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THE EFFECTS OF REINFORCEMENT/NONREINFORCEMENT RATIOS AND NUMBER OF TRIALS ON DISCRIMINATION REVERSAL LEARNING IN THE RAT

by

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Chairman of Examining Committee

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In recent years there has been a great deal of interest in discrimination reversal learning. One of the simplest types of reversal situations requires that the subject learn a two-choice discrimination to criterion. After the subject has reached criterion, the reinforcement contingencies are reversed; the former positive stimulus (S+) becomes the negative stimulus (S-), the former S- becomes the S+, and the subject must learn this second discrimination. A typical finding has been, with rats at least, that subjects take longer to learn the discrimination reversal than they did the first discrimination (e.g., more trials to reach reversal criterion than trials to reach criterion on the first discrimination).

D'Amato and Jagoda (1960) suggested that learning the discrimination reversal required more trials than learning the initial discrimination, largely because the animal had to extinguish avoidance tendencies to the former S-. They characterized early reversal learning as follows: By the end of the initial discrimination task the subject has built up sizeable approach tendencies to the S+ and rather strong avoidance tendencies to the S-. In order to reverse, the subject must extinguish approach tendencies to the former S+, but even more important, according to D'Amato and Jagoda, the subject must extinguish avoidance tendencies toward the former S-. In their opinion, the most important function of reward during reversal is to act to extinguish these formerly learned avoidance tendencies.

If it is relatively more difficult to extinguish avoidance tendencies to the old S- (new S+) than it is to extinguish approach tendencies to the old S+ (new S-), then reinforced trials to the old

S- during reversal should facilitate reversal more than do nonreinforced trials to the old S+. One way to assess the effects of reinforcement and those of nonreinforcement during reversal is to give different proportions (ratios) of reinforced trials to nonreinforced trials.

Assuming that extinction of avoidance tendencies is the difficult component of a discrimination reversal and that rewarded trials serve to extinguish these tendencies, then R/NR ratios employing a high proportion of reinforced trials should facilitate reversal more than ratios employing a low proportion of reinforced trials. In a test of this hypothesis Alfreds and Jagoda trained rats to make a simple brightness discrimination in an automated Y-maze (unpublished study). After reaching criterion on the initial discrimination, each subject was assigned to one of three groups. A control group was immediately put on free-choice reversal, while two experimental groups were given forced reversal trials. One of these E groups received a 1:3 R/NR ratio while the other E group received a 3:1 R/NR ratio. After completion of the forced reversal trials, both E groups were put on free-choice reversal and run to criterion.

Results from this study showed that each E group performed significantly better than the C group when measured by errors to reversal criterion. However, the 1:3 R/NR group was significantly superior to the 3:1 group on this measure. This difference between the E groups was in the opposite direction from that predicted by the original hypothesis. Thus, the original hypothesis was rejected, and the results of this study were interpreted as follows. Jagoda reasoned that these results suggested that the critical component of discrimination reversal learning is the establishment of avoidance tendencies to the new S-

(former S+). Learning to avoid the new S- is relatively more difficult than learning to approach the new S+, and nonreinforced trials to the new S- serve to establish avoidance tendencies to this stimulus. Thus, R/NR ratios employing high proportions of nonreinforced trials are more effective than R/NR ratios employing low proportions of nonreinforced trials.

The effectiveness of nonreinforced trials to the new S- has also been demonstrated by Stevens and Fechter (1967). In their study, rats were trained to make a two-choice simultaneous black-white discrimination in a trapezoidal discrimination box. As each subject met criterion on this initial discrimination it was assigned to one of two E groups. One of these E groups received twenty forced nonreinforced trials to the new S- (former S+), while the other E group received twenty forced reinforced trials to the new S+ (former S-). After this forced reversal, free-choice reversal training was begun. During free-choice reversal each trial consisted of the simultaneous presentation of the new S+ and the new S-.

Results from this study showed that, during free-choice reversal, the E group that had been given nonreinforced trials to the new S- was significantly superior to the E group that had been given reinforced trials to the new S+. Stevens and Fechter interpreted their findings as offering support for theoretical positions that stress the importance of inhibition or the acquisition of avoidance tendencies to S- in discrimination learning.

While the Alfreds and Jagoda study and the Stevens and Fechter study have been the only ones which clearly demonstrated the effectiveness of nonreinforcement of the incorrect response during reversal, several earlier studies had demonstrated the effectiveness of nonreinforcement during the acquisition of simple discrimination tasks that did not involve reversal learning. In an early study, Denny and Dunham (1951) trained rats in a T-maze to make a simple black-white discrimination. Their results showed that a group receiving 4 nonreinforced trials and 2 reinforced trials each day performed significantly better than a group which had 1 nonreinforced trial and 2 reinforced trials each day. In a later study, Cantor and Spiker (1954) obtained similar results with children in a simple two-choice discrimination task.

In both of these early studies the forced groups had unequal numbers of total acquisition trials, but subsequent studies have held the total number of acquisition trials constant and varied R/NR ratios. In the first of these studies, Birch (1955) combined four R/NR ratios with four different amounts of forcing. His results showed that, over-all, a 1:1 ratio produced optimal learning when rats were required to make a simple black-white discrimination.

While Birch's results did not indicate that nonreinforcement was more effective than reinforcement, in a later study Lachman (1961) clearly demonstrated the effectiveness of nonreinforced trials. In Lachman's study, rats were trained to make a brightness discrimination in an automated Y-maze. Three E groups were given different R/NR ratios: 1:3, 1:1, or 3:1. Results, as measured by percentage of correct responses during free-choice trials, showed that the 1:3 group was superior to the 1:1 group which, in turn, was superior to the 3:1 group.

Thus, the over-all results from these studies in which the effectiveness of nonreinforcement during the acquisition of simple discrimination tasks was demonstrated suggest that learning to avoid the S- may be relatively more difficult than learning to approach S+. Furthermore, the results of Alfreds and Jagoda and those of Stevens and Fechter suggest that discrimination reversal tasks are, in this respect, essentially no different from any two-choice discrimination task. That is, learning to avoid the new S- may be relatively more difficult than learning to approach the new S+ just as learning to avoid the old S- was relatively more difficult than learning to approach the old S+.

In order to examine further this view of discrimination reversal learning and to obtain preliminary information for the present study, two pilot studies were performed. In the first of these, rats were trained to make a brightness discrimination in automated discrimination shuttle boxes. After reaching criterion on the initial discrimination, each subject was assigned to a control group or to one of three E groups. Control subjects were put on free-choice reversal while all E subjects were given forced reversal trials prior to free-choice reversal. The three R/NR ratios used were: 4:1, 1:1, and 1:4. After the completion of forced reversal trials, each E subject was put on free-choice reversal and run to criterion.

When mean days to reversal criterion were analyzed, it was found that the 1:4 group learned the reversal in significantly fewer days than either the C group or the 4:1 group. Also, the 1:1 group was significantly superior to the 4:1 group on this measure.

Unfortunately, this first pilot was possibly confounded. During forced reversal, the subject was free to respond right or left, and an examination of position responding during forced reversal revealed that almost all of the subjects had gone into position responding. Thus, subjects in different E groups had differential reinforcement and differential nonreinforcement of their position responses. For example, a subject in the 4:1 group could have its position responses reinforced 80% of the time and nonreinforced 20% of the time. A subject in the 1:4 could, however, have been reinforced 20% of the time and nonreinforced 80% of the time for its position responding.

This differential reinforcement and nonreinforcement of position responding might not have constituted a problem, except that days in position during free reversal were positively correlated with days to reach reversal criterion. The effects of reinforcement and non-reinforcement might, therefore, have operated mainly on position responding rather than on responses to the new S+ and to the new S- specifically.

In order to avoid this possible source of confounding a second pilot study was run in the same apparatus, but a different forcing procedure was used. With this new forcing procedure, the subject was _not_ able to respond on the basis of position during forced reversal.

In this pilot, a second variable, number of forced reversal trials was added. Half the subjects received 120 forced reversal trials, while the other half received 240 forced reversal trials. For each level of forcing, half the subjects received a R/NR ratio of 4:1, and the other half received a R/NR ratio of 1:4. At the completion of the appropriate number of forced reversal trials each subject was placed on free reversal and run to criterion.

An analysis of variance on mean free days to reversal criterion produced one significant main effect, that of R/NR ratio, with the 1:4 group superior to the 4:1 group. In addition, the reversal learning curves showed that the 1:4 groups were consistently superior to the 4:1 groups throughout free reversal. The 240-trial groups were slightly superior to the 120-trial groups on mean free days to reversal criterion.

Number of forced reversal trials was added as a variable in order to obtain preliminary information about the role of the R/NR ratio variable during the course of acquisition of the discrimination reversal. The only study which had varied number of forced trials along with R/NR ratio, that of Birch (1955), used a simple discrimination task. His results revealed a significant interaction between ratio and days of forcing.

The inclusion of number of forced reversal trials as a variable also provided an opportunity to obtain some indication of the relationship between number of trials and the negativity associated with the new S-. D'Amato and Jagoda (1960, 1961) suggested that the negativity of S- during a simple discrimination task may decrease as number of acquisition trials increases. They argued that since the animal does not go to the S- very often during late acquisition or, for example, during overtraining trials, the negativity associated with the S- may decrease as a result of the reduced experience with this stimulus.

However, Deutsch and Biederman (1965) and Biederman (1967, 1968) have argued that this assumed reduction in the negativity of the S- does not occur because of reduced experience with this stimulus. They propose that the S- initially functions as the primary cue for discrimination, and its negativity is high at this point. Later the S+ presumably takes over the primary cue function, and, as a result, the S- loses some of its negativity. Although they disagree with D'Amato's and Jagoda's interpretation of why the negativity of S- decreases, they do agree that the negativity of S- does decrease.

In addition, they offer data they interpret as evidence in support of their position which maintains that the negativity of S- does not increase monotonically over the course of discrimination training. They argue that the relationship between number of acquisition trials and the negativity of S- is a nonmonotonic one.

Although Biederman relates his results to discrimination reversal, he does not indicate explicitly whether the same nonmonotonic relationship should hold for the negativity of the new S- over the course of reversal learning as presumably holds for the negativity of the old S- during the acquisition of the initial discrimination.

In the second pilot study there was, however, no indication that the relationship between the negativity associated with the new S- and the number of forced reversal trials was nonmonotonic. In fact, the results suggest that the relationship may be a curvilinear one.

The purpose of the present study is to investigate discrimination reversal learning as a function of R/NR ratios during forced reversal and number of forced reversal trials. If Jagoda's assumption that learning to avoid the new S- is relatively more difficult than learning to approach the new S+ is correct, then reversal performance should be facilitated by R/NR ratios employing high proportions of nonreinforced trials to the new S-. In addition, if the negativity associated with the new S- is a monotonic function of the number of forced reversal trials, then reversal performance should improve as total number of forced reversal trials increases.

METHOD

Experimental Design

The design can be summarized as a 3 x 3 factorial, the two independent variables being ratio of reinforced to nonreinforced trials during forced reversal (4:1, 1:1, 1:4) and total number of forced reversal trials (80, 200, 320). An additional group which had all of its reversal trials as free-choice trials served as the control group. The study was performed in two replications.

All Ss were run 20 trials per day to an acquisition criterion of 90% correct responding on the initial discrimination. During the initial discrimination the S+ was a bright light and the S- was a dim light. (For the rationale used to run all Ss to S+ bright and to S- dim see the discussion section pp. 58-59.) Upon reaching criterion each S was assigned to 1 of the 9 E groups or to the C group in randomized blocks.

Each S began reversal, free or forced, on the day following reaching the initial acquisition criterion. Each E S began free reversal on the day following the completion of forced reversal. During reversal, free and forced, the former S+ was now the S- and the former S- was now the S+. The reversal criterion was 90% correct responding. In order to obtain reversal curves, some Ss were run post reversal criterion.

Subjects

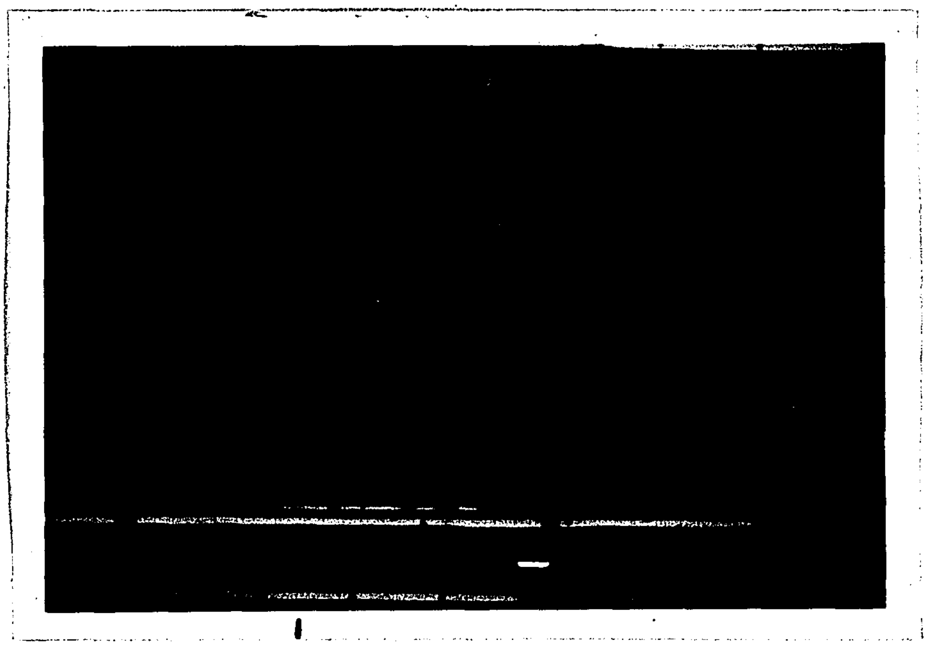
The Ss were 110 hooded female rats obtained from Carworth, Rockland County, New York. At the outset of the experiment, the Ss were experimentally naive, and were 60-80 days of age. Ss were housed in pairs, in steel-wire cages, 7" high x 7" wide x 9-1/2" deep. These cages were in a room with controlled temperature and humidity, filtered air and a 12-hr. day-night cycle. Throughout the experiment the Ss were maintained on 23 hr. water deprivation. Purina Food Chow was available ad lib.

Apparatus

The apparatus consisted of six identical Lehigh Valley shuttleboxes and BRS control equipment. The shuttleboxes were a prototype designed for this laboratory. The internal dimensions of each box were 7-1/2" high, 18" long, and 8" wide. Side walls and a hinged lid were made of transparent plexiglass. A steel-grid toggle floor with remote sensing provided information about which side of the box the animal was in. Beneath the toggle floor was a tray filled with sanicell. (See the following page for a photograph of one of these boxes.)

Each box had two removable barriers. Barrier I was aluminum and divided the shuttlebox into two equal compartments 7-1/2" high, 9" long, and 8" wide. The center hole in this barrier was 2-1/2" in diameter. To get back and forth from one side to another the S had to go through this hole. Barrier II divided the shuttlebox into four equal compartments 7-1/2" high, 9" long, and 4" wide. Each hole in this barrier was also 2-1/2" in diameter.

