THE EFFECTS OF CONTRASTED REINFORCEMENT ON PROBABILITY LEARNING IN THE T-MAZE

by

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Abstract

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Two experiments were conducted to investigate the effects of both duration and delay of reinforcement on probability (75:25) learning in the T-maze under a non-correction rerun procedure with a minimum ½ hr. between "runs". The major result of both experiments was the non-monotonicity of the learning curves for choice probability for Groups which received unequal durations of reinforcement, at zero delay, for the two sides. Specifically, in the first phase these learning curves start towards the "matching" asymptote and then move slowly towards a final asymptote which is quite different from the matching value.

Experiment I employed nine groups which received the following combinations of reinforcement: I (4,0 - 4,0), II (16,0 - 16,0), III (32,0 - 32,0), IV (16,10 - 16,10), V (16,25 - 16,25), VI (4,0 - 32,0), VII (16,25 - 16,0), VIII (32,25 - 4,0), IX F(4,0 - 32,0). The first pair of numbers refers to the reinforcement conditions on the A_1 side (larger proportion of reinforcement) while the second pair refers to the A_2 side. The first number of each pair refers to the duration in seconds of reinforcement while the second refers to the delay in seconds with which S received it.

The apparatus was a T-maze painted flat gray and covered with hinge mounted clear Plexiglas. Aluminum guillotine doors separated each of the arms and the start box from the stem. A drinking tube

similar to those used in the home cages was mounted in a recessed 4 x 2 in. drinking area. Photocell beams were placed 2 in. past the start box door, 1 3/4 in. before the choice point and 11 in. into each arm, and 2 in. before the closed door to the drinking area. They measured latency, choice time and committed time, respectively.

The non-correction rerun procedure employed for Groups I - VIII reinforced Ss for a correct turn only, i.e., if their choice corresponded with the placement of reinforcement for that trial. After an "error" reinforcement remained on the "correct" side, for subsequent "runs" until S finally made the "correct" response. A trial was thus defined as one or more "runs" terminated by a reinforcement. The choice probability measure was that for the first "run" of each trial. Group IX received a combination of free and forced trials in which each "run" was reinforced.

The results of Experiment I showed that duration of reinforcement did not influence the rate of learning or the asymptotic choice probability for Groups I - III. In addition the three time measures were similar for these Groups. The equal θ model of Bush-Mosteller (1955) showed reasonable success in describing the fine detail of the combined Groups (I - III) asymptotic choice probability data, though the combined Groups showed a slight but significant undershooting of the theoretical asymptote.

The major finding of Experiment I was the non-monotonicity of the choice probability learning curve of Group VI. This led to the rejection of the Bush-Mosteller (1955) 2θ model for the case where unequal reinforcement durations are given for the two T-maze alternatives.

Group IX (forcing group) showed the typical negatively accelerated learning for the choice probability data. It was proposed that these Ss discriminated between free and forced trials and that on free trials the Ss were operating under a non-correction model.

The three time measures for all of the Groups showed the typical negatively accelerated learning curve in which only the delay of reinforcement Groups were significantly slower than some of the no delay Groups. In addition there were some differences in response times to the A_1 and A_2 sides, within some of the Groups.

Experiment II employed the same 75:25 random reinforcement schedule in which five Groups received the following durations of reinforcement for the A_1 and A_2 sides: I (4,32 - 4,32), II (4-32), III (32-4), IV (4-8), V (4 - 4,32). Pairs of values refers to the fact that more than a single reinforcement duration was given on a side for some of the Groups.

The unequal reinforcement Groups (II - V) showed the nonmonotonicity of the choice probability learning curves thus replicating the results of Group VI of Experiment I. A two-process theory of learning was proposed to account for the non-monotonicity of the choice probability learning curves for the Groups which received unequal durations of reinforcement in both Experiments I and II. The theoretical interpretation was based on the Ss' discrimination of reinforcement "aftereffects" which were assumed to be available at the choice point at some time relatively late in the course of learning.

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The learning models elaborated by Bush and Mosteller (1955) were part of the movement to understand complex learning situations through laws derived from simpler learning situations. To obtain the learning curve for a single subject, they apply a linear operator on probability following the reinforcement or nonreinforcement of a response. This type or approach has met with particular success dealing with probability learning of infra-human Ss in the T-maze.

Probability learning in the T-maze consists of having reinforcement available on some proportion of the trials for each of the alternatives. Probability learning using infra-human Ss has been carried out using three basic procedures, the "correction", "non-correction", and the "non-correction rerun" procedures.

In all three paradigms reinforcement on each trial is placed in either goal box according to some random schedule. Under the "correction" procedure reinforcement is present on each trial in at least one of the goal boxes of the T-maze and S is allowed to retrace following entry into an empty goal box. Under the "non-correction" procedure no retracing is allowed from an empty goal box. Finally, under the "non-correction rerun" procedure no retracing is allowed but reinforcement conditions are left unchanged until on a subsequent "run" S enters the goal box containing reinforcement thus terminating a "trial".

Bush and Mosteller have elaborated a number of specialized versions of the basic linear operator learning models which differ primarily in the assumptions made concerning the effects of the trials on which S initially responds to the "incorrect" (or empty) goal box. For the Bush and Mosteller models and, more generally, for a number of other probability learning models directly reinforced trials are assumed to

result in an increase in the probability of responding to the reinforced side such that

(1) $P_{n+1}(A_1) = (1-\theta_1)P_n(A_1) + \theta_1$.

On incorrect trials the assumption is made for human Ss (Estes and Straughan, 1954) that the S corrects himself "implicitly" leading to the use there too of the operator of eq. (1). For infra-human Ss there are a number of assumptions that have been made about the effects on $P_{n+1}(A_1)$ of an initially incorrect response. The major assumptions used when an initial A_2 response is non-reinforced have been that $P_{n+1}(A_1)$ is: (a) the same as when A_1 is reinforced, which leads to the Bush and Mosteller (1955 p. 287) "equal θ model": (b) less than the increase when an A_1 response is reinforced, which leads to the "2 θ" model of Bush and Mosteller (1955, p. 289): (c) an increase in probability to the side initially chosen or a decrease in $P_{n+1}(A_1)$, which leads to the Bush and Wilson (1956) "secondary reinforcement" model; and, (d) that $P(A_1)$ is unchanged, which leads to the "identity operator" of Bush and Mosteller (1955, pp. 183 and 289).

In linear operator terms the corresponding four theoretical alternatives are:

(2) $P_{n+1}(A_1) = (1-\theta_1)P_n(A_1) + \theta_1$

(3) $P_{n+1}(A_1) = (1-\theta_2)P_n(A_1) + \theta_2$

(4) $P_{n+1}(A_1) = (1-\theta_2)P_n(A_1)$

(5) $P_{n+1}(A_1) = P_n(A_1)$.

The complete models are further specified by assuming "symmetry" between the effects of reinforcement on the right and left for A_1 and A_2 responses. Letting E_1 and E_2 stand for reinforcement presented

on the A_1 and A_2 sides four types of trials are possible. They are A_1-E_1, A_1-E_2, A_2-E_1, and A_2-E_2.

Equations (1) and (2) and "symmetry" lead to the "equal θ" model of Bush and Mosteller 1955. Applying the following linear learning operators on the four types of trials:

(6) A_1-E_1: $P_{n+1}(A_1) = (1-\theta)P_n + \theta$

(7) A_1-E_2: $P_{n+1}(A_2) = (1-\theta)P_n + \theta$.

This is equivalent to

(7a) A_1-E_2: $P_{n+1}(A_1) = (1-\theta)P_n(A_1)$

(8) A_2-E_1: $P_{n+1}(A_1) = (1-\theta)P_n(A_1) + \theta$

(9) A_2-E_2: $P_{n+1}(A_2) = (1-\theta)P_n(A_2) + \theta$

or equivalently

(9a) A_2-E_2: $P_{n+1}(A_1) = (1-\theta)P_n(A_1)$.

This model leads to a prediction of "matching" at asymptote for individual organisms or,

(10) $P_\infty(A_1) = \pi$

if θ, the learning rate parameter is less than 1, and if the probability of E_1 trials is π and of E_2 trials $(1-\pi)$.

The second model obtained from equations (1) and (2) is the "2 θ" model of Bush and Mosteller. Here

(11) A_1-E_1: $P_{n+1}(A_1) = (1-\theta_1)P_n(A_1) + \theta_1$

(12) A_1-E_2: $P_{n+1}(A_1) = (1-\theta_2)P_n(A_1)$

(13) A_2-E_1: $P_{n+1}(A_1) = (1-\theta_2)P_n(A_1) + \theta_2$

(14) A_2-E_2: $P_{n+1}(A_1) = (1-\theta_1)P_n(A_1)$.

This model leads to a prediction of "overshooting" for individual organisms at asymptote if $\theta_1 > \theta_2$, or

(15) $P_\infty(A_1) > \pi$

The third model, derived from equations (1) and (5) is Bush-Wilson's "secondary reinforcement" model. Here

(16) A_1-E_1: $P_{n+1}(A_1) = (1-\theta_1)P_n(A_1) + \theta_1$

(17) A_1-E_2: $P_{n+1}(A_1) = (1-\theta_2)P_n(A_1) + \theta_2$

(18) A_2-E_1: $P_{n+1}(A_1) = (1-\theta_2)P_n(A_1)$

(19) A_2-E_2: $P_{n+1}(A_1) = (1-\theta_1)P_n(A_1)$.

This model differs from the others in that reinforcement after an initially incorrect response (correction trial) leads to strengthening of the initial response. $P_\infty(A_1) = 1$ or 0 with the proportion of organisms absorbed on the A_1 or A_2 sides depending on θ_1 or θ_2. J. Robbins (1969) justifies the use of this model for the T-maze on the grounds that after the initial turn S does not have to return to the choice point to turn to the correct side. Thus an A_1-E_2 sequence S is equivalent to reinforcement for an A_1 choice but with some delay of reinforcement, leading to a smaller θ-value.

