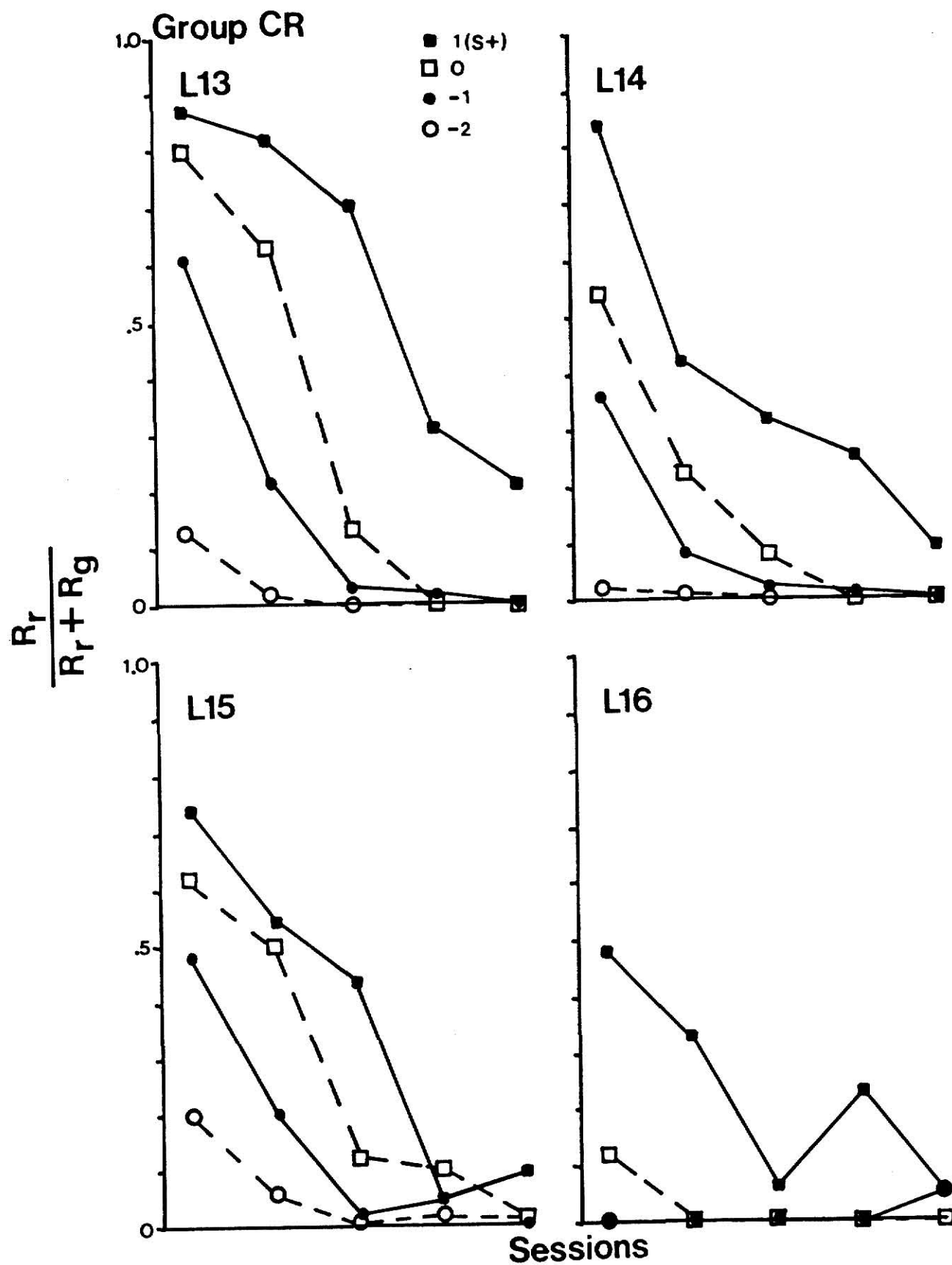
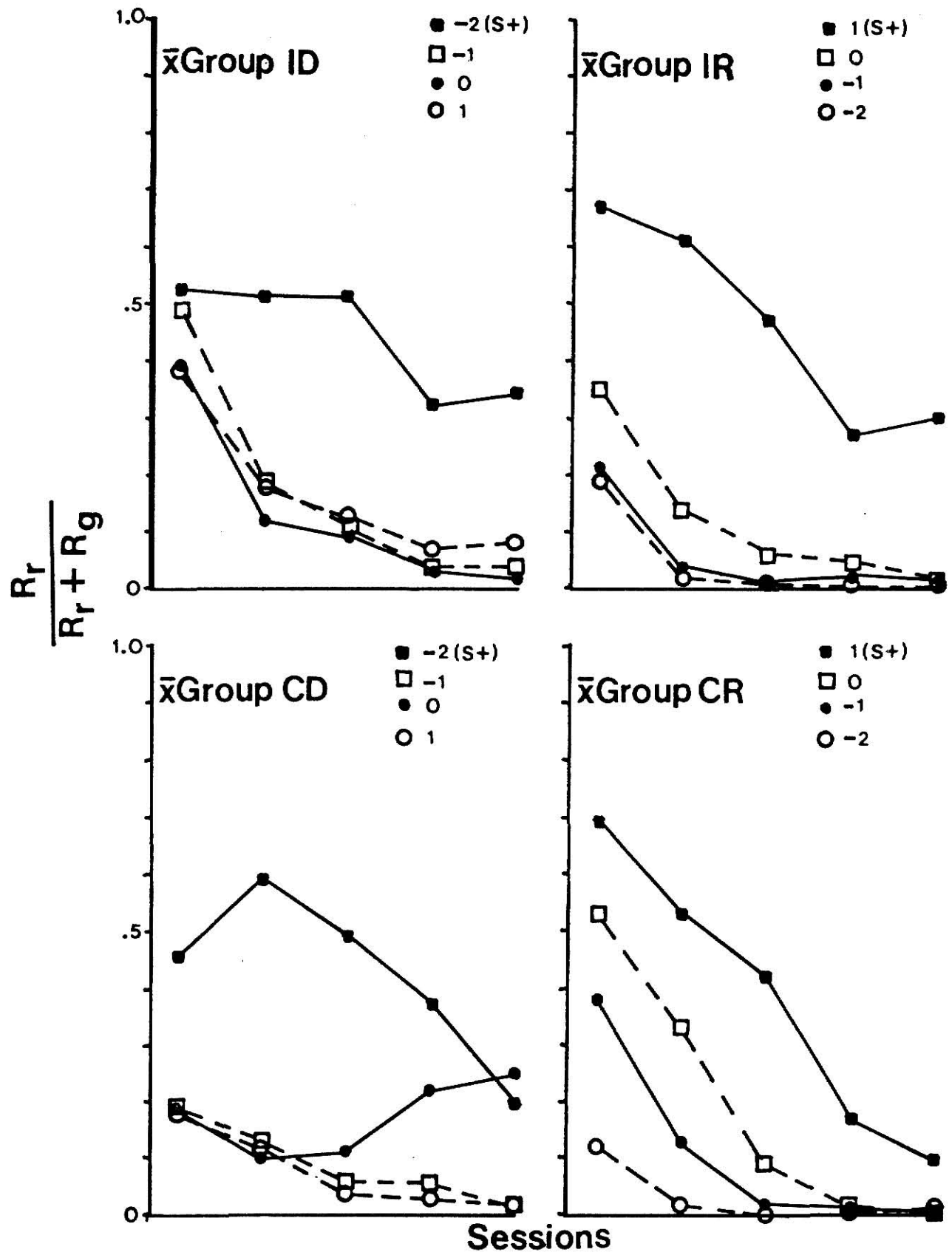