At each end of the shuttlebox was an intelligence panel with a low reflectance black surface. The internal dimensions of each panel were 8" x 7-1/2". There were two small stimulus-response-reinforcement chambers (SRRC) on each panel. Each chamber extended 2-1/2" into the panel and was 1-1/2" square.



Photograph of One of the Automated Discrimination Shuttleboxes

The rear panel of each chamber consisted of a translucent stimulus diffusion panel which was illuminated from behind by a bulb in an attached lamphousing. The onset of the two stimuli was simultaneous. On any one trial, one of these stimuli could be bright (26.0 v) and the other dim (8.5 v) or both stimuli could be bright or both could be dim. The right-left position of each stimulus, when one was bright and one was dim, was controlled by a punched tape which fed into the control panel of the box.

A response was recorded when the subject's head interrupted a thin, dark red beam of light which passed horizontally across the chamber opening. Reinforcement was provided by a .25 cc dipper which was programmed to come up automatically when a correct response was made. If an incorrect were made, the dippers remained down. At the outset of any trial, the stimuli came on on the opposite side of the box from where the subject was. For example, if the animal were on side A of the box, the stimuli would come on on side B. If the subject were on side B of the box, the stimuli would come on on side A. Once the stimuli came on, they remained on until the subject responded. If a correct response were made, the stimuli stayed on for the duration of the reinforcement. If an incorrect response were made, the stimuli remained on for .7 sec. Throughout all phases of the experiment the ITI was 10 sec.

Each BRS control panel for each shuttlebox had an 8-channel paper tape reader which provided programming. Trial by trial data were recorded on print-out-counters, and cumulative data were recorded on other counters. The print-out-counters did not operate reliably all of the time, but the cumulative counters did.

The shuttleboxes were in a small room adjacent to the room with the control panels. Each box was enclosed in light-proof, sound-absorbing housing. Ventilation and masking noise were provided by a blower in each box. A one-way observation window in each box could be covered by an opaque door when not in use.

Procedure

Adaptation, habituation, and shaping

All Ss were placed on 23 hr. water deprivation for one week prior to shaping. During this week each S was handled for approximately 3 mins. each day. The Ss were given one day of habituation which consisted of placing cage mates in the apparatus for 10 mins. Barrier I was inserted, the dippers were retracted, and the stimulus lights were off. Each S was placed on one side of the barrier and her cage mate was placed on the other side. Each S was free to go back and forth through the barrier's hole.

Shaping consisted of 10 trials given on the day following habituation. There was no barrier used during shaping. On each trial both stimuli were bright. The S could respond right or left and either response would be reinforced. The reward duration was 10 sec. per trial and the ITI was 10 sec. Both stimulus lights came on at the beginning of a trial and remained on until the S responded and for the duration of the reinforcement.

Acquisition of the initial discrimination

Discrimination training was begun on the day following shaping. Barrier I was inserted and each trial consisted of the simultaneous presentation of the S+ and the S-. On any trial the S was free to respond to either stimulus. The ITI was 10 sec., reinforcement duration 7 sec., and reinforcement magnitude was .25 cc per trial.

The S+ was programmed so that in a series of 20 trials it was on the right side on half of the trials, and it was on the left side on half of the trials. The right-left sequence used insured that no more than two consecutive right responses or two consecutive left responses would be reinforced. Each S was run 20 trials per day until reaching the criterion of 90% correct responding.

Forced reversal

During forcing Barrier II was inserted. Each S received half of her forced days on the front side of the barrier and the other half on the rear side. A forced trial consisted of the presentation of a single stimulus, either the S+ or the S- on each trial. On a forced trial, the discrimination was a successive one. Therefore, the subject could not respond right or left on a forced trial. Forced trials were programmed so that the three E groups receiving a 4:1 R/NR ratio had 4 reinforced trials and 1 nonreinforced trial during every 5 trials. The position of the nonreinforced trial was not the same in each block of 5 trials. For example, if nonreinforcement occurred on Trial 3 during Trials 1-5, then it might occur on 7 for Trials 6-10, and on Trial 11 for Trials 11-15. For the actual sequence of trials used during forcing see Appendix I. Twenty trials per day were given during forcing. Thus, for each day of forced reversal the three 4:1 groups received 16 reinforced trials and 4 nonreinforced trials per day.

The three E groups that had a 1:4 R/NR ratio had the same sequence of trials as the 4:1 groups, only where a nonreinforced trial had occurred for the 4:1 groups, a reinforced trial occurred for the 1:4 groups. Thus, for each day of forced reversal these groups had 4 reinforced trials and 16 nonreinforced trials each day.

For the three E groups with a 1:1 R/NR ratio, 10 trials were reinforced and 10 trials were nonreinforced each day. The order of presentation of reinforcement and nonreinforcement within a block of 10 trials was random with the restriction that there must be an equal number of reinforced and nonreinforced trials.

For <u>each R/NR ratio</u> level, one E group was given 4 days of forced reversal, one E group was given 10 days of forced reversal, and one E group was given 16 days of forced reversal. During forcing the ITI was 10 sec., the reward duration was 7 sec. per trial and the reward magnitude was .25 cc per trial. On the day following the completion of the appropriate number of forced days of reversal, each S in each E group began free reversal.

<u>Free Reversal</u>

During free reversal Barrier I was inserted. Each S received 20 trials per day, ITI 10 sec., reward duration 7 sec., and reward magnitude .25 cc. A free reversal trial consisted of the simultaneous presentation of the S+ and the S-. The same sequence of trials was used during reversal as was used during the acquisition of the initial discrimination, only now the S+ was the dim light, and the S- was the bright light. All Ss were run to a reversal criterion of 90% correct. In order to obtain free reversal curves, some Ss were run post criterion. Each S was run a minimum of 14 days during free reversal in order to obtain reversal curves for the first 2 weeks of free reversal learning.

RESULTS

Acquisition of the initial discrimination

Mean days to criterion and standard deviations for each group during the initial discrimination task are very similar as shown in Table 1. The over-all mean is 3.84 days and the over-all S.D. is 1.65 days.

Discrimination reversal

Analyses of variance were performed on four dependent variables: (1) mean free days to reversal criterion, (2) mean total days to reversal criterion, (3) mean errors on day 1 of free reversal and (4) mean days in position during free reversal. Since the study entailed two replications, replications were treated as an independent variable in these analyses. The only significant effect of replications occurred for errors on day 1 of free reversal. Since there was no significant replication effect on any of the other three variables, analyses of variance were performed on these variables with replications combined.

Where appropriate, pair-wise comparisons between E groups were made using Tukey's HSD test as described in Runyon and Haber (1971).

(1) Free days to reversal criterion

The analysis of variance for mean free days to reversal criterion is summarized in Table 2. This analysis produced two significant main effects: R/NR ratio and total number of forced trials. The mean performance of each ratio level at each trial level is shown graphically in Fig. 1. The Ratio x Trial interaction was not significant.

The effects of R/NR ratio on free days to reversal criterion

TABLE 1

Days to Acquisition Criterion

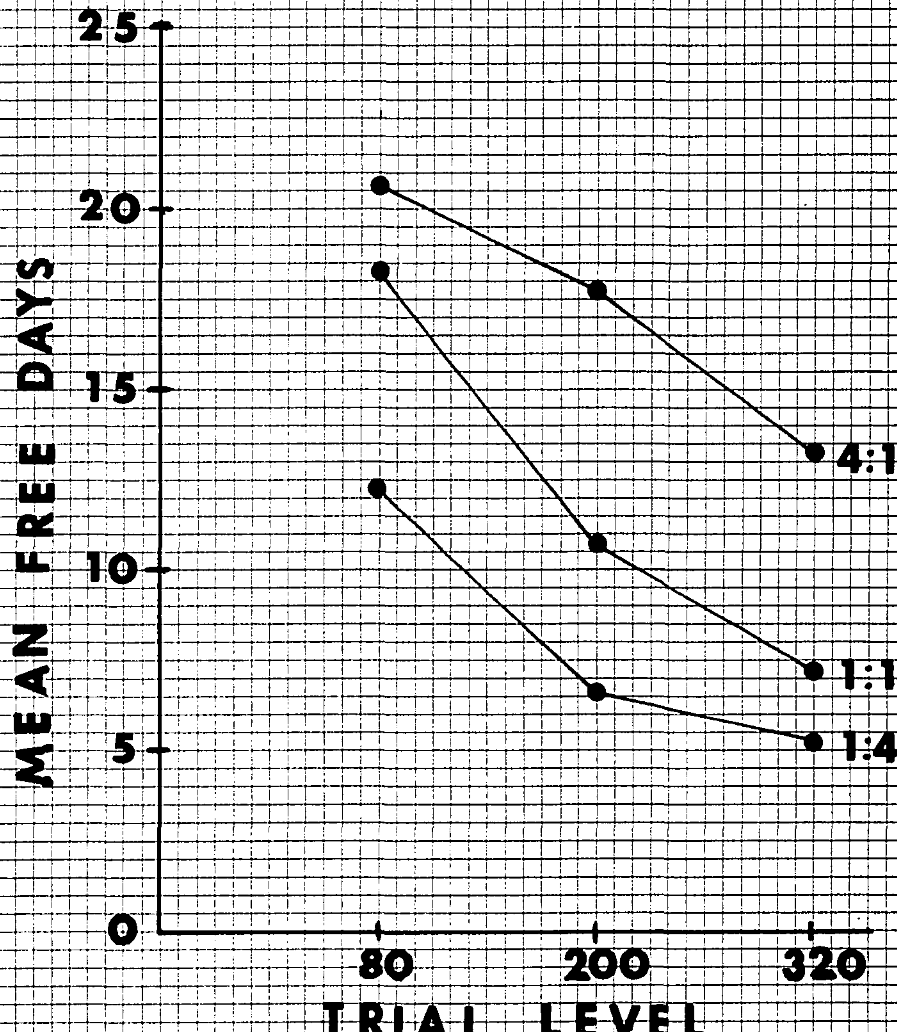
Group	N	Mean	S.D.
Control	20	4.15	1.95
80:4:1	10	4.10	1.59
80:1:1	10	3.70	1.64
80:1:4	10	3.80	1.75
200:4:1	10	4.00	1.76
200:1:1	10	3.80	2.25
200:1:4	10	3.60	1.17
320:4:1	10	3.60	1.07
320:1:1	10	3.60	1.35
320:1:4	10	4.00	2.00

TABLE 2

Analysis of Variance of Mean Free Days to Reversal Criterion

Source	df	MS	F	p
Ratio	2	638.400	55.239	$< .01$
Trials	2	563.633	48.769	$< .01$
R x T	4	23.583	2.041	n. s.
Within	81	11.557		
Total	89			

FIGURE 1. -- Mean Free Days to Reversal Criterion for Each Ratio Level at Each Trial Level


25
20
15
10
5
0
MEAN FREE DAYS
80
200
320
TRIAL LEVEL
4:1
1:1
1:4

can be summarized as follows. The mean for the three E groups with a 4:1 ratio was 17.3, the mean for the three E groups with a 1:1 ratio was 12.1, and the mean for the three E groups with a 1:4 ratio was 8.1. Each of these means was significantly different from each of the others ($p < .01$). Thus, a 1:4 ratio resulted in significantly fewer days to reversal criterion than a 1:1 ratio. This 1:1 ratio, in turn, resulted in significantly fewer days to reversal criterion than a 4:1 ratio.

These facilitative effects of decreasing R/NR ratio occurred at each level of trials. Although not all of the differences among R/NR groups were significant at each trial level, many of them were. At 80 trials the 1:4 group was significantly superior to the 1:1 group ($p < .01$), and this 1:4 group was also significantly superior to the 4:1 group ($p < .01$). At 200 trials, the 1:4 group was superior to the 4:1 group ($p < .01$), and the 1:1 group was significantly superior to the 4:1 group ($p < .01$). At 320 trials, the 1:4 group was significantly superior to the 4:1 group ($p < .01$), and the 1:1 group was significantly superior to the 4:1 group ($p < .01$).

In summary, the 1:4 groups are significantly superior to the 4:1 groups at every trial level, and at 80 trials the 1:4 group is significantly superior to the 1:1 group. The 1:1 groups are significantly superior to the 4:1 groups at 200 trials and at 320 trials. Thus, the largest effects of ratio on this variable occurred between the 1:4 groups and the 4:1 groups and between the 1:1 groups and the 4:1 groups.

The effects of total number of forced reversal trials on mean free days to reversal criterion can be summarized as follows. The mean for the three E groups with 80 trials was 17.17, the mean for the three E groups with 200 trials was 11.73, and the mean for the three E groups with 320 trials was 8.60. Each of these means was significantly different from each of the others. The 320 trial group was significantly superior to the 200 trial group ($p < .01$), and the 320 trial group was significantly superior to the 80 trial group ($p < .01$). The 200 trial group was significantly superior to the 80 trial group ($p < .01$).

These facilitative effects of increasing total number of forced reversal trials occurred at each ratio level. Not all of the differences among trial groups were significant at each ratio level, but many of them were. With a 4:1 ratio the 320 trial group was significantly superior to the 80 trial group ($p < .01$). With a 1:1 ratio the 320 trial group was significantly superior to the 80 trial group ($p < .01$), and the 200 trial group was significantly superior to the 80 trial group ($p < .01$). With a 1:4 ratio the 320 trial group was significantly superior to the 80 trial group ($p < .01$), and the 200 trial group was significantly superior to the 80 trial group ($p < .01$).

In summary, the 320 trial groups are significantly superior to the 80 trial groups at every level of ratio. The 200 trial groups are significantly superior to the 80 trial groups when the ratio is 1:1 and when the ratio is 1:4. Thus, the largest effects of trials occurred between the 320 groups and the 80 groups and between the 200 groups and the 80 groups.

(2) Total days to reversal criterion

Table 3 reports the analysis of variance for the mean total days to reversal criterion. Total days include forced days of reversal. This analysis produced two significant main effects: R/NR

TABLE 3

Analysis of Variance of Mean Total Days to Reversal Criterion

Source	df	MS	F	p
Ratio	2	638.400	55.239	$< .01$
Trials	2	101.633	8.794	$< .01$
R x T	4	23.583	2.041	n. s.
Within	81	11.557		
Total	89			

ratio and total number of forced reversal trials. The mean performance for each ratio level at each trial level is presented in Fig. 2. The Ratio x Trial interaction was not significant.

When forced days were added to free days to obtain total days, the magnitude of the absolute differences among ratio groups within the same trial level remained the same, since adding forced trials was adding a constant to each ratio group within the same trial level. Therefore, the results of the R/NR ratio effects were exactly the same as when mean free days to reversal criterion were analyzed.

However, the trial effects, while still significant, were in the opposite direction to that found when mean free days to criterion were analyzed. The mean for the three E groups with 320 trials was 24.60, the mean for the three E groups with 200 trials was 21.73, and the mean for the three E groups with 80 trials was 21.17. The 320 trial groups were significantly poorer than the 80 trial groups ($p < .01$), and the 320 trial groups were significantly poorer than the 200 trial groups ($p < .01$).

These trial effects occurred at each ratio level, but most of the differences among trial groups within each ratio level did not reach significance. A few of them did, however. With a 4:1 ratio the 320 trial group is significantly poorer than the 80 trial group ($p < .05$). With a 1:4 ratio the 320 trial group was significantly poorer than the 80 trial group ($p < .05$), and the 320 trial group was significantly poorer than the 200 trial group ($p < .05$).