The fourth model obtained from equations (1) and (4), is Bush and Mosteller's "identity operator" model. Here

(20) A_1-E_1: $P_{n+1}(A_1) = (1-\theta_1)P_n(A_1) + \theta_1$

(21) A_1-E_2: $P_{n+1}(A_1) = P_n(A_1)$

(22) A_2-E_1: $P_{n+1}(A_1) = P_n(A_1)$

(23) A_2-E_2: $P_{n+1}(A_1) = (1-\theta_1)P_n(A_1)$.

This model predicts each organism will respond 100% to the A_1 or A_2 side at asymptote. The side each S is "absorbed" on will depend on θ and π. For small θ all organisms will be absorbed on the larger π side. For θ equal to 1 the proportion of Ss absorbed on the larger π side will be exactly π. For intermediate values of θ the proportion of Ss absorbed will be between π and 1.

For the correction procedure some investigators have reported "probability matching" at asymptote (Brunswick, 1939; Estes, 1957a; Parducci and Polt, 1958) in the group learning curves. Bitterman et. al. (1958) pointed out that the matching result might be a result of averaging data from Ss which were behaving differently. J. Robbins (1969) showed that while group data revealed matching the individual Ss tended to become absorbed (i.e., responding to one alternative or the other close to 100% of the time). These findings are in disagreement with the equal θ model which predicts individual organism matching and J. Robbins concluded that her data were best fit by the Bush-Wilson secondary reinforcement model.

Under the non-correction procedure individual S absorption at asymptote is the typical finding. Weinstock et. al. (1965) showed that the identity operator of Bush and Mosteller gave a good fit to the "fine detail" of the data.

Weinstock et al. (1972) using a non-correction rerun procedure found that the choice behavior of individual Ss matched the probability of reinforcement for each side. The measurement of the choice response used is that of the first "run" following a reinforced response. The non-correction-rerun procedure insures that Ss would have been directly reinforced on one side of the maze π of the time and $1 - \pi$ of the time for the alternative response thus meeting the conditions of the linear models. If on non-reinforced "runs" $P(A_1)$ is unchanged (the identity operator) the errors should have no effect and the appropriate operator from the linear model should be adequate for directly reinforced runs. The matching result of Weinstock provided confirmation of the equal θ model with the assumption of the

identity operator on non-reinforced runs.

The present research plans to extend the work of Weinstock et al. (1972) by employing unequal reinforcement conditions for the two alternatives to test the assumption that the Bush-Mosteller "2θ" model applies to this situation. The general class of models has only a single parameter which may vary with reinforcement. The issue in question here is whether groups receiving different durations or delays of reinforcement will exhibit differences in their rate of approach to asymptote. Further, if they do, can the $\underline{\theta}$-values estimated from these groups be used to predict the learning curves for groups which receive unequal reinforcement conditions? Put otherwise, do the two learning operators, corresponding to the two different reinforcement conditions, combine independently or will there be "contrast" effects (Dunham, 1968: Black 1968) due to presenting two values of reinforcement? Experiment I is designed to answer these questions.

Experiment I

Application of the Bush-Mosteller "2 θ" model to probability learning in the T-maze leads to explicit predictions in the non-contingent paradigm given that the θ-values are known. Under the "non-correction rerun" procedure the four possible outcomes for a "run" are: A_1-E_1, A_1-E_0, A_2-E_2 and A_2-E_0. A_1 and A_2 represent responses to the two alternatives with events E_1 and E_2 their respective reinforcement. Event E_0 represents non-reinforcement. The appropriate probability operators are:

(24) A_1-E_1: $P_{n+1}(A_1) = (1-\theta_1)P_n(A_1) + \theta_1$

(25) A_1-E_0 & A_2-E_0: $P_{n+1}(A_1) = P_n(A_1)$

(26) A_2-E_2: $P_{n+1}(A_1) = (1-\theta_2)P_n(A_1)$.

The complete model may be derived by assuming "symmetry" between events for both sides of the T-maze.

To find $\overline{P}_{n+1}(A_1)$ we need only weight equations (24) and (26) by their respective proportion of occurrence and sum. Given that π_1 is the proportion of A_1 reinforced and π_2 is the proportion of A_2 reinforced,

(27) $\overline{P}_{n+1}(A_1) = \{(1-\theta_1)P_n+\theta_1\}\pi_1 + \{(1-\theta_2)P_n\}\pi_2$

If we clear equation (27) we get

(28) $\overline{P}_{n+1}(A_1) = P_n\pi_1 - \theta_1P_n\pi_2 + P_n\pi_2 - \theta_2P_n\pi_2$.

Given equal reinforcement conditions on both sides of the maze we assume that $\theta_1 = \theta_2$. Substituting $\pi_2 = 1 - \pi_1$ gives

(29) $\overline{P}_{n+1}(A_1) = P_n(1-\theta) + \theta\pi_1$.

Using difference equations (Goldberg, 1958) to find the recursive form:

(30) $\overline{P} = \pi_1 - (\pi_1+P_0)(1-\theta)^n$.

Since $\theta<1$ as $n\to\infty$, $(1-\theta)^n$ goes to zero and we are left with

(31) $\overline{P}_\infty(A_1) = \pi_1$

which gives us matching at asymptote. It should be noted that the matching result does not depend on the possible values of θ, but only on the fact that they are the same for both alternatives of the T-maze. Groups with different θ-values should be reflected in separate rates of approach to the same final asymptote.

Assuming under unequal conditions of reinforcement for the two alternatives that $\theta_1 \neq \theta_2$ we find from (28) that

(32) $\overline{P}_{n+1}(A_1) = P_n\{(1-\theta_1)\pi_1 + (1-\theta_2)\pi_2\} + \theta_1\pi_1$.

Using difference equations to find the recursive form

(33) $\overline{P}_{n+1}(A_1) = \{(1-\theta_1)\pi_1 + (1-\theta_2)\pi_2\}^n P_0 + \theta_1\pi_1 \left[\frac{1-\{(1-\theta_1)\pi_1+(1-\theta_2)\pi_2\}^n}{1-(1-\theta_1)\pi_1+(1-\theta_2)\pi_2}\right]$

As $n\to\infty$ the terms raised to the nth power go to zero and so

(34) $\overline{P}_\infty(A_1) = \frac{\theta_1\pi_1}{1 - (1-\theta_1)\pi_1 - (1-\theta_2)\pi_2}$.

Since $\pi_2 = 1 - \pi_1$ we have

(35) $\overline{P}_\infty(A_1) = \frac{\theta_1\pi_1}{\theta_2 + (\theta_1-\theta_2)\pi_1}$.

In the present experiment five groups of rats were run under different duration and delay of reinforcement conditions with each group having equal reward conditions for both sides of the T-maze. The plan was to estimate θ-values for these groups and then use them to predict the learning curves and final asymptotes of four groups receiving contrasted reinforcement conditions. For the equal reward conditions reinforcement durations of 4, 16 and 32 sec. and delays of reinforcement of 10 and 25 sec. were employed. The "contrast" groups received unbalanced combinations of these values. Since

D. Robbins (1969) found that time spent in consummatory behavior was the critical variable in amount of reinforcement effects, we employed duration rather than magnitude of reinforcement.

Method

Subjects

Seventy-four female albino rats, 70-80 days old at the start of the experiment supplied by Rockland Farms, Rockland, New York, were used. The Ss were individually housed in a large air-conditioned colony room in the Brooklyn College laboratories.

Apparatus

An enclosed T-maze painted flat gray and 5 in. high and 5 in. wide throughout was used. The apparatus was housed in a rectangular 6 x 9½ x 12 ft. room off of the colony room. The two arms of the T-maze were along the 6 ft. wide end wall with the stem centered and perpendicular to the 9½ ft. length. The start box was 9½ in. long and the stem was 8 3/4 in. long. Each arm was 25 in. long and the choice area was 5 in. wide. Aluminum guillotine doors separated each of the arms and the start box from the stem. The doors could be operated singly or in unison by means of strings centrally located behind the start box. The doors in each arm were located 24 in. from the end wall to form a goal box. A drinking tube similar to those used in the home cages was mounted on the far wall (the wall away from E who stood nearest the start box) of the goal box in a recessed 4 x 2 in. drinking area. Recessed aluminum guillotine doors, which were not visible to the S at the choice point, could be lowered or lifted in front of each drinking tube by means of strings centrally located behind the start box. The apparatus was covered by hinged 3/4 in. Plexiglas throughout.

All photoelectric equipment was from Farmer Electric Co. (model PE-4) and were set for dark operation. They activated

Standard Electric timers (.01 sec.) with manual resets.

The experimental room was illuminated from a single 4 ft. long 40 w. flourescent ceiling fixture approximately 4 ft. over the stem of the maze. The fixture was covered with opaque paper to dim the illumination. A 10 in. fan in the wall over the door at the right rear side of the experimental room ran continuously to provide a masking noise.

Procedure

After Ss were received they were given three days of ad lib food and water. Two and a half weeks before the start of the experiment Ss were gradually introduced to an 18½ hr. water deprivation schedule by initially keeping Ss on a 10 hr. deprivation schedule for three days and then shifting to the full deprivation schedule. The Ss were handled 2 min. each day and watered for 1½ hrs., ½ hr. after the last S had been handled. One week before the start of the experiment the Ss were split into two running "shifts" of 37 Ss and each was maintained on separate 19½ hr. deprivation schedules. At this time each S in both shifts was randomly assigned to one of nine groups. Groups I-V had 10 Ss each, while Groups VI-IX had 6 Ss each. One S in Group VII died leaving 5 Ss in that group.

Groups I-IX were given the reinforcement conditions indicated in Table I. All Ss received a 75-25 probability schedule with the high probability side (A_1 side) being right and left, respectively, for half the Ss in each group. Reinforcement schedules were randomly assigned in blocks of twelve trials with the restriction that at least one reinforcement on the A_2 side be present within both the first and

last 6 trials of a block and with each block having reinforcements in the ratio of 9:3. Each shift was run at its appropriate time each day but within each shift the Ss were run in a new random order each day. Each S was given 6 "runs" per day with a minimum ½ hr. interval between "runs". Within a day the order of running for each S was fixed.