Figure Caption

Figure 17. The mean ratio of responding for each stimulus and session per experimental group. Each graph presents the course of absolute extinction of responding averaged across the total response ratios from each individual subject within a group.

Figure 17



STIMULUS GENERALIZATION AND MATCHING  
IN CONCURRENT VARIABLE INTERVAL SCHEDULES

by

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B.A., State University College at Cortland, N.Y., 1976

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Psychology

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1982

## ABSTRACT

An experiment was conducted to determine the feasibility of employing a procedure which yields approximately equal interval measures of the strength of response tendencies for the study of stimulus generalization. The matching of relative response rates to relative rates of reinforcement on concurrent variable-interval variable-interval schedules was the basis for interval scale measures of the strength of response tendencies. One specific objective was to compare the rate of extinction of the strength of the response tendency to the conditioned stimulus with the rate of extinction of the strength of generalized response tendencies. A second objective was to compare generalization gradients yielded when the training stimulus was at either end of the portion of the brightness dimension employed. A third objective was to determine the effects of interchanging the locations of the training and comparison stimuli upon the brightness generalization gradients. Pigeons were trained on concurrent schedules with VI 1-min to a red, training stimulus and VI 4-min to a green, comparison stimulus. Eight pigeons were trained with the brightest of four possible stimulus values on the red key while eight were trained with the dimmest. Four pigeons from each of the above groups were trained with interchanging locations of stimuli and component schedules while the other eight were trained with the stimuli and component schedules always on the same key. Generalization tests were made by changing the VI 1-min schedule to extinction and changing the brightness of that key to each of four test brightnesses on different test trials. While a number of the pigeons failed to accurately match the relative frequencies of response to those of contingent stimuli, the results suggest that the strength of the generalized response tendencies decreases more rapidly than the strength of the responses to

the training stimulus. The two groups trained with the brightest stimulus showed an orderly initial generalization gradient while the groups trained with the dimmest showed flat initial generalization gradients. The position cue manipulation had little effect. It was concluded that this technique for measuring the strength of response tendencies on an interval scale may be profitably applied to the study of stimulus generalization.