(3) Errors on day 1 of free reversal

The analysis of variance for mean errors made on day 1 of free reversal is reported in Table 4. This analysis produced three significant main effects: R/NR ratio, total number of forced reversal

FIGURE 2. -- Mean Total Days to Reversal Criterion for Each Ratio Level at Each Trial Level

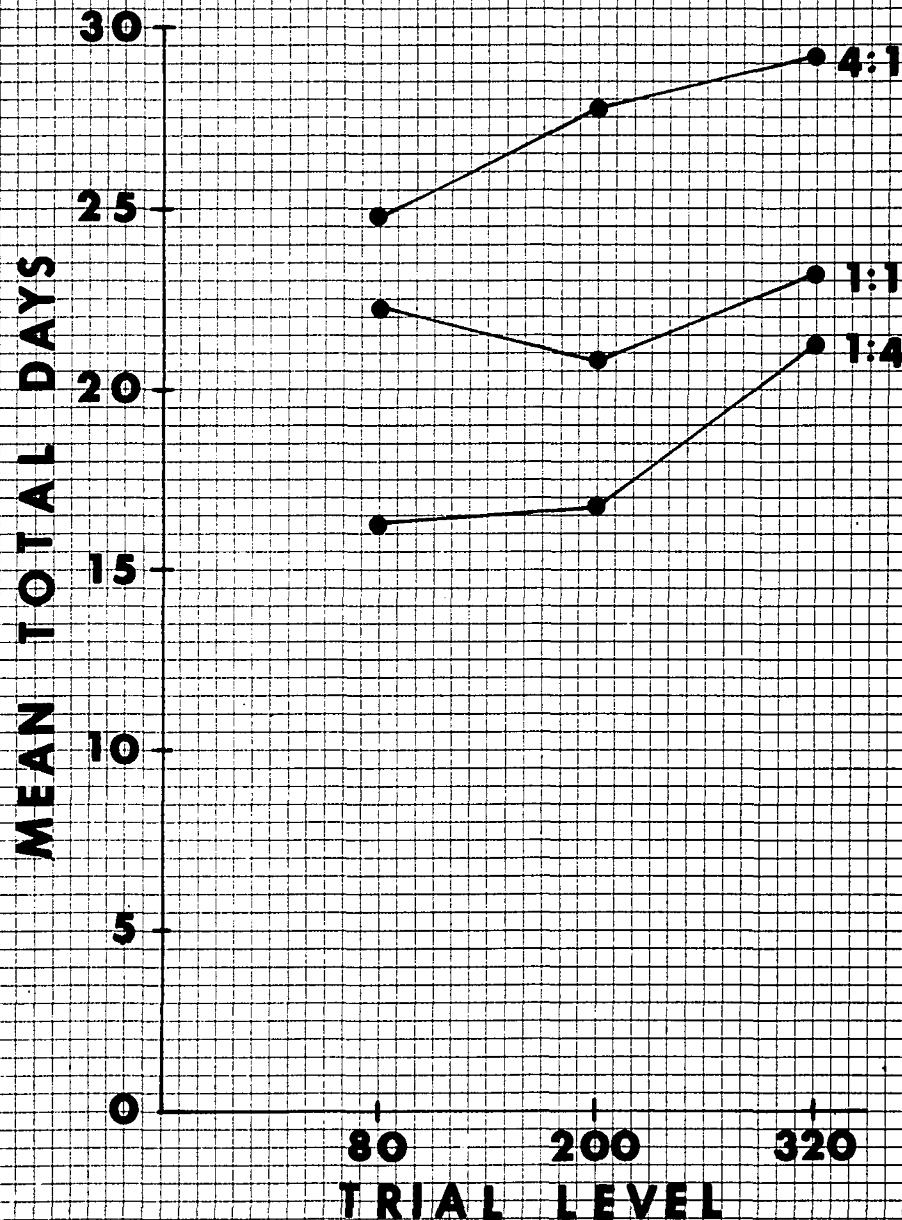

MEAN TOTAL DAYS
30
25
20
15
10
5
0
80
200
320
TRIAL LEVEL
4:1
1:1
1:4

TABLE 4

Analysis of Variance of Mean Errors on Day 1 of Free Reversal

Source	df	MS	F	p
Ratio	2	97.911	10.071	$< .01$
Trials	2	230.011	23.659	$< .01$
Replications	1	40.000	4.114	$< .05$
R x T	4	21.278	2.189	n. s.
R x Rp	2	3.733		
T x Rp	2	9.100		
R x T x Rp	4	5.633		
Within	72	9.722		
Total	89			

trials, and replications. Fig. 3 presents the mean performance for each ratio level at each trial level. The Ratio x Trial interaction was not significant.

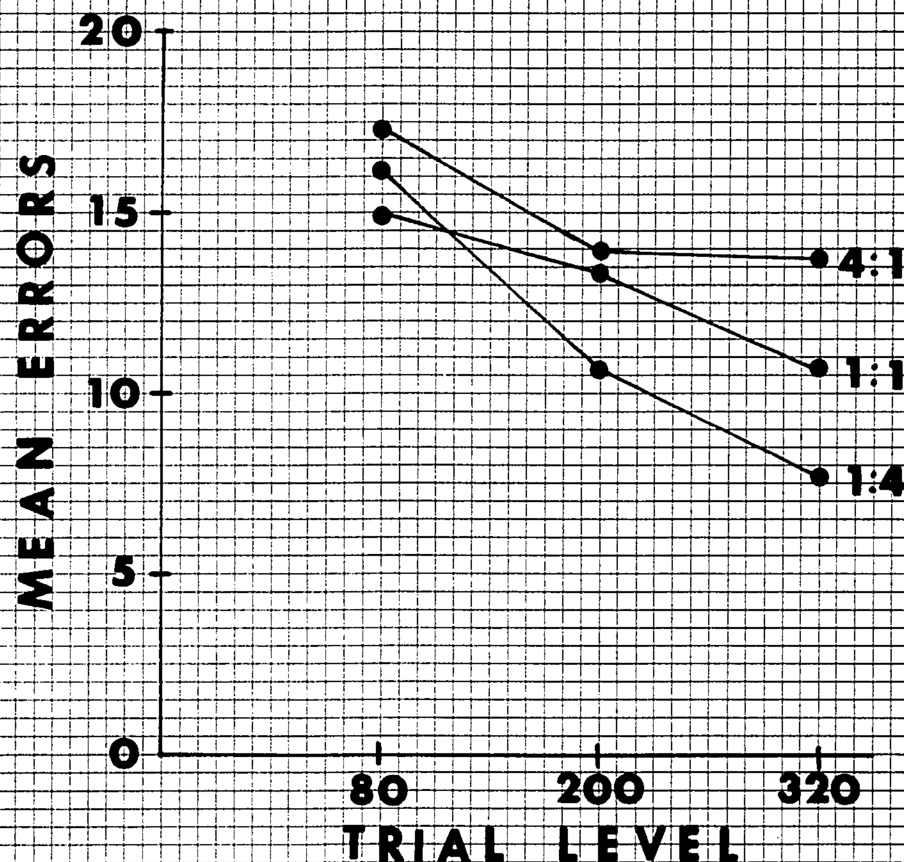
The mean for the three E groups with a 4:1 ratio was 15.07, the mean for the three E groups with a 1:1 ratio was 13.00, and the mean for the three E groups with a 1:4 ratio was 11.47. The 1:4 groups were significantly superior to the 4:1 groups ($p < .01$). The 1:1 groups were significantly superior to the 4:1 groups ($p < .05$).

These facilitative effects of decreasing ratio on errors occurred at most trial levels, but at 80 trials and at 200 trials there were no significant differences among ratio groups. At 320 trials, however, the 1:4 group is significantly superior to the 4:1 group ($p < .01$).

The effects of total number of forced trials on errors are as follows. The mean for the three E groups with 80 trials was 16.17, the mean for the three E groups with 200 trials was 12.67, and the mean for the three E groups with 320 trials was 10.70. The 320 trial groups are significantly superior to the 200 trial groups ($p < .01$), and the 320 trial groups are significantly superior to the 80 trial groups ($p < .01$). The 200 trial groups are significantly superior to the 80 trial groups ($p < .01$).

These facilitative effects of increasing number of trials on errors occurred at each ratio level, but with a 4:1 ratio or with a 1:1 ratio the differences among trial groups did not reach significance. With a 1:4 ratio, however, the 320 trial group is significantly superior to the 80 trial group ($p < .01$), and the 200 trial group is significantly superior to the 80 trial group ($p < .01$).

FIGURE 3. -- Mean Errors on Day 1 of Free Reversal for Each Ratio Level at Each Trial Level



20
15
10
5
0
MEAN ERRORS
4:1
1:1
1:4
80
200
320
TRIAL LEVEL

(4) Days in position during free reversal

Table 5 summarizes the analysis of variance for mean days in position during free reversal.[1] This analysis resulted in two significant main effects and a significant interaction. The nature of the interaction can be seen graphically in Fig. 4. When there are 200 forced trials or when there are 320 forced trials the 1:4 ratio resulted in fewer days in position than a 1:1 ratio, and a 1:1 ratio resulted in fewer days in position than a 4:1 ratio. When there were 80 trials, however, a 1:1 ratio resulted in more days in position than a 4:1 ratio. With a 1:1 ratio or with a 1:4 ratio 320 trials resulted in fewer days in position than 200 trials, and 200 trials resulted in fewer days in position than 80 trials. With a 4:1 ratio, however, there was no appreciable difference between 200 trials and 80 trials in days in position.

The mean for the three E groups with a 4:1 ratio was 9.30, the mean for the three E groups with a 1:1 ratio was 7.07, and the mean for the three E groups with a 1:4 ratio was 4.07. The 1:4 groups were significantly superior to the 4:1 groups ($p < .01$), and the 1:4 groups were also significantly superior to the 1:1 groups ($p < .01$). The 1:1 groups were significantly superior to the 4:1 groups ($p < .05$).

At 80 trials, the differences among ratio groups do not reach significance. At 200 trials, the 1:4 group is significantly superior to the 4:1 group ($p < .01$), and the 1:1 group is significantly superior to the 4:1 group ($p < .05$). At 320 trials, there are no significant differences among ratio groups.

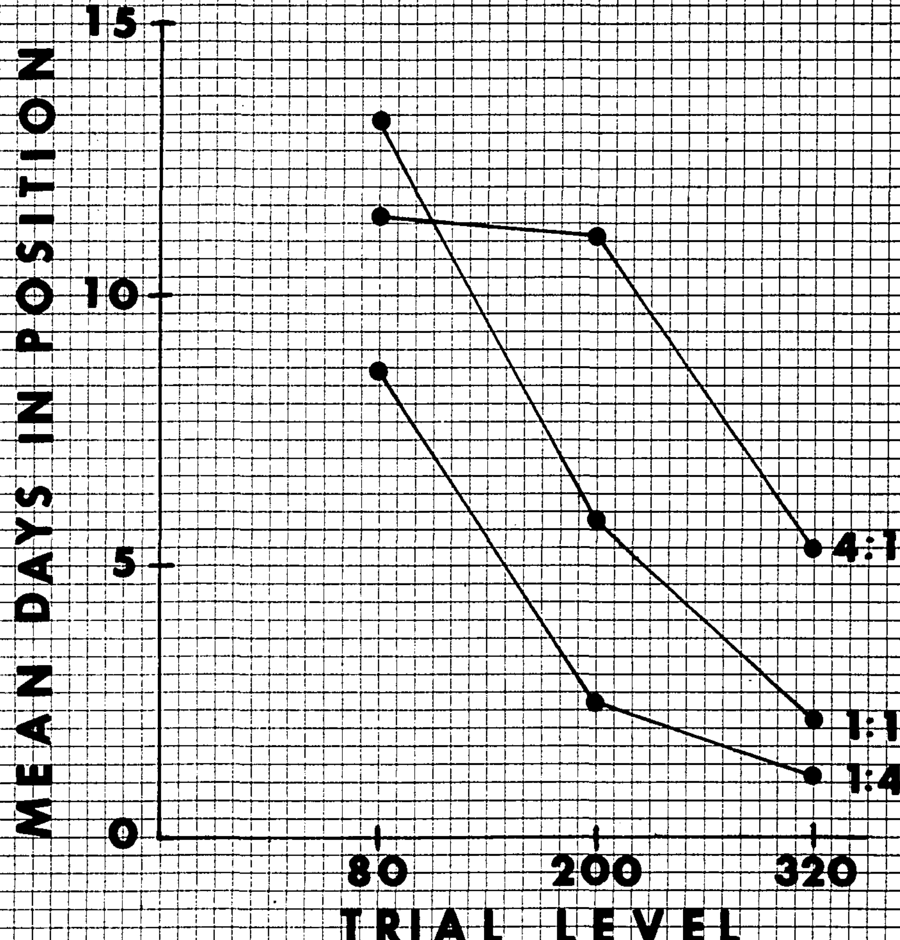
[1]If a subject gave 80% or more responses to the same side on one day, then the subject was scored as responding on the basis of position for that day.

TABLE 5

Analysis of Variance of Mean Days in Position during Free Reversal

Source	df	MS	F	p
Ratio	2	206.878	19.304	< .01
Trials	2	511.078	47.688	< .01
R x T	4	41.444	3.867	< .01
Within	81	10.717		
Total	89			

FIGURE 4. -- Mean Days in Position during Free Reversal for Each Ratio Level at Each Trial Level


MEAN DAYS IN POSITION
15
10
5
0
80
200
320
TRIAL LEVEL
4:1
1:1
1:4

The mean for the three E groups with 80 trials was 11.10, the mean for the three E groups with 200 trials was 6.47, and the mean for the three E groups with 320 trials was 2.87. The 320 trial groups are significantly superior to the 200 trial groups ($p < .01$) and to the 80 trial groups ($p < .01$). The 200 trial groups are significantly superior to the 80 trial groups ($p < .01$). Thus, each of these means is significantly different from each of the others.

With a 4:1 ratio the 320 trial group is significantly superior to the 200 trial group ($p < .01$) and to the 80 trial group ($p < .01$). With a 1:1 ratio the 320 trial group is significantly superior to the 80 trial group ($p < .01$), and the 200 trial group is significantly superior to the 80 trial group ($p < .01$). With a 1:4 ratio the 320 trial group is significantly superior to the 80 trial group ($p < .01$), and the 200 trial group is significantly superior to the 80 trial group ($p < .01$).

Comparisons of the control group with each of the experimental groups

Dunnett's test as described in Edwards (1960) was used to compare the C group with each of the E groups on four dependent variables: (1) mean free days to reversal criterion, (2) mean total days to reversal criterion, (3) mean errors on day 1 of free reversal and (4) mean days in position during free reversal.

(1) Free days to reversal criterion

On mean free days to reversal criterion any E group which had received a R/NR ratio of 1:4, regardless of number of forced trials, was significantly superior to the C group. Any E group which had received 320 trials, regardless of R/NR ratio, was significantly superior to the C group on this measure. Also, the 200 trial group with a 1:1 R/NR ratio was significantly superior to the C group.