In Table I is presented the reinforcement conditions employed. The duration of reinforcement conditions refers to the length of time S has to engage in drinking behavior. Delay of reinforcement was defined from the time S broke a photocell 2 in. before the recessed drinking area. Breaking this photocell started a Standard Electric .01 sec. timer. At the start of each run, for all Groups, the door in front of each drinking tube was initially in the closed position and was raised after the appropriate delay. For the zero delay condition this meant raising the door after S had broken the last photocell.

The non-correction rerun procedure was employed for Groups I-VIII. The Ss were reinforced for a correct turn only, i.e., if their choice corresponded with the placement of reinforcement for that response. For all "errors" Ss were confined in the goal box for 30 sec. Approximately 35 min. later S was given his next "run" with reinforcement remaining on the "correct" side. This procedure was continued until S finally made the "correct" response. A "trial" was thus defined as one or more "runs" terminated by a reinforcement. This procedure insured that precisely 75% of the reinforcements were received on the A_1 side and 25% on the A_2 side.

Table 1 -- Reinforcement Conditions for the A_1 and A_2 Sides for Groups I-IX of Experiment I.

Group	A_1 Side		A_2 Side		Group Designation
	Duration (Sec.)	Delay (Sec.)	Duration (Sec.)	Delay (Sec.)	
I	4	0	4	0	4,0-4,0
II	16	0	16	0	16,0-16,0
III	32	0	32	0	32,0-32,0
IV	16	10	16	10	16,10-16,10
V	16	25	16	25	16,25-16,25
VI	4	0	32	0	4,0-32,0
VII	16	25	16	0	16,25-16,0
VIII	32	25	4	0	32,25-4,0
IX (forced trial group)	4	0	32	0	F4,0-32,0

Group IX was run employing a combination of free and forced trials. Two trials were randomly chosen both from the first six and last six trials of each block of twelve trials with the first of these trials being a free trial in which the S was allowed access to both sides of the T-maze to ascertain preference data. Any response S made on these free trials was reinforced. The second of these trials was a "forced" trial to maintain the 9:3 reinforcement schedule. All forced trials including the remaining eight trials in each block, allowed S access to the desired alternative only and were reinforced. In addition each S in this group was yoked to an S in Group VI and received the same number of reinforcements per day and generally received the same random reinforcement schedule as its partner. Because of the free trial procedure of Group IX there were some discrepancies between the reinforcement schedules for the yoked Ss.

The choice measure used for Groups I-VIII was that of the first "run" of each trial. For all runs, three speed measures were taken. The first was the "start time" or the time from the raising of the start box door to the interruption of a photocell beam 2 in. from the start box door. "Choice time" was measured from the interruption of two photocell beams, one 1 3/4 in. before the choice point and the other 11 in. in each arm. Finally, "committed time" was measured from the interruption of the last photocell beam to the interruption of one 2 in. from the closed water tube door, a distance of 8 in.

The choice measure for Group IX was that of the "free" trials. For both the free and forced trials the three speed measures were also recorded.

Fifteen minutes prior to the beginning of each shift the racks

of cages containing the Ss individual cages were brought into the experimental room from the colony room. A typical "run" for each S was performed as follows. The S was removed from its home cage and placed in the start box, facing the start box door. Three sec. later both the start box door and the two goal box doors were raised. On the forced trials of Group IX only the designated goal box door was raised. The water tube door was raised after the appropriate delay or remained closed depending on whether S made a "correct" or "incorrect" response. S was then removed from the goal box and returned to its home cage. All choice and time data were then recorded and the apparatus reset for the next S. Depending on the conditions of the Group and whether a "run" was reinforced or not, the time to complete a "run" varied to a maximum of approximately 60 sec.

The experiment was carried out in four phases. In Phase I all Ss received two blocks (24 trials) of 50 - 50 probability training with Groups VI-IX receiving both reinforcement conditions equally on each side of the maze and with the "forcing" procedure not yet introduced for Group IX. This was done to try to get each S to an initial choice probability of .5. In Phase II all Ss were shifted to their 75-25 probability schedules and were run until it was judged that the choice data were asymptotic, a total of 10 blocks of trials (120 trials). In Phase III a reversal to a 25-75 probability schedule was instituted only for Groups I-V. This phase was to be used for parameter estimation. Groups VI-IX continued under the Phase II conditions. Phase III was continued until the choice data appeared to be asymptotic, a total of 10 blocks of trials (120 trials). Finally Phase IV was carried out only with Groups I-VI of which

Groups I-V were randomly divided into two subgroups one of which was given the same reinforcement conditions as Group VI, while the other subgroup was given a 75-25 reversal again with a shift to the reinforcement conditions of Group VI. The reinforcement conditions for Group VI remained the same as they were in Phase III.

Results

Choice Data

The side on which the larger proportion of reinforcement was presented during Phase II for each S was defined to be the A_1 side. All tests of significance on proportion of A_1 responses were calculated after applying the Freeman-Tukey (1961) transformation (or for n>50 the Fisher & Yates (1953, p. 66) arc sine transformation). The transformations are performed to obtain homogeneity of variance. The transformation was applied to the choice data for each S over the trials being analyzed.

Separate analyses of variance were performed for each "Phase" to determine whether there were any "side preferences" and whether the two "shifts" differed. For Phase I blocks 1 and 2 were used while for Phases II and III only data from the last 5 asymptotic blocks of each were used. Tables 2a - 4b show that no differences due to "side" or "shift" for Phases I-III respectively were found. Therefore in all later analyses the left and right sides were combined to provide the proportion of A_1 responses as the basic measure. The data for shifts were also combined in all later analyses.

Phase I: Table 5 shows the mean proportion of A_1s for blocks 1 and 2 by "side" for Groups I-IX. Analysis of the mean A_1 proportion over the 24 trials shows no differences among the nine Groups (Table 6). Included is the comparison between the grand mean of the Groups and the expected proportion of .5, which was not significant. Thus the Groups were the same at the start of Phase II.

Table 2a - Analysis of Variance Based on Mean A_1 Proportion as a Function of "Side" for the Two Blocks of Twelve Trials of Phase I for Groups I-IX of Experiment I

Source	SS	DF	MS	F
Left vs. Right	119.696	1	119.696	3.023
Group	136.209	8	17.026	0.430
L. vs. R. x Group	162.145	8	20.268	0.512
Error	2177.499	55	39.591	
Total	2595.549	72		

Table 2b - Analysis of Variance Based on Mean A_1 Proportion as a Function of "Shift" for the Two Blocks of Twelve Trials of Phase I for Groups I-IX of Experiment I

Source	SS	DF	MS	F
Shift	64.011	1	64.011	1.735
Group	147.942	8	18.493	0.501
Shift x Group	388.568	8	48.571	1.317
Error	2029.009	55	36.891	
Total	2629.530	72		

*$p < .05$

Table 3a - Analysis of Variance Based on Mean A_1 Proportion as a Function of "Side" for the Five Asymptotic Blocks of Twelve Trials of Phase II for Groups I-V of Experiment I

Source	SS	DF	MS	F
Left vs. Right	85.805	1	85.805	2.007
Group	1984.736	4	496.184	11.605*
L. vs. R. x Group	241.816	4	60.454	1.414
Error	1710.228	40	42.756	
Total	4022.585	49		

Table 3b - Analysis of Variance Based on Mean A_1 Proportion as a Function of "Shift" for the Five Asymptotic Blocks of Twelve Trials of Phase II for Groups I-V of Experiment I

Source	SS	DF	MS	F
Shift	98.842	1	98.842	2.216
Group	1984.736	4	496.184	11.123*
Shift x Group	155.259	4	38.815	0.870
Error	1183.748	40	44.594	
Total	3422.585	49		

*$p < .05$

Table 4a - Analysis of Variance Based on Mean A_1 Proportion as a Function of "Side" for the Five Asymptotic Blocks of Twelve Trials of Phase III for Groups I-VIII of Experiment I.

Source	SS	DF	MS	F
Left vs. Right	45.596	1	45.596	1.526
Group	3168.596	7	452.657	15.150*
L. vs. R. x Group	327.172	7	46.739	1.564
Error	1523.820	51	29.879	
Total	5065.844	66		

Table 4b - Analysis of Variance Based on Mean A_1 Proportion as a Function of "Shift" for the Five Asymptotic Blocks of Twelve Trials of Phase III for Groups I-VIII of Experiment I.

Source	SS	DF	MS	F
Shift	35.507	1	35.507	1.028
Group	2844.473	7	406.353	11.768*
Shift x Group	78.539	7	11.220	0.325
Error	1761.024	51	34.530	
Total	4719.543	66		

*$p < .05$

Table 5 - Mean Proportion of A_1 Responses for Phase I by Block and by "Side" for Groups I-IX of Experiment I

	Block 1			Block 2			Combined Blocks 1 and 2		
Group	Left	Right	Combined	Left	Right	Combined	Left	Right	Combined
I	.516	.566	.542	.550	.383	.466	.533	.475	.504
II	.567	.467	.517	.60	.574	.587	.584	.520	.552
III	.45	.50	.475	.50	.45	.475	.475	.475	.475
IV	.516	.516	.517	.483	.50	.492	.50	.508	.504
V	.533	.467	.508	.367	.383	.375	.45	.425	.438
VI	.50	.472	.486	.50	.542	.521	.150	.507	.504
VII	.528	.527	.528	.417	.522	.470	.472	.524	.498
VIII	.528	.542	.533	.471	.458	.465	.50	.50	.50
IX	.50	.444	.473	.611	.611	.611	.556	.527	.542
mean	.515	.500	.508	.500	.491	.496	.508	.496	.502

Table 6 - Analysis of Variance Based on Mean A_1 Proportion for the Two Blocks of Twelve Trials of Phase I for Groups I-IX of Experiment I

Source	SS	DF	MS	F
Grand Mean	8.665	1	8.665	0.220
Groups	165.653	8	20.702	0.527
Error	2515.216	64	39.300	
Total	2689.525	73		

*p < .05

Phase II and III

Balanced reinforcement - 0 delay: Inspection of the early portion of the learning curves for the balanced duration of reinforcement condition, Groups I-III in Figure 1, shows no differences in rate of learning among them during Phase II and Phase III. This was confirmed by the non-significant results of the analyses of variance based on total number of A_1 responses for both the first two and first four blocks of Phases II and III (Tables 7a - 8b). Therefore the plan to estimate each Group's θ-value for predictive purposes was abandoned.

It remained to answer the question of how closely Groups I-III conformed to the theoretical model for the case. Inspection of the asymptotic portions of the learning curves for Phase II (blocks 8-12) and Phase III (blocks 18-22) in Figure 1 reveals no differences among the Groups. This is confirmed by the non-significant Group effect in the analyses for each Phase (Tables 9-10). The means over the asymptotic trials for Groups I-III were .755, .715 and .690 respectively for Phase II and .302, .307 and .268 respectively for Phase III. The mean asymptotic proportion of A_1s for the combined groups respectively for Phase II and Phase III were .722 and .292. Both of these means were significantly different from the expected values of .75 and .25 respectively as the significant grand mean effect in the analyses of Tables 11 and 12 showed.

Because Groups I-III were similar over Phases II and III the Groups were combined in order to perform further tests of the model. The difference between $P(A_1|E_1)$ and $P(A_1|E_2)$ over the asymptotic trials for each Phase was employed to estimate θ (Estes & Straughn, 1954). $P(A_1|E_1) = .7296$ and $P(A_1|E_2) = .7172$ for Phase II while

Figure 1 - Mean Proportion of A_1s over Blocks of Twelve Trials for Groups I-III over Phases II and III of Experiment I

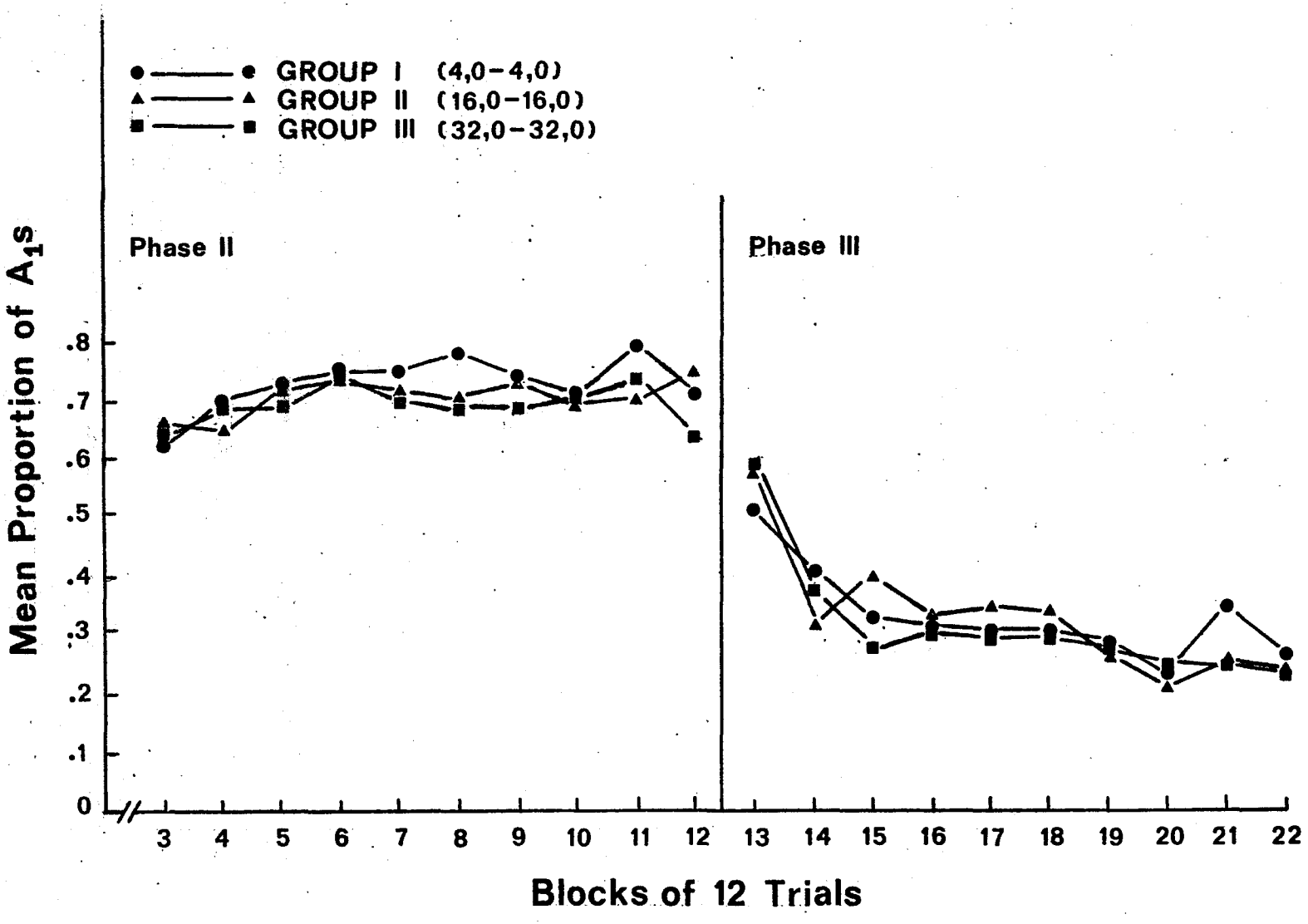

GROUP I (4,0-4,0)
GROUP II (16,0-16,0)
GROUP III (32,0-32,0)
Phase II
Phase III
Mean Proportion of A_1s
0
.1
.2
.3
.4
.5
.6
.7
.8
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Blocks of 12 Trials

Table 7a - Analysis of Variance Based on Number of A_1 Responses for Blocks 3-4 of Phase II for Groups I-III of Experiment I

Source	SS	DF	MS	F
Between	0.067	2	0.067	0.003
Within	303.300	27	11.233	
Total	303.367	29		

Table 7b - Analysis of Variance Based on Number of A_1 Responses for Blocks 3-6 of Phase II for Groups I-III of Experiment I

Source	SS	DF	MS	F
Between	1.067	2	0.533	0.103
Within	139.900	27	5.182	
Total	140.967			

*$p < .05$

Table 8a - Analysis of Variance Based on Number of A_1 Responses for Blocks 13-14 of Phase III for Groups I-III of Experiment I

Source	SS	DF	MS	F
Between	4.467	2	2.233	0.465
Within	129.700	27	4.804	
Total	134.167	29		

Table 8b - Analysis of Variance Based on Number of A_1 Responses for Blocks 13-16 of Phase III for Groups I-III of Experiment I

Source	SS	DF	MS	F
Between	2.867	2	1.433	0.146
Within	265.300	27	9.826	
Total	268.167	29		

*$p < .05$

Table 9 - Analysis of Variance Based on Mean Proportion of A_1 Responses over Asymptotic Blocks 8-12 of Phase II for Groups I-III of Experiment I

Source	SS	DF	MS	F
Grand Mean	102.342	1	102.342	8.272*
Between	77.341	2	38.670	3.126
Within	334.034	27	12.372	
Total	513.717	30		

*$p < .05$

Table 10 - Analysis of Variance Based on Mean Proportion of A_1 Responses over Asymptotic Blocks 18-22 of Phase III for Groups I-III of Experiment I

Source	SS	DF	MS	F
Grand Mean	181.548	1	181.548	11.168*
Between	25.002	2	12.501	0.769
Within	438.910	27	16.256	
Total	645.460	30		

*$p < .05$

$P(A_1|E_1) = .7296$ and $P(A_1|E_2) = .6777$ for Phase III. This gives $\theta_{orig.} = .0126$ and $\theta_{reversal} = .0519$ for the two Phases. The conditional probabilities reveal that the Ss tend to stay on the A_2 side after an E_2 during Phase III. This A_2 response is actually the old A_1 response. The theoretical learning curves for both Phase II and Phase III for each θ-value were then generated using

(36) $P_n(A_1) = \pi - (\pi - P_0)(1 - \theta)^n$,

where π equaled .75 and .25 respectively for Phases II and III, $P_0 = .508$ and .706 respectively, n equaled the trial number and $\theta = .0126$ and .0519 for the two respective Phases.

Figure 2 shows the two theoretical learning curves and the obtained learning curve for the combined Groups. It reveals that the learning curve derived from the reversal data fits the obtained curve more closely. The greatest discrepancies are found in the asymptotic portions where the obtained curve undershoots the expected asymptote for both Phases.

Further qualitative analysis of the model was accomplished by comparison of the obtained error run lengths 0-5 with the expected values (Table 11) and comparison between the obtained and expected pairs and triplets of all A_1 and A_2 response sequences (Table 12). The obtained sequential statistics were taken from the "first run" of a trial, i.e., the first response S makes following a reinforcement. The expected values for both Phase II and Phase III were derived using the obtained asymptotes and not the .75 and .25 theoretical asymptotes.

Inspection of the obtained "error runs" (Table 11) shows too few "runs" of greater than "2" and too many of length "1". The largest discrepancy is for "error runs" of length "1" to the smaller π side.