(2) Total days to reversal criterion

None of the E groups was significantly superior to the C group on mean total days to reversal criterion. In fact, any E group which had a R/NR ratio of 4:1 took significantly more days to reach criterion than the C group. Thus, a 4:1 ratio resulted in slower reversal on this measure regardless of the number of forced reversal trials received.

(3) Errors on day 1 of free reversal

All of the E groups except the 80-4:1 group were superior to the C group on this measure. However, only four of the E groups, 200-1:1, 200-1:4, 320-1:1, and 320-1:4, were significantly superior to the C group on this measure.

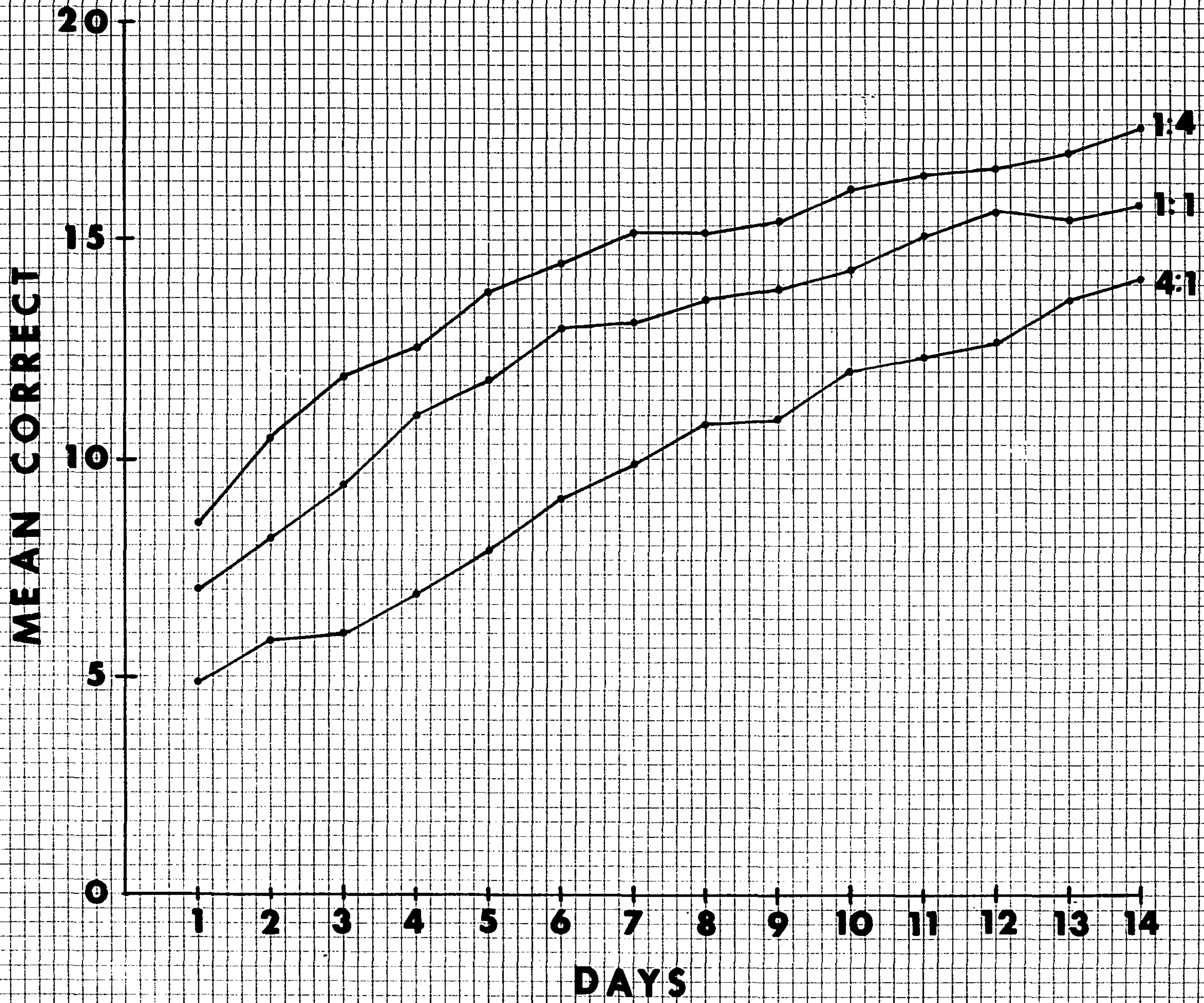
(4) Days in position during free reversal

All of the E groups except the 80-4:1 group and the 80-1:1 group were superior to the C group on mean days in position during free reversal. However, only five E groups were significantly superior to the C group on this measure. Any E group which had received 320 trials, regardless of R/NR ratio, was significantly superior to the C group. Also, the 200-1:1 group and the 200-1:4 group was each significantly superior to the C group.

Reversal learning curves for free reversal

Fig. 5 gives the reversal learning curves for the R/NR ratio groups. An examination of these reversal learning curves shows that performance, as measured by mean number of correct responses each day for the first 14 days of reversal, is best in the 1:4 group. The 1:4 group is consistently superior to the other ratio groups

FIGURE 5. -- Reversal Learning Curves during the First 14 Days of Free Reversal for Groups that Had Received Different R/NR Ratios


MEAN CORRECT
0
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
DAYS
1:4
1:1
4:1

throughout the first 14 days of free reversal. The 4:1 group is the slowest, and the 1:1 group is intermediate.

The R/NR ratio effects at each trial level during the first 14 days of free reversal are presented in the reversal learning curves in Figs. 6, 7, and 8. The clearest consistent separation of ratio groups occurred when there were 200 forced reversal trials (Fig. 7). At each trial level the largest over-all differences in reversal performance are found between the 1:4 groups and the 4:1 groups. The slopes of the reversal curves tend to be steepest with 320 trials (Fig. 8). The smallest over-all difference among ratio groups occur when there are 80 trials (Fig. 6).

Fig. 9 gives the reversal learning curves for the trial groups. The 320 trial group is consistently superior to the 200 trial group and to the 80 trial group throughout the first 14 days of free reversal. The 80 trial group is the poorest, and the 200 trial group is intermediate.

The trial effect at each ratio level during the first 14 days of free reversal can be seen in Figs. 10, 11, and 12. The clearest separation of trial groups occurred when the R/NR ratio was 1:1 (Fig. 11). With a 1:1 ratio the 320 trial group is consistently superior to the 200 trial group, and the 200 trial group is consistently superior to the 80 trial group. When the R/NR ratio is 4:1 the 80 vs 320 groups diverge most after 8 days of free reversal (Fig. 10). During the first 6 days of free reversal the 320 trial group and the 200 trial group are very close, and they do not begin to diverge greatly until after day 6. With a 1:4 ratio the 200 trial group and the 320 trial group is each superior to the 80 trial group (Fig. 12).

FIGURE 6. -- Reversal Learning Curves during the First 14 Days of Free Reversal for Groups that Had Received Different R/NR Ratios and 80 Forced Reversal Trials

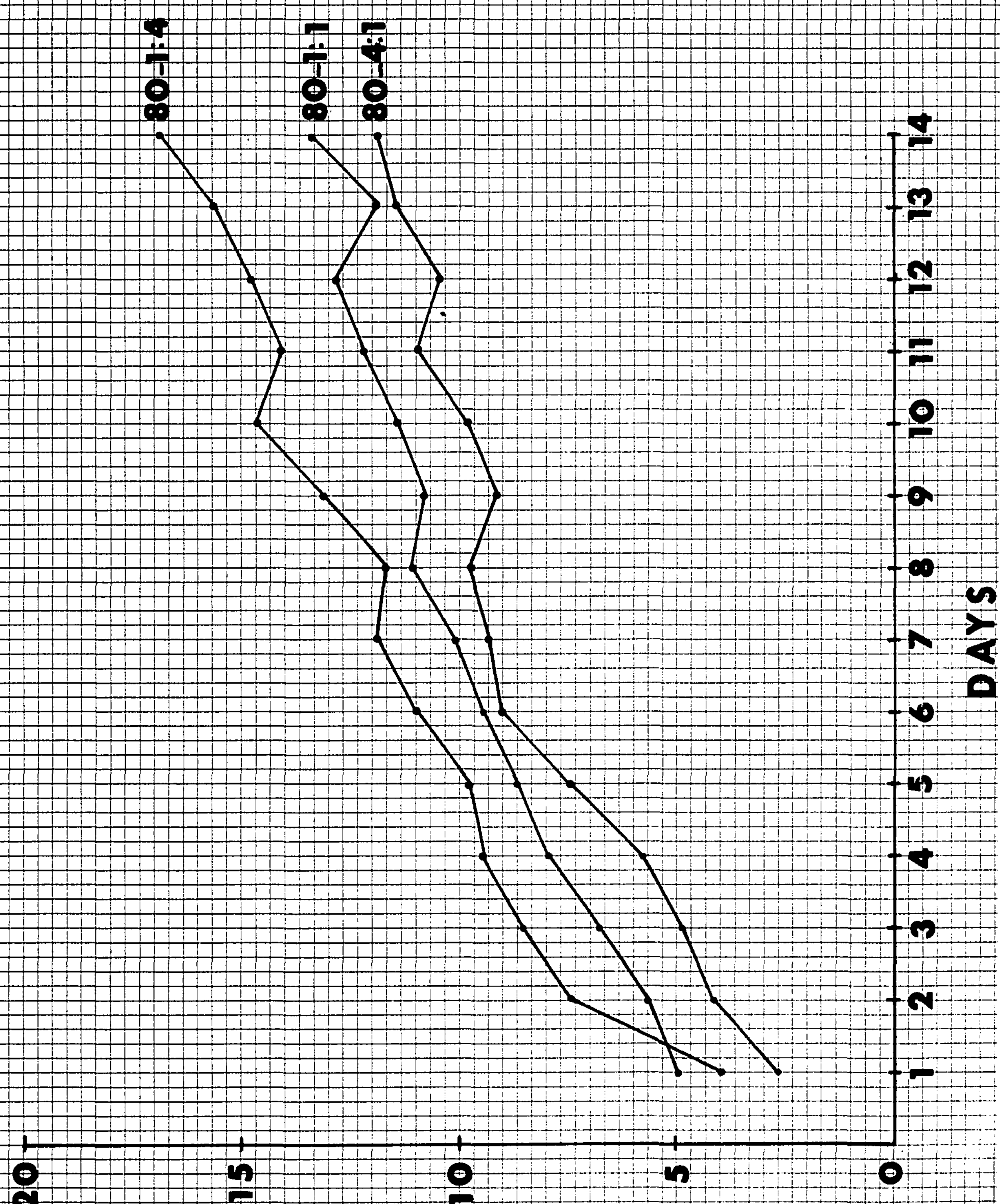

MEAN CORRECT
0
5
10
15
20
DAYS
1
2
3
4
5
6
7
8
9
10
11
12
13
14
80-1:4
80-1:1
80-4:1

FIGURE 7. -- Reversal Learning Curves during the First 14 Days of Free Reversal for Groups that Had Received Different R/NR Ratios and 200 Forced Reversal Trials

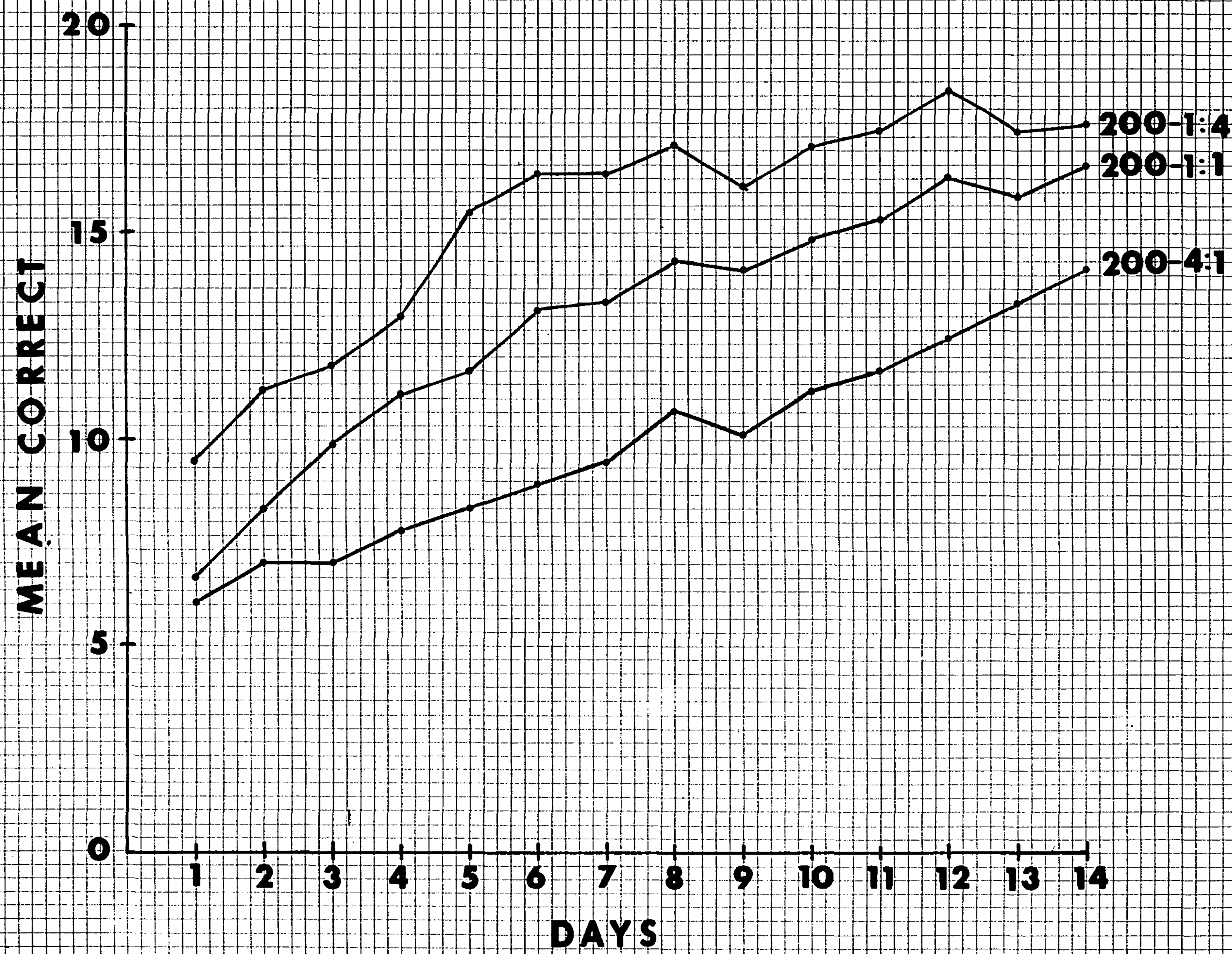

200-1:4
200-1:1
200-4:1
MEAN CORRECT
0
5
10
15
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14
DAYS

FIGURE 8. -- Reversal Learning Curves during the First 14 Days of Free Reversal for Groups that Had Received Different R/NR Ratios and 320 Forced Reversal Trials