Figure 2 - Mean Proportion of A_1s over Blocks of Twelve Trials for the Combined Data of Groups I-III and the Theoretical Curves Employing θ orig. = .0126 and θ reversal = .0519 for Phases II and III of Experiment I

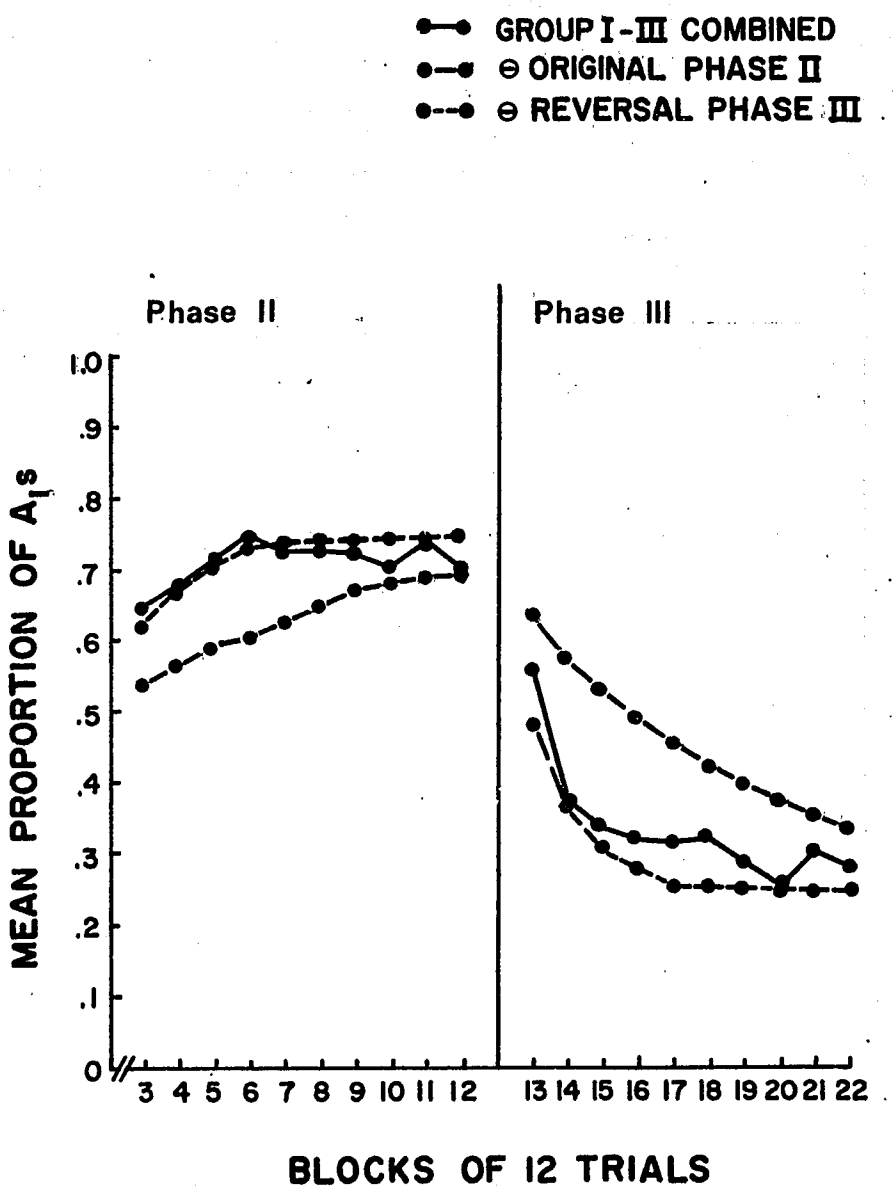

GROUP I-III COMBINED
⊖ ORIGINAL PHASE II
⊖ REVERSAL PHASE III
Phase II
Phase III
MEAN PROPORTION OF A1s
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
3 4 5 6 7 8 9 10 11 12
13 14 15 16 17 18 19 20 21 22
BLOCKS OF 12 TRIALS

Table 11 - Expected and Obtained Mean Proportion of Error Run Lengths 0 Through 5 to the A_1 and A_2 Sides over the Asymptotic Blocks of Phases II and III of Experiment I. The Expected Proportions are Derived Employing the Obtained Asymptotes of the Combined Groups I-III for Each Phase.

	Phase II				Phase III			
Error Run Length	Expected		Obtained		Expected		Obtained	
	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2
0	.5418	.0694	.5386	.0810	.0731	.5307	.0740	.5352
1	.0702	.0809	.1098	.1780	.0871	.0703	.1754	.1048
2	.0507	.0225	.0416	.0226	.0251	.0495	.0254	.0448
3	.0366	.0062	.0188	.0006	.0073	.0350	.0030	.0158
4	.0265	.0017	.0010	.0054	.0021	.0248	0	.0007
5	.0191	.0005	.0015	.0005	.0006	.0175	0	.0017

Table 12 - Sequential Statistics: Expected and Obtained Mean Proportion of Pairs and Triplets of A_1 and A_2 Responses over the Asymptotic Blocks of Phase II and III for Groups I-III of Experiment I. The Expected Proportions are Derived Employing the Obtained Asymptote of the Combined Groups I-III over Each Asymptotic Segment.

	Phase II		Phase III	
Sequence	Expected	Obtained	Expected	Obtained
A_{11}	.5219	.5016	.0855	.1111
A_{12}	.2005	.2193	.2069	.2273
A_{21}	.2005	.2248	.2069	.2223
A_{22}	.0771	.0541	.5007	.4837
A_{111}	.3770	.3429	.0250	.0089
A_{112}	.1449	.1559	.0605	.0576
A_{121}	.1449	.1792	.0605	.0766
A_{211}	.1449	.1581	.0605	.0542
A_{221}	.0557	.0439	.1464	.1504
A_{212}	.0557	.0673	.1464	.1694
A_{122}	.0557	.0434	.1464	.1459
A_{222}	.0214	.0089	.3543	.3366

for each Phase (A_2 in Phase II and A_1 in Phase III). Table 12 shows agreement within 2% between most of the obtained and expected "sequential statistics".

Figures 3 and 4 show the individual Ss learning curves for Groups I-III for Phase II and III as cumulative frequency of A_1 responses over blocks of 12 trials starting with the S with the lowest cumulative frequency. The starting point of each additional S is stepped up by 10 on the Y-axis. Note the essentially parallel learning curves which indicate that the Ss are responding similarly.

The final comparison demonstrated the agreement between the expected variance of the transformed measure over the asymptotic trials, of 13.7 (for both Phases II and III), and the obtained variance estimate for each Phase. The MS within for Phase II was 12.37 (Table 9) and for Phase III was 16.26 (Table 10).

In summarizing these theoretical analyses, the primary issue concerns the undershooting of both the .75 and .25 asymptotes. Both of the differences between the expected and obtained asymptotes though small were significant. This agrees with the findings of Weinstock et. al. (1972) who also reported undershooting of the expected asymptote. When the obtained asymptotes are used to generate other statistics there is reasonable agreement between the obtained and expected values except for the lack of error runs greater than"2"

Balanced Delay-16 sec. Duration: Inspection of Figure 5, which shows the Groups II, IV and V learning curves for Phases II and III, reveals that delay of reinforcement influenced choice performance. Analyses of the cumulative frequency of A_1 responses for the initial two and four

Figure 3 - Cumulative Frequency of A_1 Responses as a Function of Blocks of Twelve Trials over Phase II for Individual Ss in Groups I-III of Experiment I. The Starting Point for Each S is Stepped up by 10 on the Y- Axis.

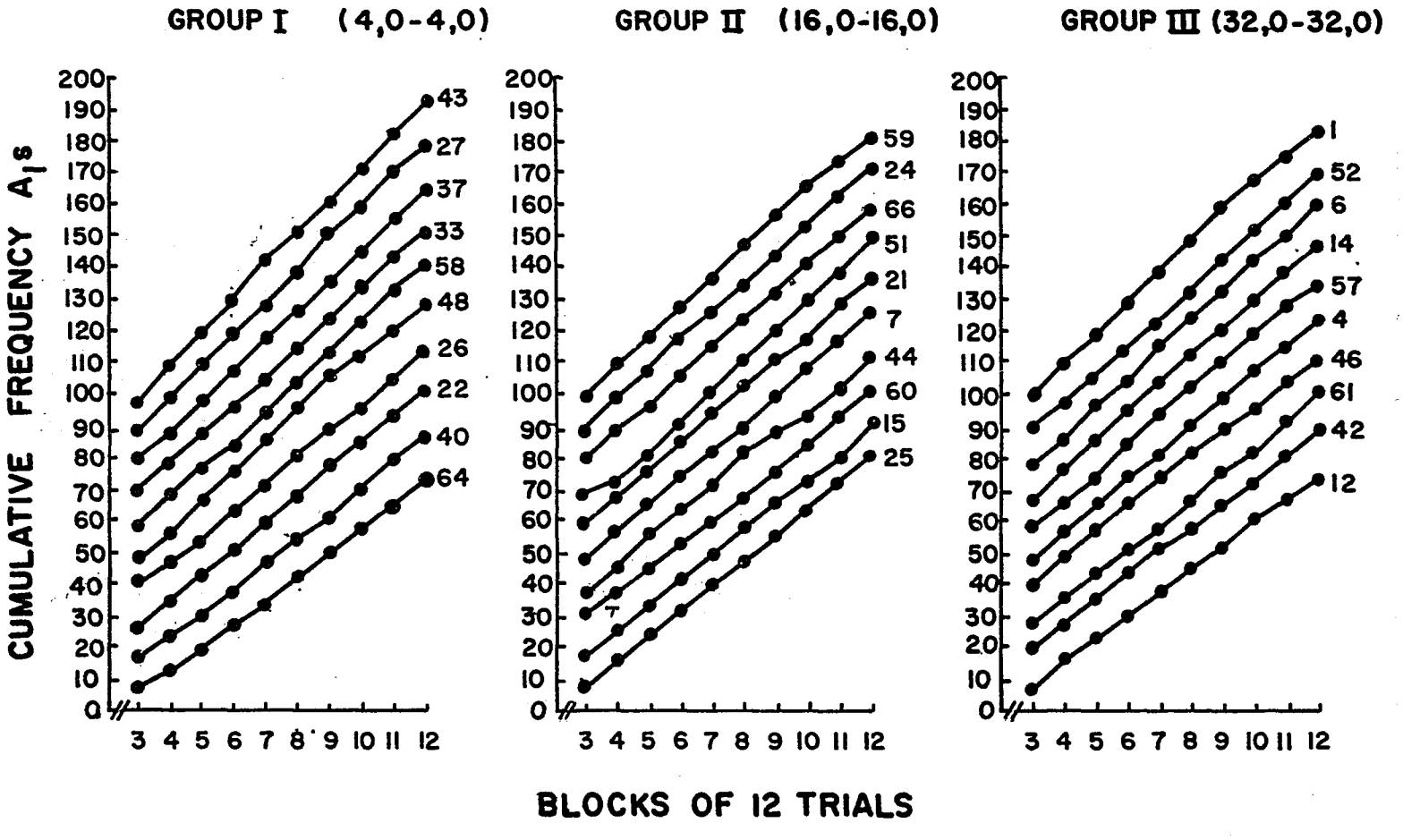

GROUP I (4,0-4,0)
GROUP II (16,0-16,0)
GROUP III (32,0-32,0)
CUMULATIVE FREQUENCY A_{1s}
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
3 4 5 6 7 8 9 10 11 12
43 27 37 33 58 48 26 22 40 64
59 24 66 51 21 7 44 60 15 25
1 52 6 14 57 4 46 61 42 12
BLOCKS OF 12 TRIALS

Figure 4 - Cumulative Frequency of A_1 Responses as a Function of Blocks of Twelve Trials over Phase III for Individual Ss in Groups I-III of Experiment I. The Starting Point for Each S is Stepped up by 10 on the Y- Axis.