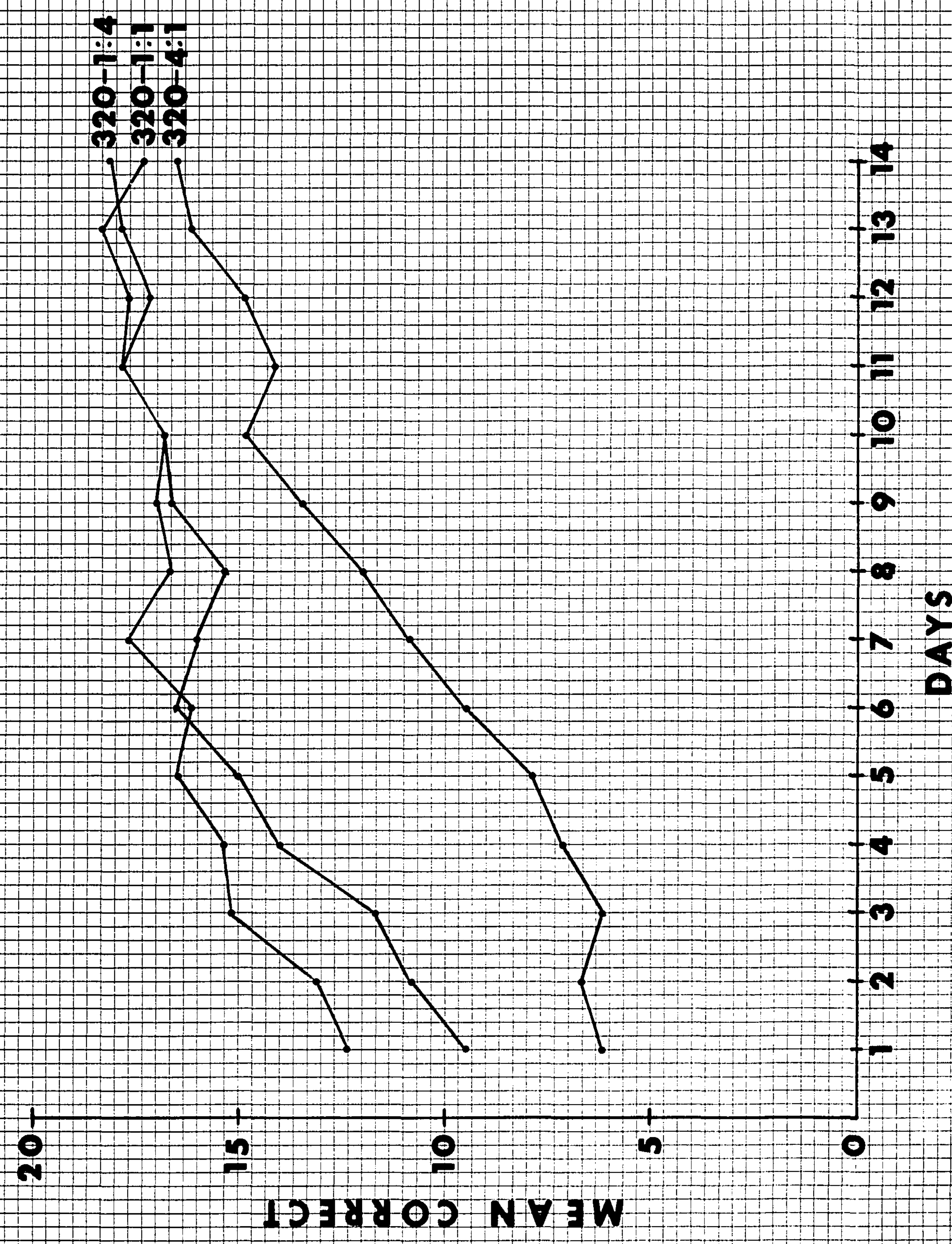

320-1:4
320-1:1
320-4:1
MEAN CORRECT
0
5
10
15
20
DAYS
1
2
3
4
5
6
7
8
9
10
11
12
13
14

FIGURE 9. -- Reversal Learning Curves during the First 14 Days of Free Reversal for Groups that Had Received Different Numbers of Forced Reversal Trials

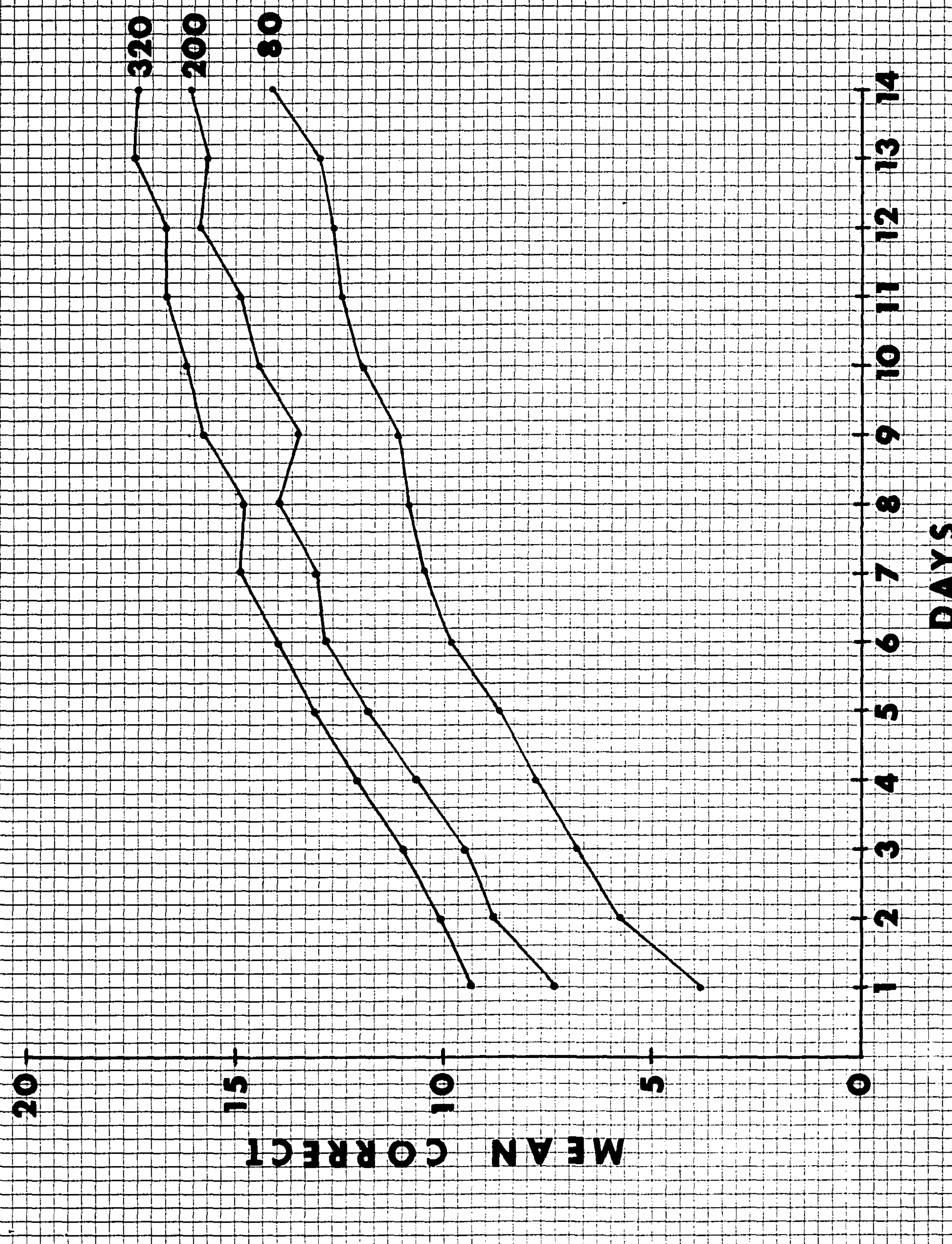

320
200
80
MEAN CORRECT
0
5
10
15
20
DAYS
1
2
3
4
5
6
7
8
9
10
11
12
13
14

FIGURE 10. -- Reversal Learning Curves during the First 14 Days of Free Reversal for Groups that Had Received Different Numbers of Forced Reversal Trials and a 4:1 R/NR Ratio

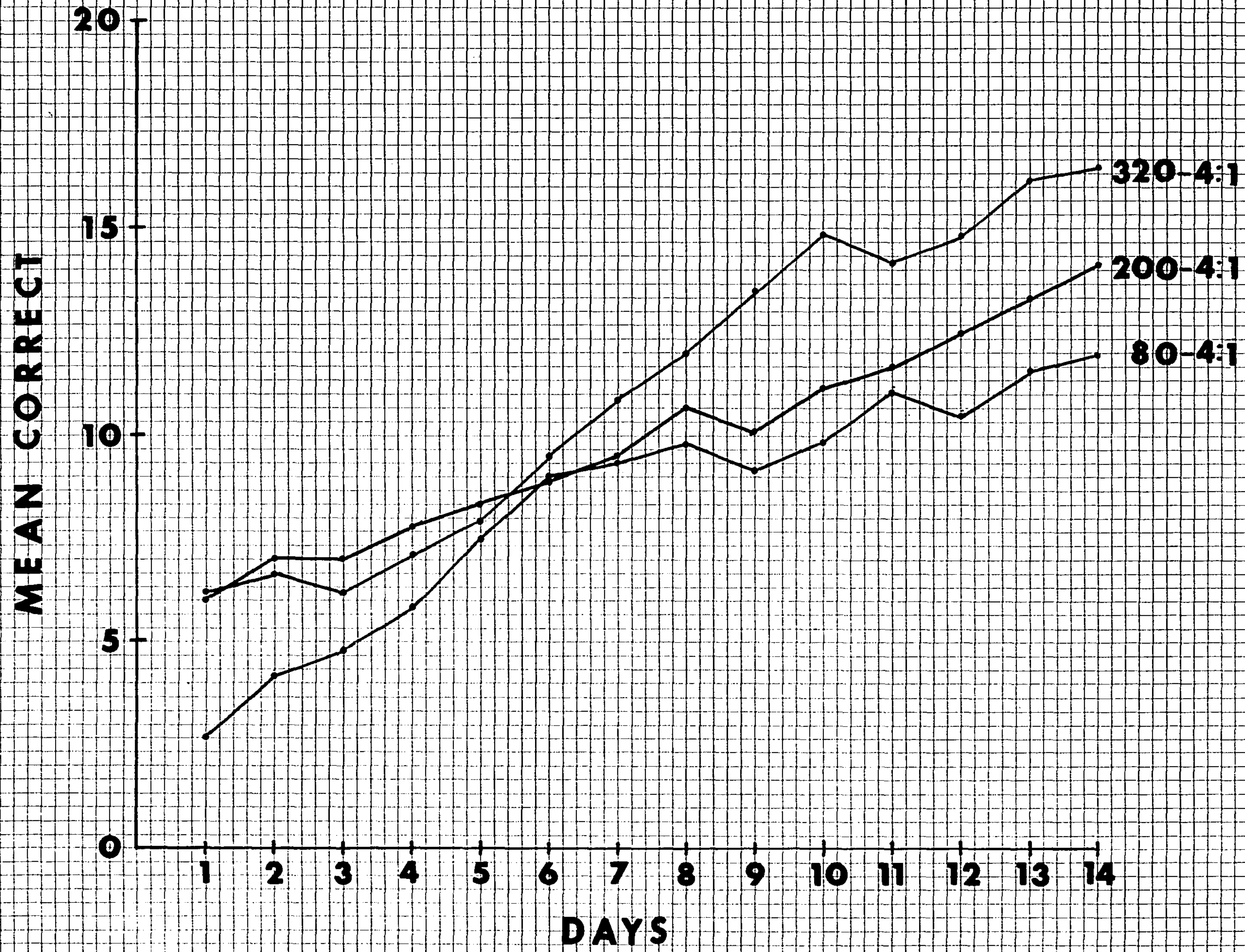

MEAN CORRECT
DAYS
0
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
320-4:1
200-4:1
80-4:1

FIGURE 11. -- Reversal Learning Curves during the First 14 Days of Free Reversal for Groups that Had Received Different Numbers of Forced Reversal Trials and a 1:1 R/NR Ratio

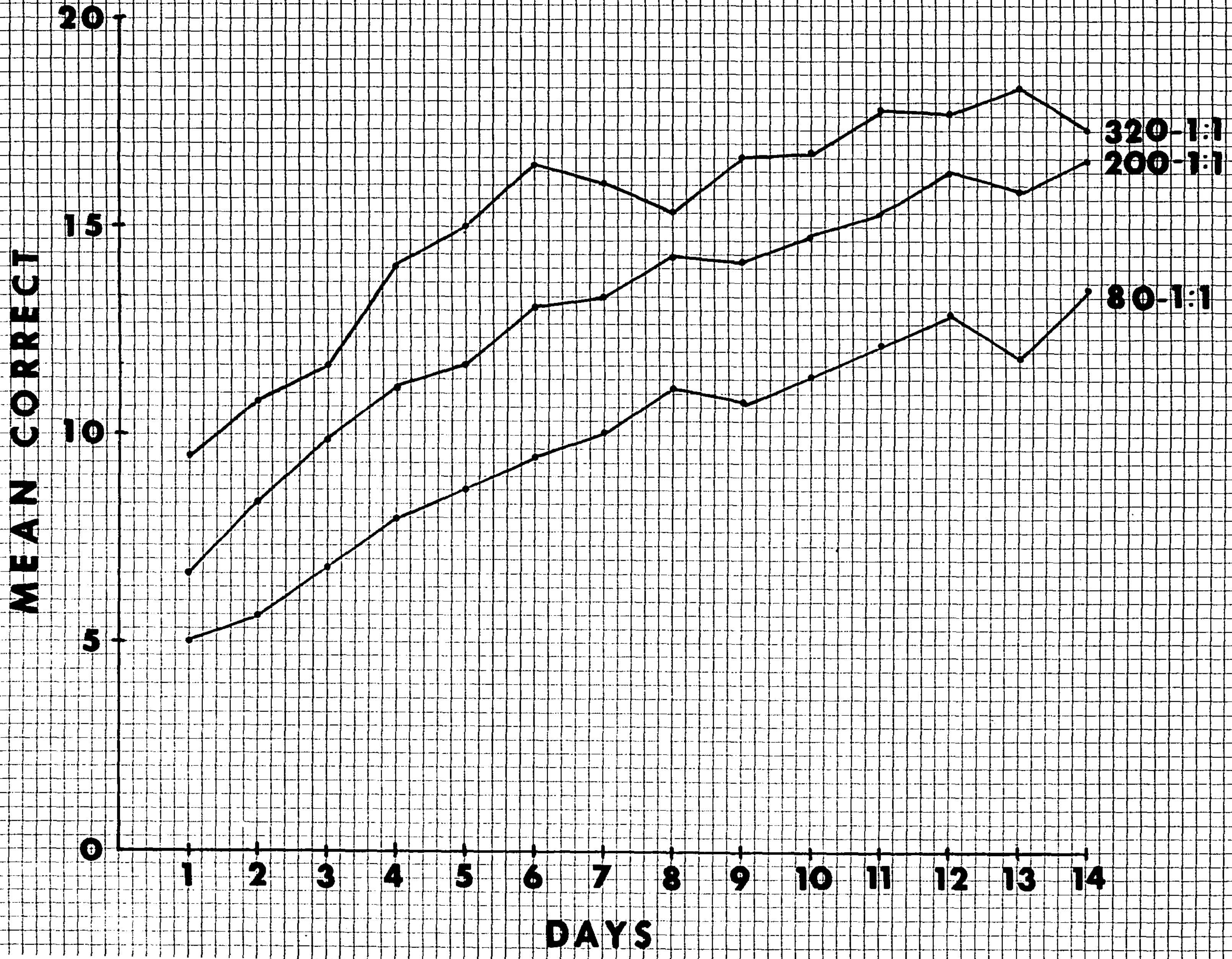
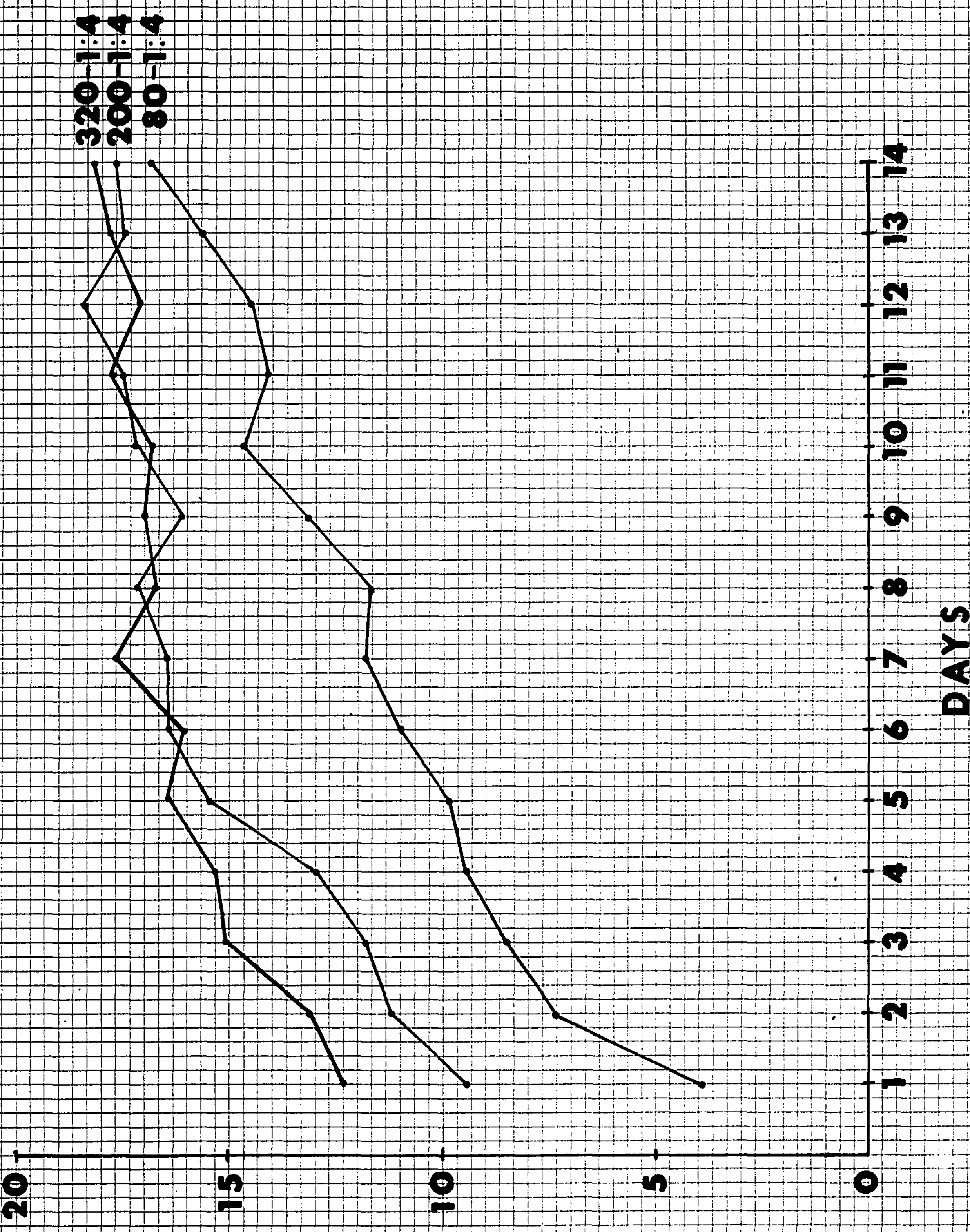

320-1:1
200-1:1
80-1:1
MEAN CORRECT
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
DAYS

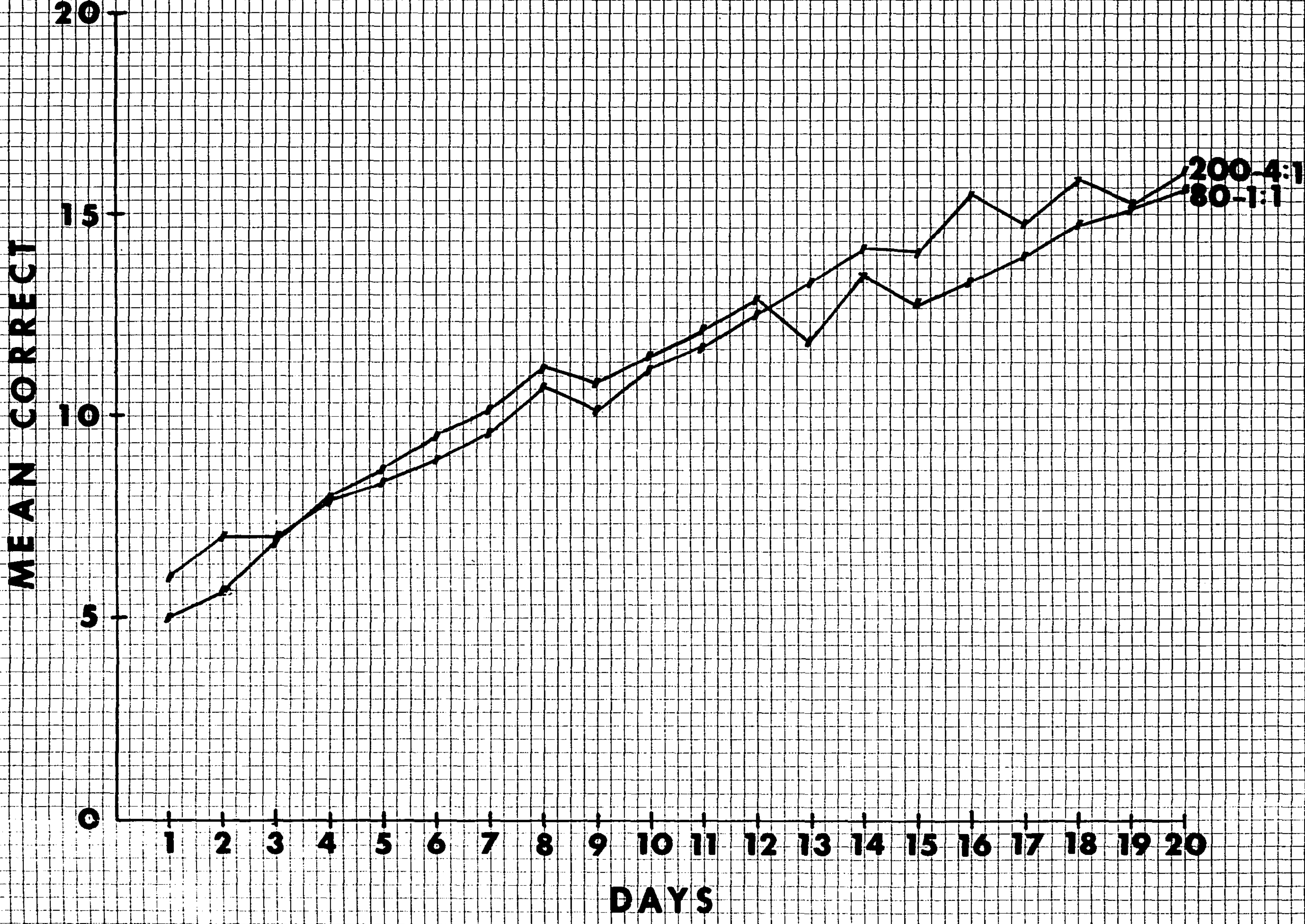
FIGURE 12. -- Reversal Learning Curves during the First 14 Days of Free Reversal for Groups that Had Received Different Numbers of Forced Reversal Trials and a 1:4 R/NR Ratio


320-1:4
200-1:4
80-1:4
DAYS
1
2
3
4
5
6
7
8
9
10
11
12
13
14
MEAN CORRECT
0
5
10
15
20

Some of the most interesting comparisons of free reversal learning curves are found when groups receiving equal numbers of nonreinforced trials during forced reversal are examined. Fig. 13 compares group 80-1:1 with group 200-4:1. Each of these groups had 40 nonreinforced trials during forced reversal. Although these two groups received a different total number of forced trials and different R/NR ratios during forcing, their reversal learning curves for the first 20 days of free reversal are quite similar. Fig. 14 compares group 200-1:4 with group 320-1:1. Each of these groups had 160 nonreinforced trials during forced reversal. Their performance during the first 14 days of free reversal is strikingly similar. Fig. 15 compares group 80-1:4 with group 320-4:1. Each of these groups received 64 nonreinforced trials during forced reversal. Their performance during free reversal is similar, especially during days 8 through 14.

Fig. 16 presents the reversal learning curve for the control group, and Fig. 17 presents the reversal learning curves for the control group and for each of the E groups. The performance of the C group during the first 14 days of free reversal was, in general, poorer than that of each of the 9 E groups. The only E group which was inferior to the C group was the 80-4:1 group. On days 1 through 8 the performance of the C group is generally closest to that of the 80-4:1 group, but beginning on day 9 the C group diverges and remains superior to the 80-4:1 group.

FIGURE 13. -- Reversal Learning Curves during the First 20 Days of Free Reversal for Groups that Had Received 40 Nonreinforced Trials during Forced Reversal



MEAN CORRECT
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
DAYS
200-4:1
80-1:1

43a

FIGURE 14. -- Reversal Learning Curves during the First 14 Days of Free Reversal for Groups that Had Received 160 nonreinforced Trials during Forced Reversal

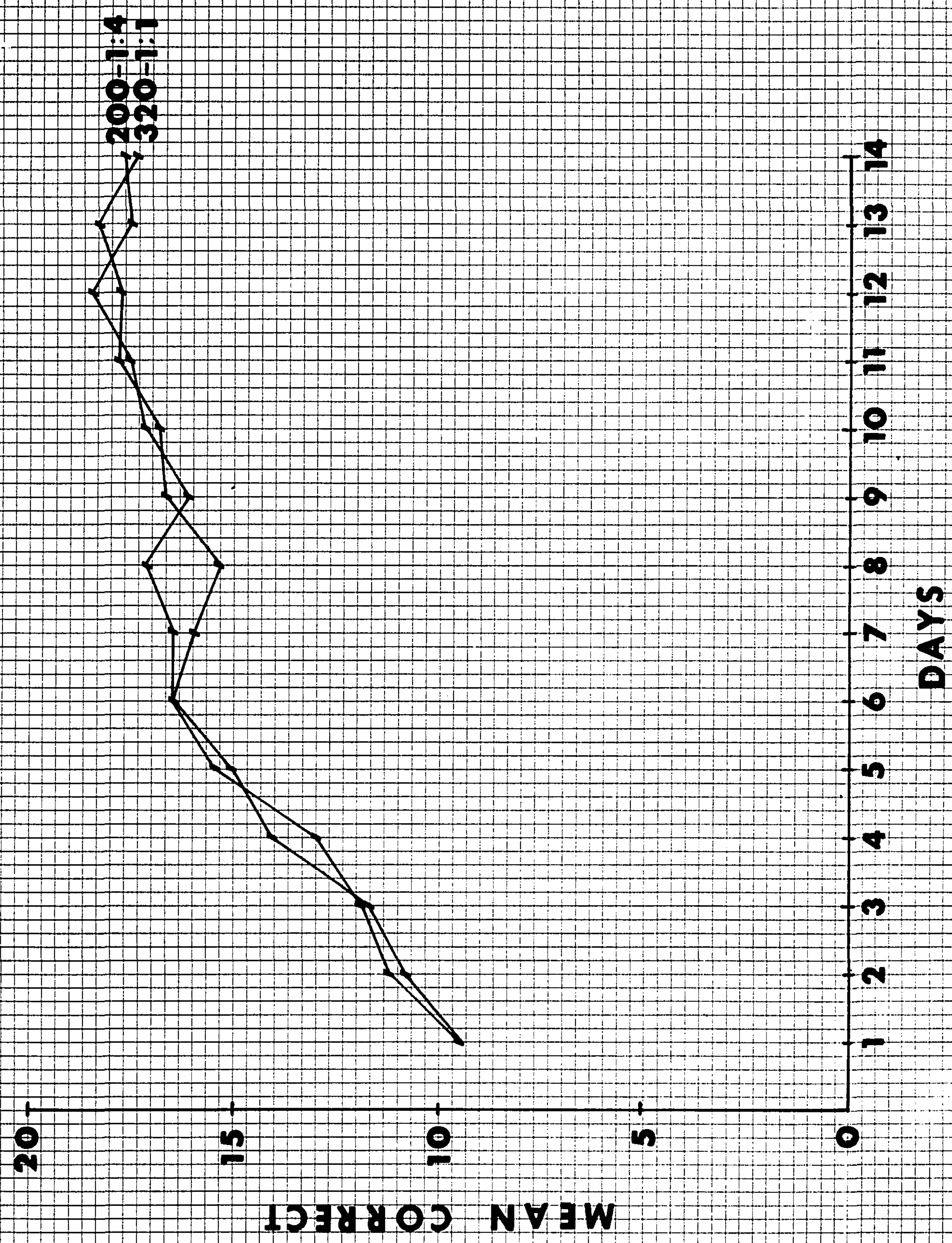

200-1:4
320-1:1
DAYS
1
2
3
4
5
6
7
8
9
10
11
12
13
14
MEAN CORRECT
0
5
10
15
20

FIGURE 15. -- Reversal Learning Curves during the First 14 Days of Free Reversal for Groups that Had Received 64 nonreinforced Trials during Forced Reversal