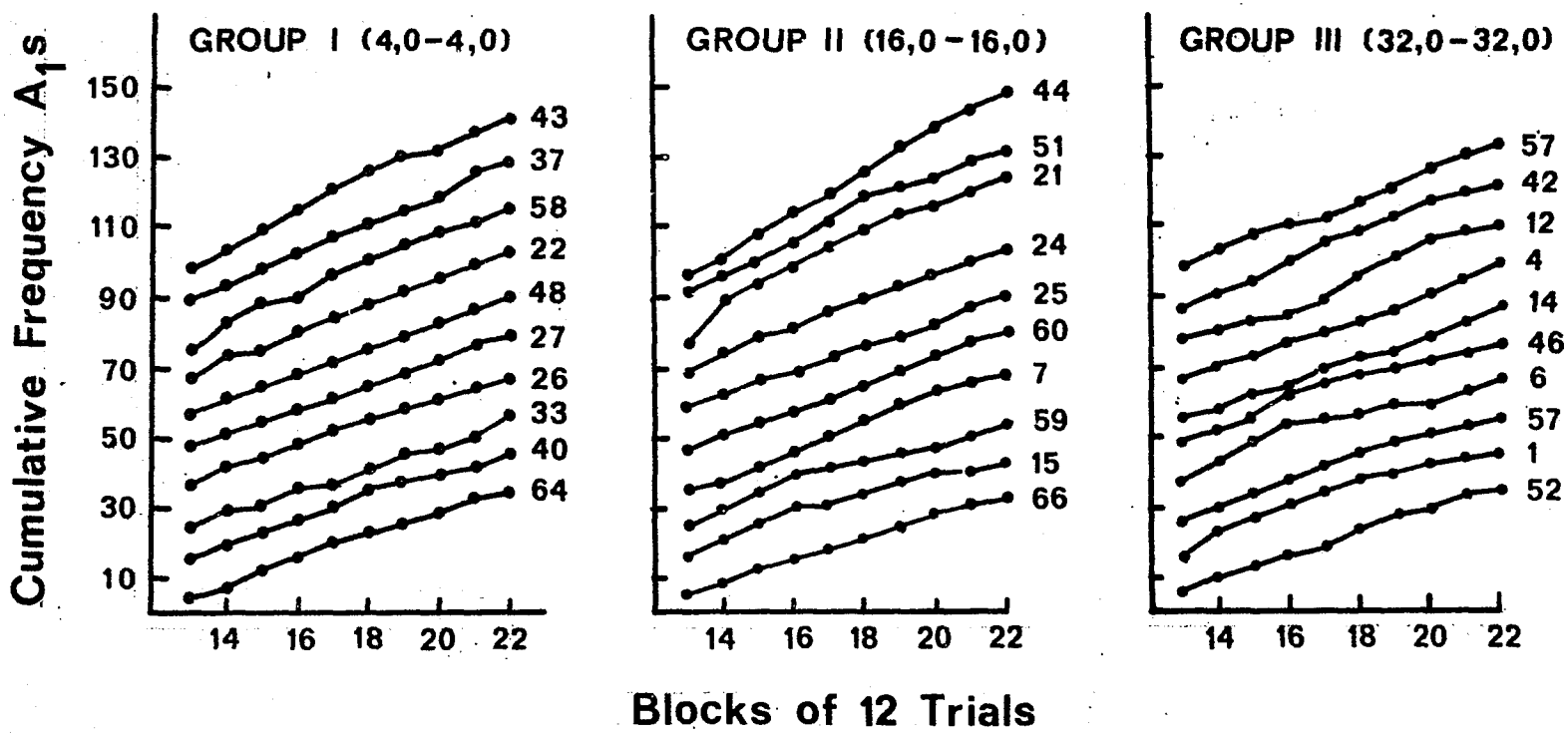
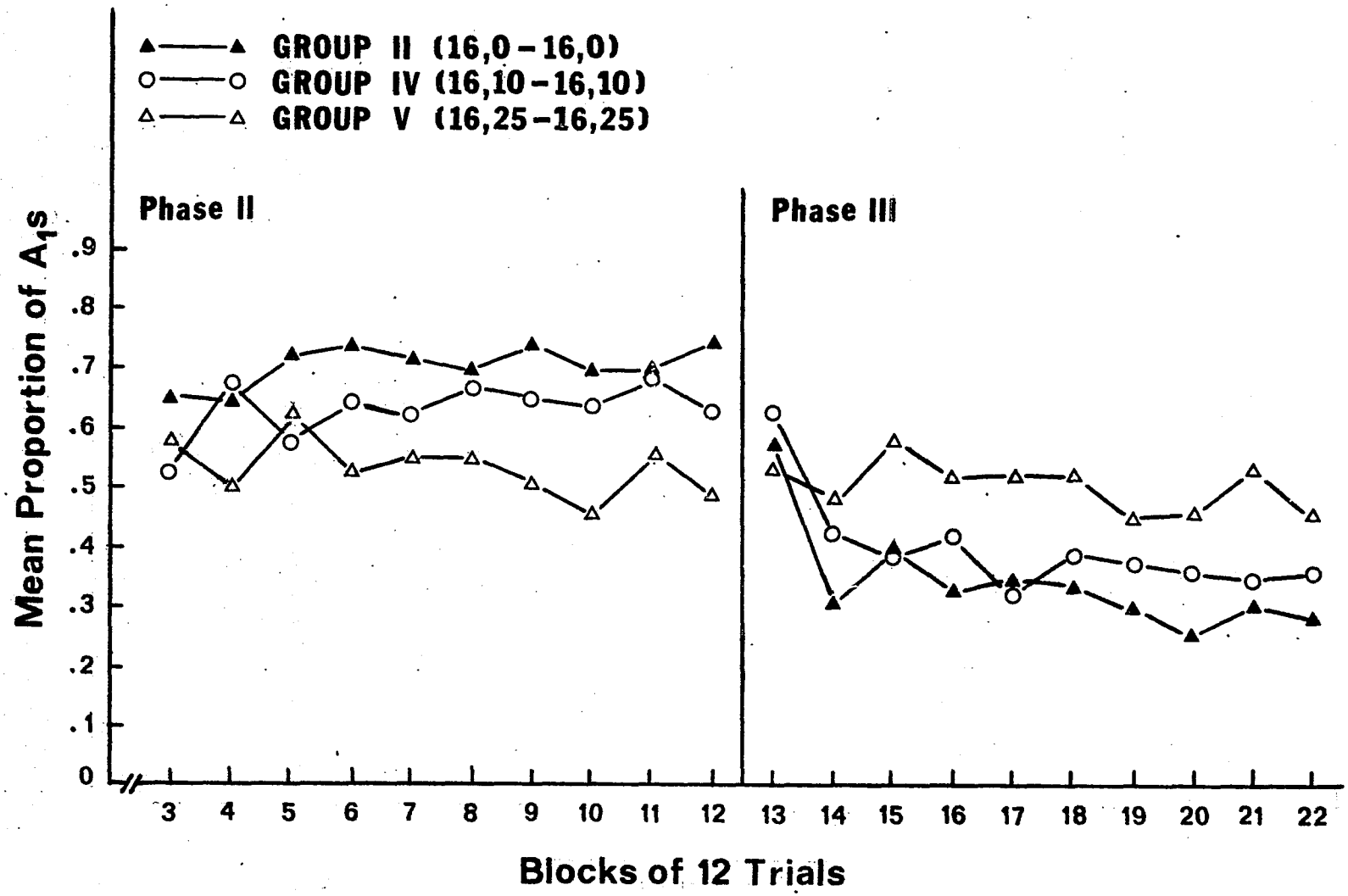

GROUP I (4,0-4,0)
GROUP II (16,0-16,0)
GROUP III (32,0-32,0)
Cumulative Frequency A_1s
150
130
110
90
70
50
30
10
43
37
58
22
48
27
26
33
40
64
44
51
21
24
25
60
7
59
15
66
57
42
12
4
14
46
6
57
1
52
14
16
18
20
22
Blocks of 12 Trials

Figure 5 - Mean Proportion of A_1s over Blocks of Twelve Trials for Groups II, IV and V over Phases II and III of Experiment I.


GROUP II (16,0-16,0)
GROUP IV (16,10-16,10)
GROUP V (16,25-16,25)
Phase II
Phase III
Mean Proportion of A_1s
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Blocks of 12 Trials

blocks of the learning curve for each Phase (Tables 13-14) reveals that the "rate" effect for Groups is not significant over the first two blocks of either Phase, but is significant over the first four blocks of each Phase. During Phases II and III only the difference between Groups II and V is significant ($p < .05$). The individual Group compairsons employed the Tukey (b) multiple comparison procedure (Winer, 1971, p. 198).

It is difficult to assess the rate parameter over the delay conditions as GroupsV responds around .5 throughout both Phases. A correlated t-test between the Phase II and Phase III asymptotes for Group V reveal no difference between them ($t = 0.896$, $p \neq .05$, $df = 9$). In addition, separate correlated t-tests between the transformation .5 value and the obtained asymptotes for Phases II and III for Group V are not significant, $t = 0.891$ and $t = 0.136$, ($p > .05$, $df = 9$) for Phases II and III respectively.

Because of the similarity of the Group II and IV rates during the first two and first four blocks of Phases II and III plus the finding that Group V did not differ from its initial .5 rate, the plan to estimate these Group's $\underline{\theta}$-values was also abandoned.

Inspection of the asymptotic portion of the learning curves for Groups II, IV and V for Phases II and III, reveals differences in response levels. This is confirmed by the significant Group effect found in the analyses of Tables 15 and 16. Comparison of the differences between all pairs of means employing the Tukey (b) procedure, revealed that for both Phases II and III the difference between Groups II and IV were not significant ($p > .05$), while for both Phases II and

Table 13a - Analysis of Variance Based on Number of A_1 Responses for Blocks 3-4 of Phase II for Groups II, IV and V of Experiment I.

Source	SS	DF	MS	F
Between	42.867	2	21.433	2.915
Within	198.500	27	7.352	
Total	241.367	29		

Table 13b - Analysis of Variance Based on Number of A_1 Responses for Blocks 3-6 of Phase II for Groups II, IV and V of Experiment I.

Source	SS	DF	MS	F
Between	225.867	2	112.933	6.488*
Within	470.000	27	17.407	
Total	685.867	29		

*$p < .05$

Table 14a - Analysis of Variance Based on Number of A_1 Responses for Blocks 13-14 of Phase III for Groups II, IV and V of Experiment I.

Source	SS	DF	MS	F
Between	20.867	2	10.433	1.304
Within	216.100	27	8.004	
Total	236.967	29		

Table 14b - Analysis of Variance Based on Number of A_1 Responses for Blocks 13-16 of Phase III for Groups II, IV and V of Experiment I.

Source	SS	DF	MS	F
Between	211.667	2	105.833	5.295*
Within	539.700	27	19.989	
Total	751.367	29		

*$p < .05$

Table 15 - Analysis of Variance Based on Mean Proportion of A_1 Responses over Asymptotic Blocks 8-12 of Phase II for Groups II, IV and V of Experiment I.

Source	SS	DF	MS	F
Between	1139.353	2	569.676	8.875*
Within	1733.049	27	64.187	
Total	2872.402	29		

*P < .05

Table 16 - Analysis of Variance Based on Mean Proportion of A_1 Responses Over Asymptotic Blocks 18-22 of Phase III for Groups II, IV and V of Experiment I.

Source	SS	DF	MS	F
Between	778.931	2	389.465	10.454*
Within	1005.848	27	37.254	
Total	1784.779	29		

*$p < .05$

III Group V was different from both Groups II and IV. The means for Groups II, IV and V were .715, .663 and .520 respectively for Phase II and .307, .370 and .489 respectively for Phase III.

Figure 6 shows the learning curves for individual Ss over Phases II and III for Groups IV and V. They reveal essentially parallel curves which again indicates that the Ss were performing similarly. No tests of the previously discussed models were performed with these Groups as "n" was small and the Groups could not be combined.

Contrasted Reinforcement Conditions: Figure 7 shows the learning curves for Groups VI to IX over Phase II. The Group learning curves clearly demonstrate the effect of the contrasted reinforcement conditions. The mean asymptotic (blocks 18-22) A_1 response levels were .437, .115, .408 and .000 for Groups VI and IX, respectively. The individual learning curves for each S can be found in Figure 8 and they again demonstrate that Ss within a Group perform similarly except for S number 72 in Group VI.

It is difficult to assess the contrasted reinforcement effects as the study was not a parametric one and was not designed with these analyses in mind. For this reason no tests of significance were employed. The results will be discussed qualitatively using Figure 6 as the basis for comparisons.

The asymptotic portions of the learning curves for Groups VI-VIII indicate that the Ss are able to reach stable intermediate levels of responding based on the effects of the contrasted reinforcement conditions. Only Group IX, which received the same reinforcement conditions as Group VI but under the forced trial procedure, stabilized at 0% A_1 responding.

Figure 6 - Cummulative Frequency of A_1 Responses as a Function of Blocks of Twelve Trials over Phase II and III for Individual Ss in Groups IV and V of Experiment I. The Starting Point for Each S is Stepped up by 10 on the Y- Axis.

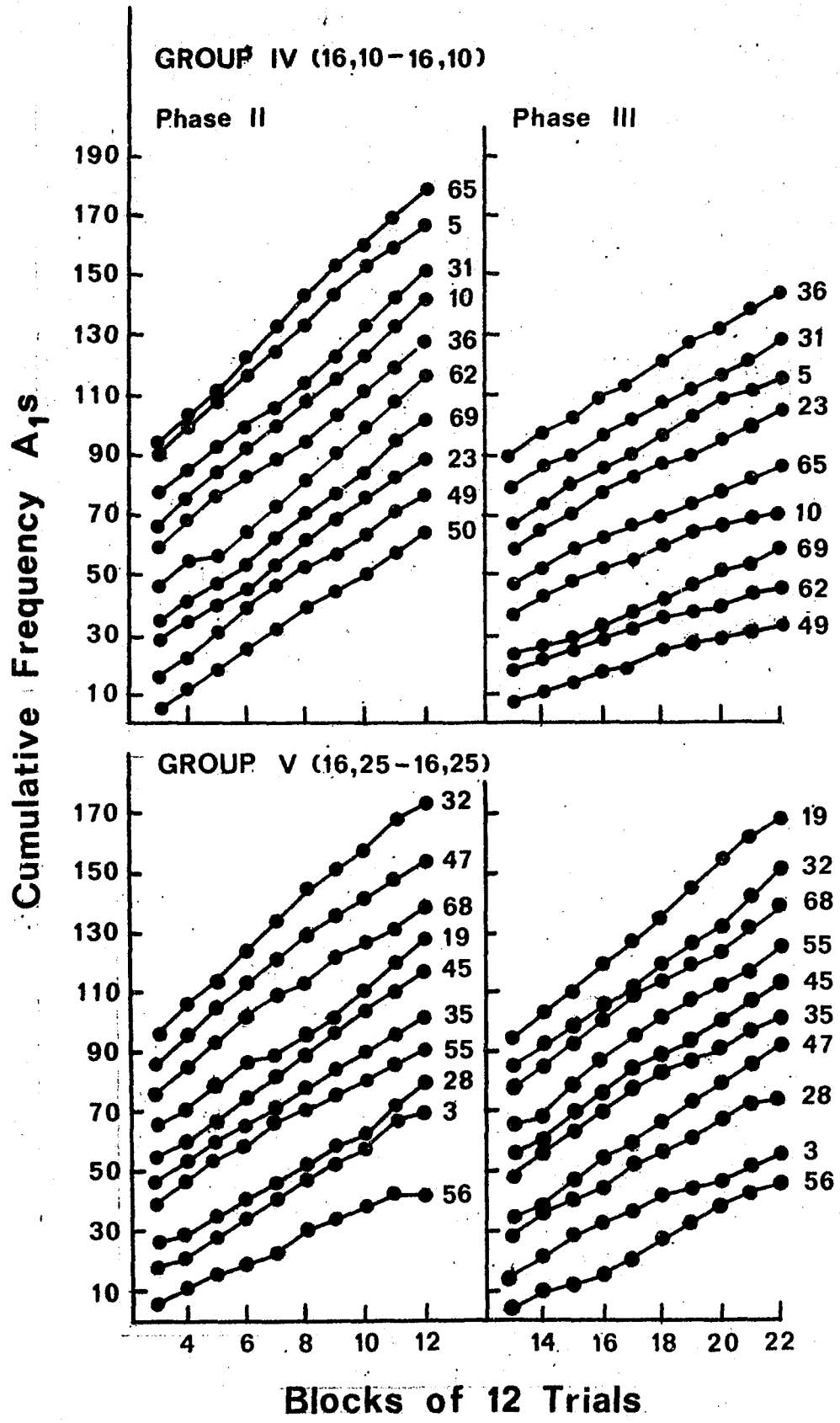

GROUP IV (16,10-16,10)
Phase II
Phase III
GROUP V (16,25-16,25)
Cumulative Frequency A_1s
190
170
150
130
110
90
70
50
30
10
65
5
31
10
36
62
69
23
49
50
36
31
5
23
65
10
69
62
49
32
47
68
19
45
35
55
28
3
56
19
32
68
55
45
35
47
28
3
56
4
6
8
10
12
14
16
18
20
22
Blocks of 12 Trials

Figure 7 - Mean Proportion of A_1s Over Blocks of Twelve Trials for Groups VI, VII and Viii over Phases II and III of Experiment I. Group IX is Shown in Blocks of Two Trials.