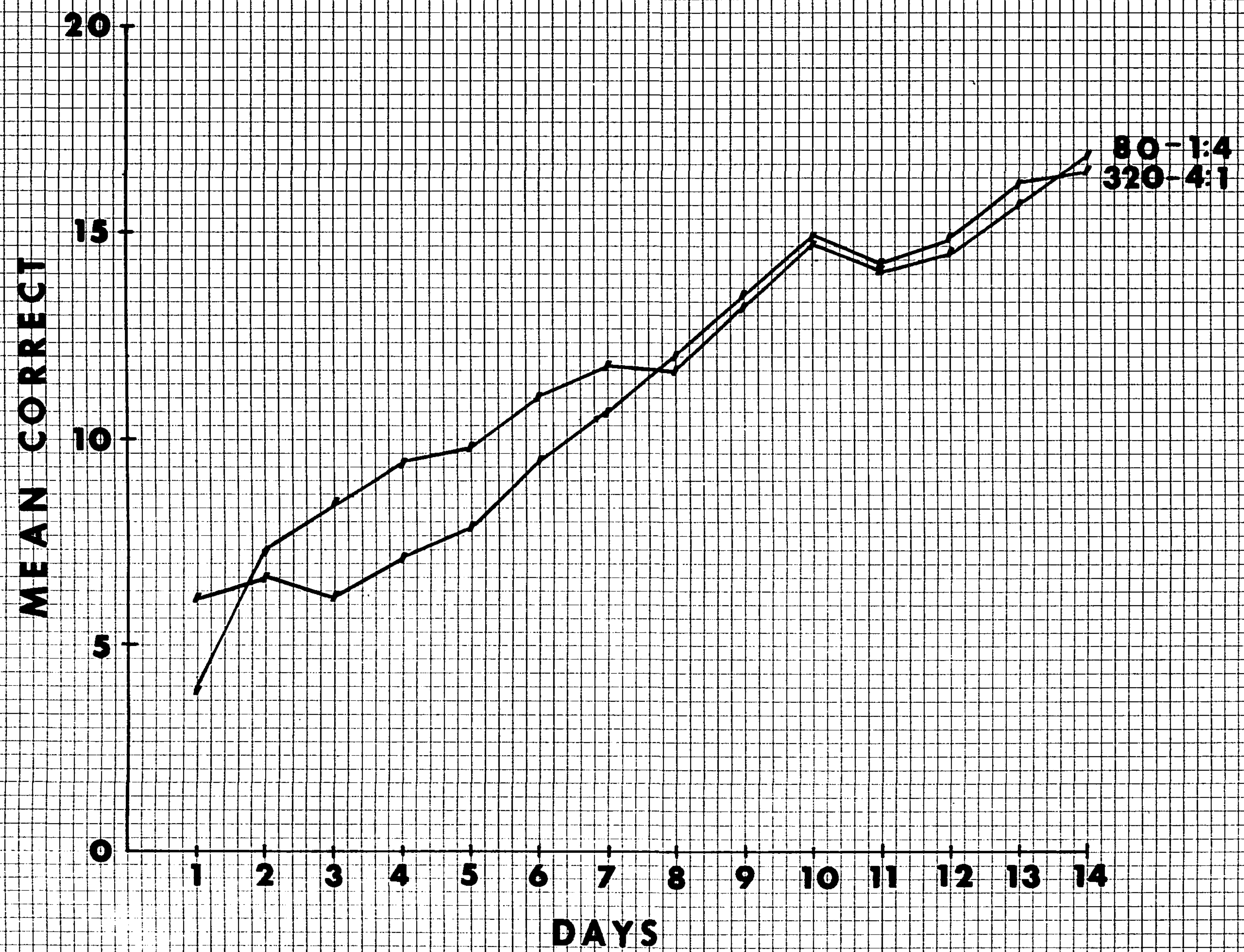

80-1:4
320-4:1
MEAN CORRECT
0
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
DAYS

FIGURE 16. -- Reversal Learning Curve during the First 20 Days of Free Reversal for the Control Group

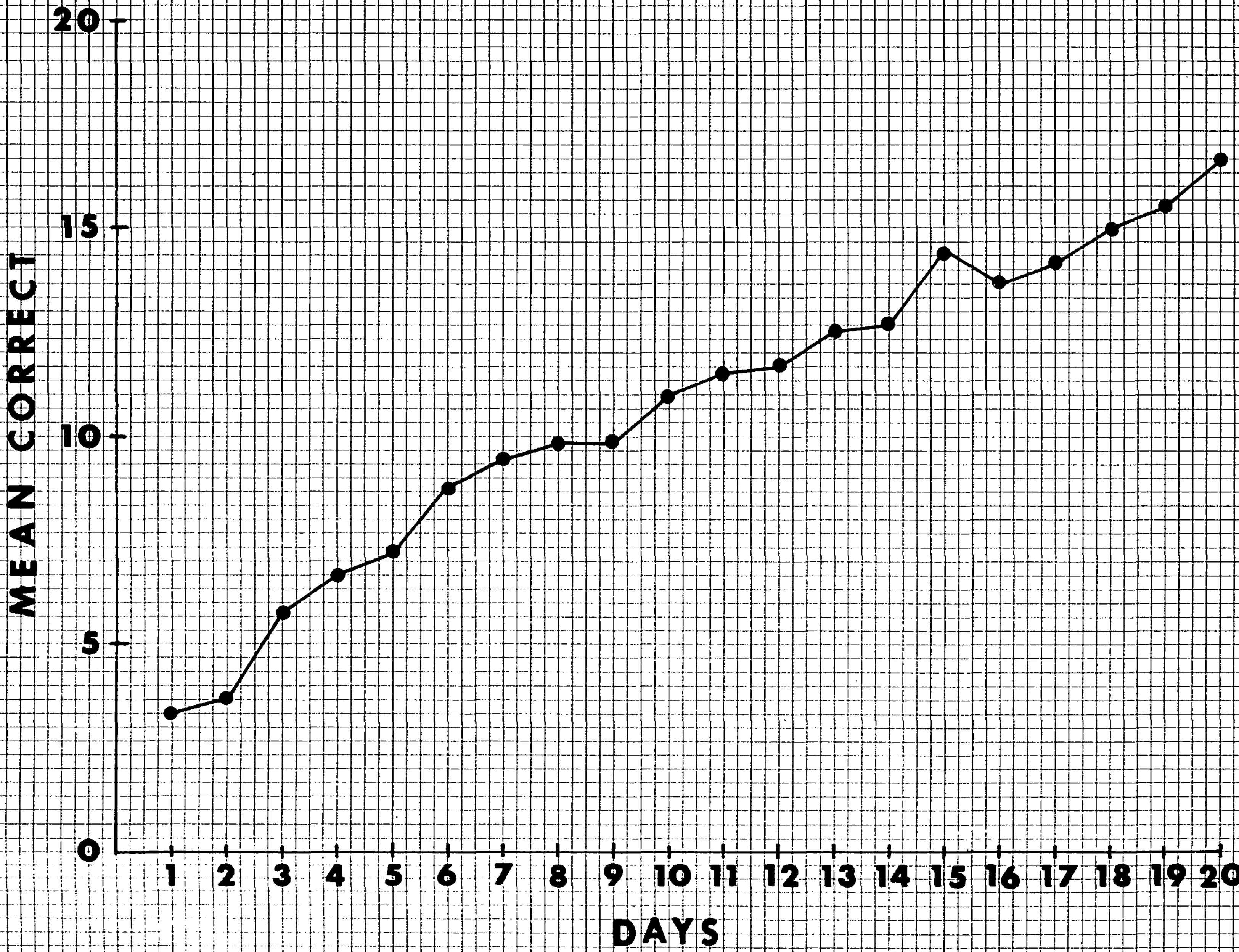
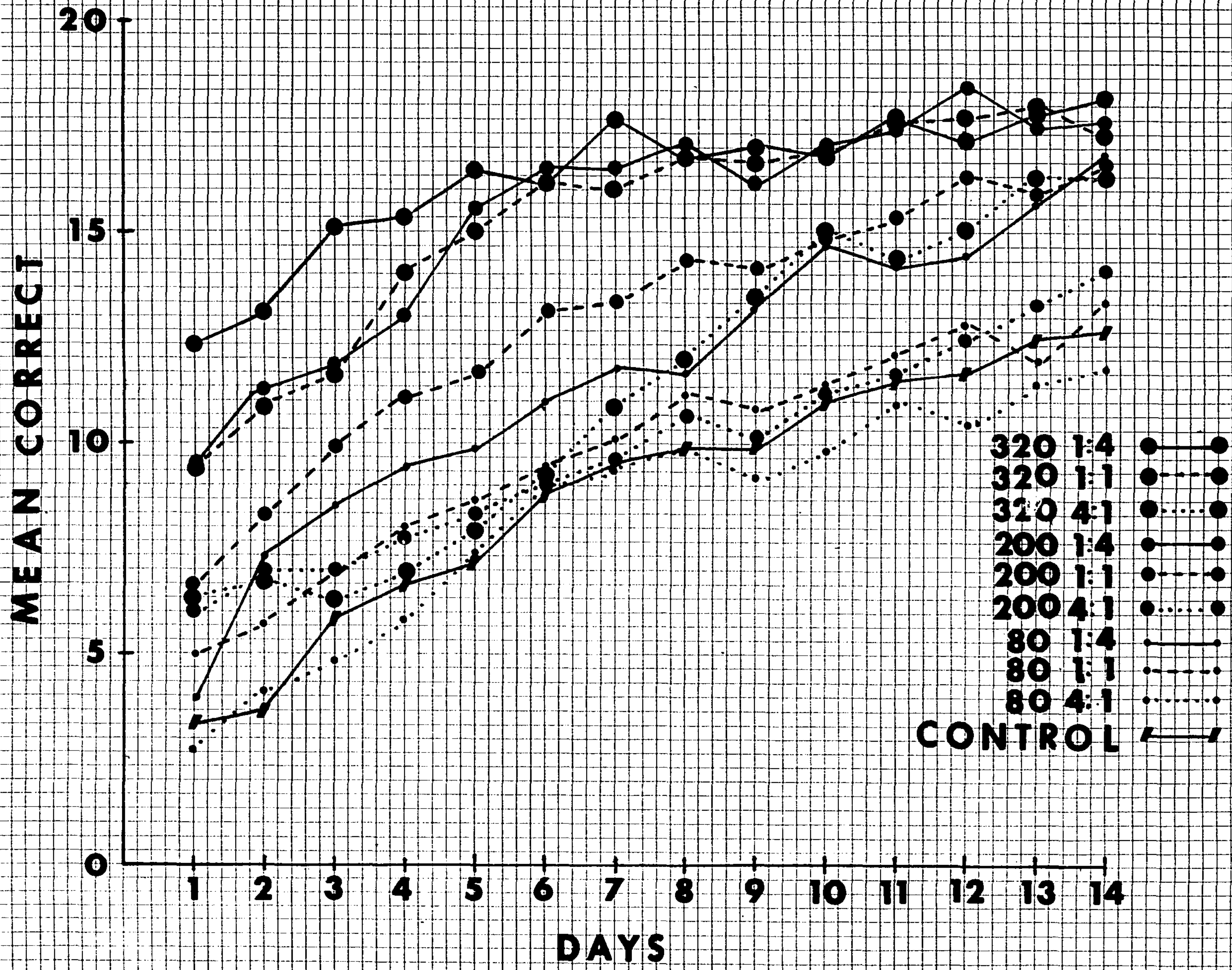

MEAN CORRECT
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
DAYS

FIGURE 17. -- Reversal Learning Curves during the First 14 Days of Free Reversal for Each of the Experimental Groups and for the Control Group


MEAN CORRECT
0
5
10
15
20
DAYS
1
2
3
4
5
6
7
8
9
10
11
12
13
14
320 1:4
320 1:1
320 4:1
200 1:4
200 1:1
200 4:1
80 1:4
80 1:1
80 4:1
CONTROL

DISCUSSION

The effects of giving forced reversal trials with differential ratios of reinforced trials to the new S+ (former S-) and nonreinforced trials to the new S- (former S+) are clear. When groups that had different R/NR ratios during forced reversal were put on free reversal those groups that had received R/NR ratios with high proportions of nonreinforced trials were clearly superior to those groups that had received R/NR ratios with low proportions of nonreinforced trials. On almost all measures of reversal performance that were examined, groups that had received R/NR ratios of 1:4 were superior to groups that had received R/NR ratios of 1:1. These 1:1 groups were, in turn, superior to groups that had received R/NR ratios of 4:1. In addition, these facilitative effects of decreasing R/NR ratio occurred at each level of number of forced trials given.

The effects of total number of forced reversal trials are also clear. The greater the number of forced reversal trials given, the better performance was during free reversal. Groups that had been given sixteen days (320 trials) of forced reversal were, in general, superior to those groups that had been given ten days (200 trials) of forced reversal. Those groups that had been given ten days of forced reversal were, in general, superior to groups that had been given four days (80 trials) of forced reversal.

Thus, both independent variables had highly significant effects in the predicted direction on reversal performance. There were also interesting similarities in performance during free reversal between groups that had received equal numbers of nonreinforced trials during forcing. For any two groups receiving an equal number of nonreinforced trials during forcing, their reversal learning curves during free reversal tended to be almost identical. In fact, for <u>any</u> dependent variable, when mean comparisons between any two groups that had received an equal number of nonreinforced trials were made, the means were usually very similar or almost identical. No such similarities in reversal performance occurred between groups that had received equal numbers of reinforced trials during forcing. This pattern of results suggests that the crucial variable operating in the present study may have been the absolute number of nonreinforced trials received during forced reversal.

It appears, then, that the over-all results obtained are clearly consistent with Jagoda's hypothesis that, during reversal, learning to avoid the new S- is relatively more difficult than learning to approach the new S+. Perhaps the simplest way to view a discrimination reversal is to assume that it is merely a second discrimination which the subject must learn. Learning to avoid the new S- is difficult, therefore, for essentially the same reasons that learning to avoid the old S- was difficult during the first discrimination.

It may be recalled that D'Amato and Jagoda (1960, 1961) suggested that given the usual motive incentive conditions operating in experimental situations; approach responses to both discriminanda are relatively high in the response hierarchy. They pointed out that under an appetitive drive animals quite "normally" approach stimuli that are not otherwise aversive. From their point of view, approach responses to S+ need little conditioning. The major task that the animal faces is learning to extinguish these approach tendencies toward the incorrect stimulus. High numbers of nonreinforced trials to the incorrect stimulus should facilitate discrimination learning, since extinction presumably occurs on nonreinforced trials.

It seems that the most parsimonious interpretation of the data from the present study is that the task which the animal faces in a discrimination reversal is essentially no different from that in the initial discrimination. Although the basic requirements of the two situations may not be essentially different, the animal has had prior conditioning to the S+ and to the S- by the time the reversal task is reached. The role of nonreinforcement of the incorrect response may, therefore, be even more critical in the reversal situation than it was in the initial discrimination.

In the initial discrimination, nonreinforcement presumably extinguished approach responses to S-. In that situation, however, approach tendencies to S- were not specifically reinforced, except, perhaps through generalization from S+ to S-. In the reversal situation, however, responses to the new S- (old S+) have had a great deal of reinforcement during the initial discrimination task. It is possible that learning to avoid the new S- in reversal is more difficult than learning to approach the new S+, because extinction of formerly learned approach responses to the old S+ (new S-) may require longer than extinction of formerly learned avoidance responses to the old S- (new S+). There are data from at least one study by Trapold, Gross, and Lawton (1968) which indicate that avoidance responses to the old S- extinguish faster than do approach responses to the old S+ when latency is the response measure.

There are at least two possible reasons why extinction of formerly learned approach responses may require longer than extinction of formerly learned avoidance responses. One reason could be that the negativity associated with the old S- may be low by the end of the initial discrimination, since the animal is going mostly to S+ at this point and rarely to S-. This reduced experience with S- during late acquisition could decrease the negativity associated with this stimulus. If the negativity associated with S- is low at the end of the initial discrimination, then avoidance tendencies to it may not be as strong as are approach tendencies to S+. This possible difference in strength between approach tendencies to the old S+ and avoidance tendencies to the old S- might account for differential rates of extinction of these response tendencies during reversal.

A second possibility is that it may be easier to extinguish avoidance tendencies, even if they are strong, than it is to extinguish approach tendencies. For a highly motivated animal avoidance tendencies could be difficult to learn initially, but easy to extinguish when the animal is forced to go to the old S- and receives reinforcement there during reversal. Conversely, approach responses may be easy for a highly motivated animal to learn, but difficult to extinguish while the animal is still highly motivated. Thus, large numbers of nonreinforced trials to the old S+ may be necessary to extinguish these formerly learned approach responses.

Extinction of formerly learned approach responses to the old S+ (new S-) may have occurred, because of frustration effects which occurred as a result of nonreinforcement. The view that nonreward can result in frustrative effects is, of course, not new. Amsel (1962) argued that the burden of evidence is that avoidance of nonreward is a more powerful factor in discrimination learning than is approach to reward. He suggested that this factor is very relevant to any point of view which makes nonreward a determiner of inhibition to S-, and he stressed that avoidance of nonreward is a powerful factor because frustration results when nonreward occurs.

Thus, in the present study, those animals that received a high number of nonreinforced trials to the new S- may have built up very strong avoidance tendencies to this stimulus based on frustration effects. For these animals, the negativity associated with the new S- may have been quite strong. When put on free reversal they, therefore, avoided this stimulus.

It may be recalled that Biederman (1967, 1968) argued that the negativity associated with S- does not increase monotonically over the course of discrimination learning. He suggested that S- functions as the primary cue during early discrimination and its negativity is high at this point. Later, however, S+ presumably takes over the primary cue function. As a result of this shift in cue function S- supposedly loses some of its negativity.

Biederman did not indicate explicitly that the cue functions of the new S+ and those of the new S- should change during reversal learning as they presumably did during the initial discrimination. It seemed possible though, that they might. In the present study, however, there was no indication that the cue functions of the new S+ and those of the new S- changed during the course of reversal learning. There was, however, no way of directly assessing the cue functions of the new S+ and the new S- separately. At least there was, however, no indication that the new S- lost any negativity as reversal learning progressed.

For example, if the new S+ functions as the primary cue for discrimination during late acquisition of the reversal, and if the new S- loses some of its negativity as a result of this shift in cue function, then the following prediction seems reasonable. After

320 forced reversal trials, a 4:1 R/NR ratio group might be superior to a 1:4 R/NR ratio group. Clearly, the results obtained in the present study are not consistent with this prediction.

One might argue, however, that 320 forced reversal trials do not represent "late" acquisition in reversal. Yet, when the reversal performance of the control group is examined it can be seen in Fig. 16 that this group was well along in the acquisition of the discrimination reversal by day 16 (320 trials). In addition, when the free reversal performance of the 320 trial group with a 1:4 ratio is examined it is clear that this group is also well along in the acquisition of the reversal by the first day of free reversal (See Fig. 17).

Also, when the free reversal performance of the 320-1:4 group is compared with that of the 320-4:1 group it is apparent that the 320-1:4 group is clearly superior to the 320-4:1 group during the first 14 days of free reversal (See Fig. 17). It seems, therefore, that if the negativity associated with the new S- decreases, this decrease is not apparent in the present study.

The results obtained suggest, therefore, that the new S- may be the primary cue for the discrimination reversal, and learning to avoid this new S- is the critical component in the acquisition of the discrimination reversal. It seems that the animal must mainly learn to avoid the new S-, and nonreinforced trials to this stimulus facilitate this learning.

Although there is no doubt that nonreinforcement of the incorrect responses facilitated reversal learning, the role of position responding during free reversal should probably be examined also. The role of position responding in previous reversal studies has not been entirely clear. Sperling (1969) has pointed out that differences in the amount of position responding are not by themselves a sufficient condition to account for differences in trials to reversal criterion. Less position responding is correlated with faster reversal, however, when differences are observed. Sperling (1970) has also suggested that discriminative responding and position responding may be so confounded in a simultaneous training situation, that choice data may reflect the difference between amount of control that S+ has over responding and the amount of control that position preference has over responding.

In the present study the results did indicate a positive correlation between mean days in position and mean free days to reversal criterion. Fewer days in position were associated with fewer days to reversal criterion. Groups that reached reversal criterion quickly spent very few days in position. For example, the E group that received sixteen days of forced reversal with a R/NR ratio of 1:4 had a mean of 1.1 days in position. Some subjects in the fast reversal groups never went into position.

A close examination of the position data reveals that there was a tendency for the groups that stayed in position for the most days to go into position later than those groups that stayed in position for fewer days. In addition, when number of incorrect choices during early free reversal were examined it was found that those groups that went into position later tended to respond to the old S+ for more trials than did those groups that went into position later. Thus, subjects who were in groups that had received few nonreinforced trials during forced reversal tended to perseverate to the old S+ during free reversal. Since these subjects had not received much nonreinforcement during forced reversal, it is possible that encountering nonreinforcement during early free reversal produced frustration. Going into position responding may have been a response to this frustration.

Some subjects who were in groups that had received many nonreinforced trials during forcing did go into position during free reversal, but these subjects tended not to stay in position for very many days. If a subject were responding completely on the basis of position, S- would be encountered on fifty percent of the trials. For those subjects who had received many nonreinforced trials during forced reversal, the negativity associated with S- may have been very strong. Thus, these subjects may have extinguished position responding quickly, since one consequence of position responding was encountering S-.

The position data also suggest that the total number of forced reversal trials affected the probability that the S+ and the S- would function as the discriminative stimuli controlling the subject's responses during free reversal. As total number of forced reversal trials increased, the mean days in position during free reversal decreased. It seems plausible that the more experience the subject had during forced reversal the more likely it would be that the subject would respond to the S+ and the S- during free reversal and less likely to respond on the basis of position.[1]

This analysis of why position responding occurred and why there were differences among groups in number of days spent in position is highly speculative. It is probably impossible to determine, within

[1] It will be recalled that position responding was not possible during forced reversal.

the limits of the present study, what causal relationship existed, if any, between experience during forced reversal and position responding during free reversal. Nonetheless, experimental groups did differ in number of days in position during free reversal.

Perhaps one of the most important implications of the reversal data obtained in the present study is related to the numerous studies and theoretical confusion surrounding the overtraining reversal effect (ORE). Mackintosh (1969) has pointed out that there is currently no single theory that can easily account for all of the data from the overtraining reversal studies. Although the present study did not employ overtraining trials, the results obtained do suggest a possible explanation for the occurrence of the ORE in those studies where it has been observed.

A very typical finding in overtraining reversal studies has been that overtrained subjects respond to the old S+ more during early reversal than do criterion trained subjects. Since the overtrained subjects are responding more often to the old S+, they are receiving more nonreinforced trials during early reversal than are criterion trained subjects. If learning to avoid the new S- (old S+) is the difficult component of reversal learning, as the data from the present study suggest, then it is possible that the ORE occurs because overtrained subjects receive more nonreinforced trials during early reversal than do criterion trained subjects. This explanation of the ORE has at least one advantage - simplicity. It does not, for example, require postulating unobservable "attentional" responses. Since the ORE has often been cited as major evidence supporting attentional models of discrimination learning, it seems that one of the most crucial implications of the present study is that these models are not necessary...at least where the ORE is involved.

In summary, the over-all results obtained in the present study clearly demonstrated the effectiveness of nonreinforcement of the incorrect response in reversal. The crucial variable which seemed to be operating was the absolute number of nonreinforced trials to the new S- received during forced reversal. These results support the hypothesis that learning to avoid the new S- is relatively more difficult than learning to approach the new S+. The data suggest that, in this respect at least, the task that faces the subject in a discrimination reversal is essentially no different from that in the original discrimination task.

One may, of course, raise a question about the equivalency of a forced reversal trial and a free reversal trial. Obviously, there are procedural differences between the two. In the present study, a forced reversal trial consisted of the presentation of a single stimulus at a time - either the S+ or the S-. A free reversal trial consisted of the simultaneous presentation of the S+ and the S-. Also, on a free reversal trial the subject was free to respond right or left.

A comparison of the control group, which received <u>only</u> free reversal trials, with each E group suggests that the amount of learning that occurs on a free reversal trial may not be <u>exactly</u> the same as the amount that occurs on a forced trial. Although almost all of the E groups were superior to the C group on all measures of performance during free reversal, a close examination of the number of correct responses on certain days of free reversal suggests that free reversal trials may result in slightly faster reversal learning than do forced reversal trials. For example, the C group had a "self-imposed" R/NR ratio which averaged out to be approximately 1:3 over the first 4 days of free reversal. Thus, over Days 1 through 4 the C group received a R/NR ratio which was most like that of the E group which had received 4 days of forced reversal with a R/NR ratio of 1:4.

On Day 5 of free reversal the C group's mean number of correct responses was 7.0. On Day 1 of free reversal, which can be viewed as Day 5 for the E group that received 4 days of forced reversal with a R/NR ratio of 1:4, the mean number of correct responses was 3.9. This difference in mean number of correct responses on Day 5, while not striking, does suggest that 4 days of free reversal resulted in slightly faster learning than did 4 days of forced reversal.

Considering the procedural differences between a forced trial and a free trial, however, this difference in performance could actually be viewed as quite small. It seems, therefore, that the possible differences in effects between a forced trial and those of a free trial are not really a crucial issue in the present study.

One may question the legitimacy of running all of the subjects to S+ bright and to S- dim during the first discrimination task. It would seem appropriate, even necessary, to have used counterbalancing. However, in brightness discrimination studies with rats in which the stimuli are lights of different intensities it is not uncommon to run all of the subjects to S+ bright, since different rates in acquisition to S+ bright and to S+ dim can occur. Lachman (1961), for example, pointed out that during discrimination with a nonpreferred S+ (e.g., a bright stimulus for negatively phototropic animals such as rats), the proportion of correct responses begins around .25 and terminates at unity. Whereas the initial proportion of correct responses to a preferred S+ (e.g., a dim stimulus) begins around .75 and terminates at unity. Differences in acquisition with preferred and nonpreferred discriminanda involve, therefore, different rates (slopes) of learning.

Thus, in the present study, if 1/2 of the subjects had been run to S+ bright and 1/2 to S+ dim, then these two groups might have gone into reversal with very different rates of acquisition to S+. One may argue that this problem limits the generality of the results obtained, since, during reversal, nonreinforcement was given to a possibly non-preferred stimulus (bright) and reinforcement was given to a possibly preferred stimulus (dim). However, if the dim stimulus were preferred, then the effects of reinforcement should have operated to increase this preference. Therefore, groups receiving many reinforced trials during forced reversal should have performed better than groups receiving few reinforced trials. This was obviously not the case.

In addition, whatever preference may have existed for the dim stimulus initially was probably reduced by experience during the first discrimination task in which responses to this stimulus were nonreinforced. Also, if S+ bright had any negativity associated with it because it was bright, then this negativity should have been reduced, since responses to this stimulus were reinforced during the first discrimination. It seems, therefore, that by the time the animal reached reversal, initial "preferences" and "nonpreferences" should have been overcome because of experience during the first discrimination task.

The most important contribution of the present study is that its results suggest a great deal about the basic nature of discrimination reversal learning. Specifically, the results indicate the tremendous influence that nonreinforcement of the incorrect response during reversal has on learning. The extent of this influence strongly suggests that learning to avoid the new S- is the critical component of reversal learning. This interpretation of reversal learning could be central to any theory of discrimination learning which stresses the inhibitory control that S- exerts over discriminative responding.

SUMMARY

Results from previous studies suggested that in discrimination reversal tasks learning to avoid the new S- was relatively more difficult than learning to approach the new S+. In order to examine this view of discrimination reversal learning, reinforcement/nonreinforcement (R/NR) ratios and number of trials were varied during forced reversal. Three R/NR ratios, 4:1, 1:1, and 1:4, were combined with 80, 200, and 320 forced reversal trials. It was predicted that reversal performance should be facilitated by decreasing R/NR ratios and by increasing number of forced reversal trials.

In a test of these hypotheses, 110 female hooded rats were trained to make a two-choice simultaneous brightness discrimination in automated discrimination shuttleboxes. After reaching an acquisition criterion of 90% correct responding on this first discrimination task, each subject began reversal training. During reversal the former S+ was now the S-, and the former S- was now the S+. Experimental subjects were given forced reversal trials while control subjects were put immediately on free-choice reversal. After the completion of forced reversal trials, experimental subjects were put on free-choice reversal. All subjects were run to a reversal criterion of 90% correct responding.

The effects of giving forced reversal trials with differential ratios of reinforced trials to the new S+ (former S-) and nonreinforced trials to the new S- (former S+) were clear. When groups that had different R/NR ratios during forced reversal were put on free reversal those groups that had received R/NR ratios with high proportions of nonreinforced trials were clearly superior to those groups

that had received R/NR ratios with low proportions of nonreinforced trials. On almost all measures of reversal performance that were examined, groups that had received R/NR ratios of 1:4 were superior to groups that had received R/NR ratios of 1:1. These 1:1 groups were, in turn, superior to groups that had received R/NR ratios of 4:1. In addition, these facilitative effects of decreasing R/NR ratios occurred at each level of number of forced trials given.

The effects of total number of forced reversal trials were also clear. The greater the number of forced reversal trials given, the better, in general, performance was during free reversal. Groups that had been given 320 forced reversal trials were, in general, superior to groups that had been given 200 forced reversal trials. These groups that had been given 200 forced reversal trials were, in general, superior to groups that had been given 80 forced reversal trials.

Thus, both independent variables had highly significant effects in the predicted direction on reversal performance. In addition, there were interesting similarities in performance during free reversal between groups that had received equal numbers of nonreinforced trials during forcing. Reversal learning curves during free reversal tended to be almost identical for any two groups that had received equal numbers of nonreinforced trials during forced reversal. No such similarities in performance occurred between groups that had received equal numbers of reinforced trials. This pattern of results suggested that the crucial variable operating in the present study was the absolute number of nonreinforced trials received during forced reversal.

The over-all results strongly support the view that learning to avoid the new S- is the crucial component of reversal learning. The importance of establishing avoidance tendencies to the new S- was discussed, and it was suggested that extinction of formerly learned approach tendencies may require longer than extinction of formerly learned avoidance tendencies. On the basis of the results obtained in the present study a possible explanation for the occurrence of the overtraining reversal effect was suggested.

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Appendix I

Sequence of reinforced trials and nonreinforced trials during forcing (each day)

Trial	4:1 ratio	1:1 ratio	1:4 ratio
1.	R	R	NR
2.	R	R	NR
3.	R	R	NR
4.	NR	NR	R
5.	R	NR	NR
6.	NR	R	R
7.	R	NR	NR
8.	R	R	NR
9.	R	NR	NR
10.	R	NR	NR
11.	R	R	NR
12.	NR	R	R
13.	R	NR	NR
14.	R	NR	NR
15.	R	NR	NR
16.	R	R	NR
17.	R	NR	NR
18.	NR	R	R
19.	R	R	NR
20.	R	NR	NR

R = reinforced trial to the new S+ (old S-)
NR = nonreinforced trial to the new S- (old S+)