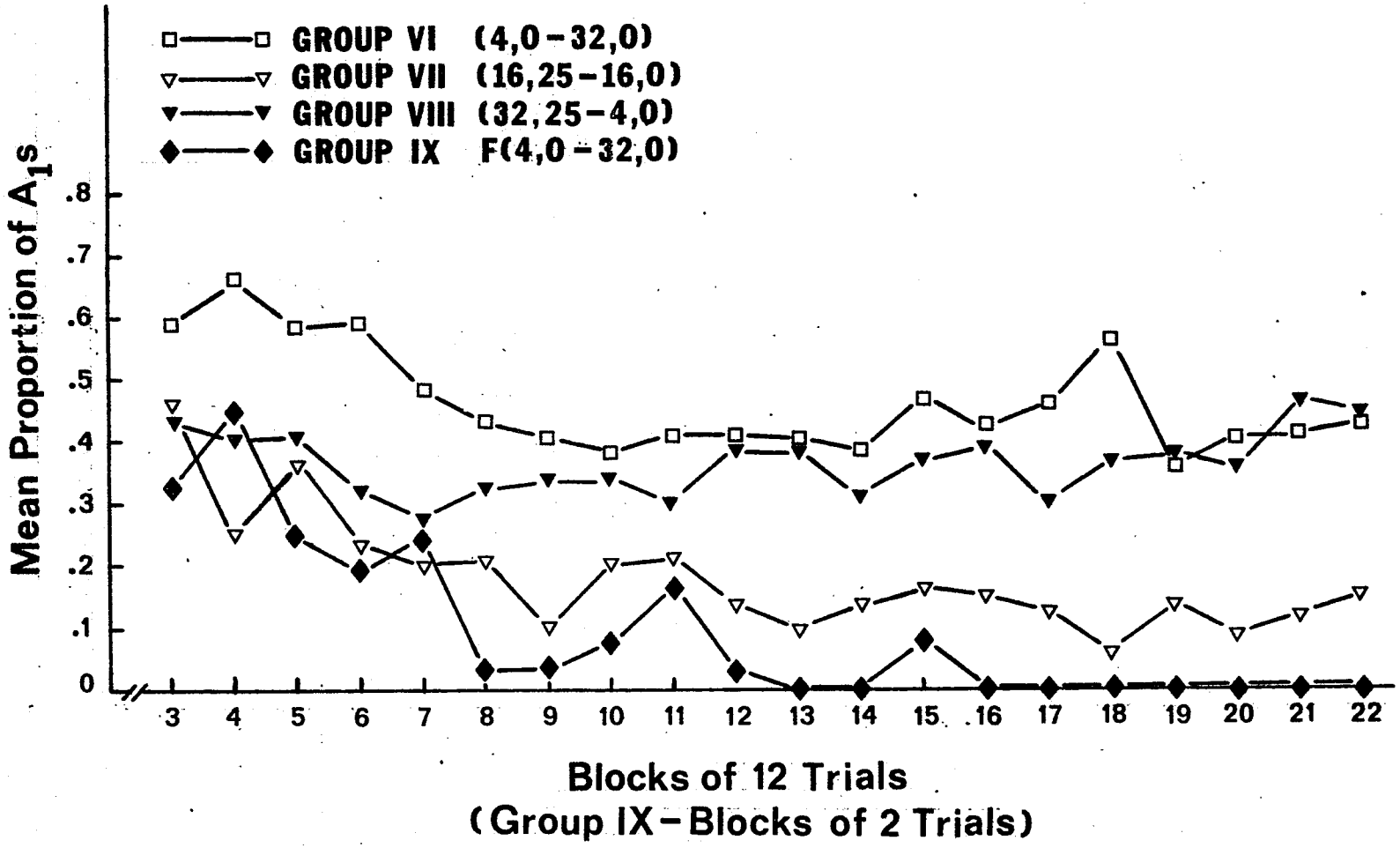
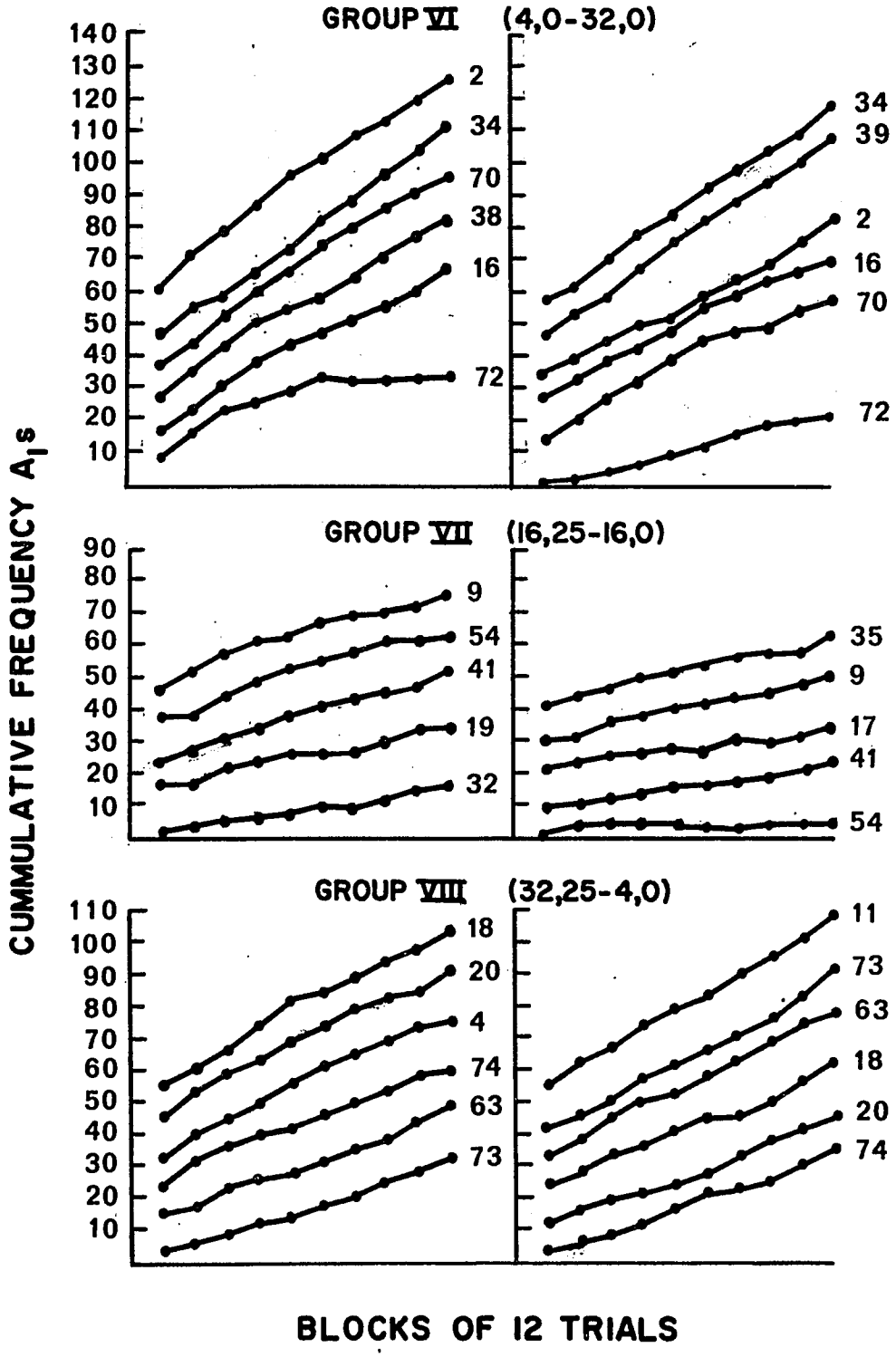

GROUP VI (4,0-32,0)
GROUP VII (16,25-16,0)
GROUP VIII (32,25-4,0)
GROUP IX F(4,0-32,0)
Mean Proportion of A_1s
.8
.7
.6
.5
.4
.3
.2
.1
0
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Blocks of 12 Trials
(Group IX-Blocks of 2 Trials)

Figure 8 - Cumulative Frequency of A_1 Responses as a Function of Blocks of Twelve Trials over Phase II for Individual Ss in Groups VI, VII and VIII of Experiment I. The Starting Point of Each S was Stepped up by 10 on the Y- Axis.


GROUP VI (4,0-32,0)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
2
34
70
38
16
72
34
39
2
16
70
72
GROUP VII (16,25-16,0)
90
80
70
60
50
40
30
20
10
9
54
41
19
32
35
9
17
41
54
GROUP VIII (32,25-4,0)
110
100
90
80
70
60
50
40
30
20
10
18
20
4
74
63
73
11
73
63
18
20
74
CUMMULATIVE FREQUENCY A,s
BLOCKS OF 12 TRIALS

Group VI is the only Group which did not proceed directly toward their final asymptote. It differed from Groups VII and VIII in that its reinforcement conditions were at zero delay for both alternatives while for Groups VII and VIII there was delay of reinforcement for one alternative. Group VI showed an initial rise toward the .75 asymptote before starting their descent towards their asymptotic .42% A_1s. This initial rise suggested a two phase learning process. In the two-phase reinforcement process the first apparently involves the presence or absence of reinforcement, rather than its duration while the second phase appears also to reflect the effect of reinforcement duration.

Therefore, it was decided to run a fourth experimental phase (Phase IV) in which Groups I-V would be split in half. For half of each Group the reinforcement value alone would be changed to those of Group VI. For the remaining half of each Group, the reinforcement values would be changed to those of Group VI and simultaneously, the Ss would receive another 75- 25 probability reversal. During this phase, Group VI would continue to receive its same reinforcement conditions.

It has been hypothesized that those Ss which received only the reinforcement magnitude change would show a steady adjustment to the Group VI asymptotic level. Those Ss that received both the reversal and reinforcement magnitude change would show an initial jump toward the new .75 probability side and then, as the effect of the difference in reinforcement duration was felt, would adjust toward the Group VI asymptotic level. The two Groups which should demonstrate this effect

most vividly should be the delay of reinforcement Groups IV and V. The introduction of immediate reinforcement for these two Groups should have the primary effect and then the effect of reinforcement magnitude should be felt.

Figure 9 shows the mean proportion of A_1 responses over blocks 23-27 for the combined Groups I-III, the combined Groups IV and V, and Group VI individually. Block 22, the last block prior to the shift in included. Inspection of this Figure 9 shows Ss in the change of reinforcement condition proceeding directly toward the Group VI asymptotic value. Ss who had received both the probability reversal and the reinforcement duration change responded toward the .75 side and then declined toward the Group VI asymptotic value. Group VI remained at a steady level throughout. This effect is more clearly demonstrated in Figure 10 which shows each Group separately.

Time Data

Latency, "choice time" and "committed time" were converted to reciprocals, 1/sec., 10/sec., and 1/sec. respectively throughout. The two aspects of the time measures of interest for statistical purposes were Phase I (24 trials) and Blocks 17-22 (72 trials). Blocks 17-22 were taken as the asymptotic portion of the learning curve for Groups I-IX.

Separate analyses of variance were performed for the two segments to determine whether there were any "side preferences" and whether the two "shifts" differed for the latency, choice and committed time measures. Tables 17a-22b show that no differences due to "side" were found. There was an effect due to "shift" for committed time over Phase I and for choice time over Blocks 17-22.

Figure 9 - Mean Proportion of A_1 Responses as a Function of Blocks of Twelve Trials for Groups I-III, IV-V, and VI over Phase IV of Experiment I.

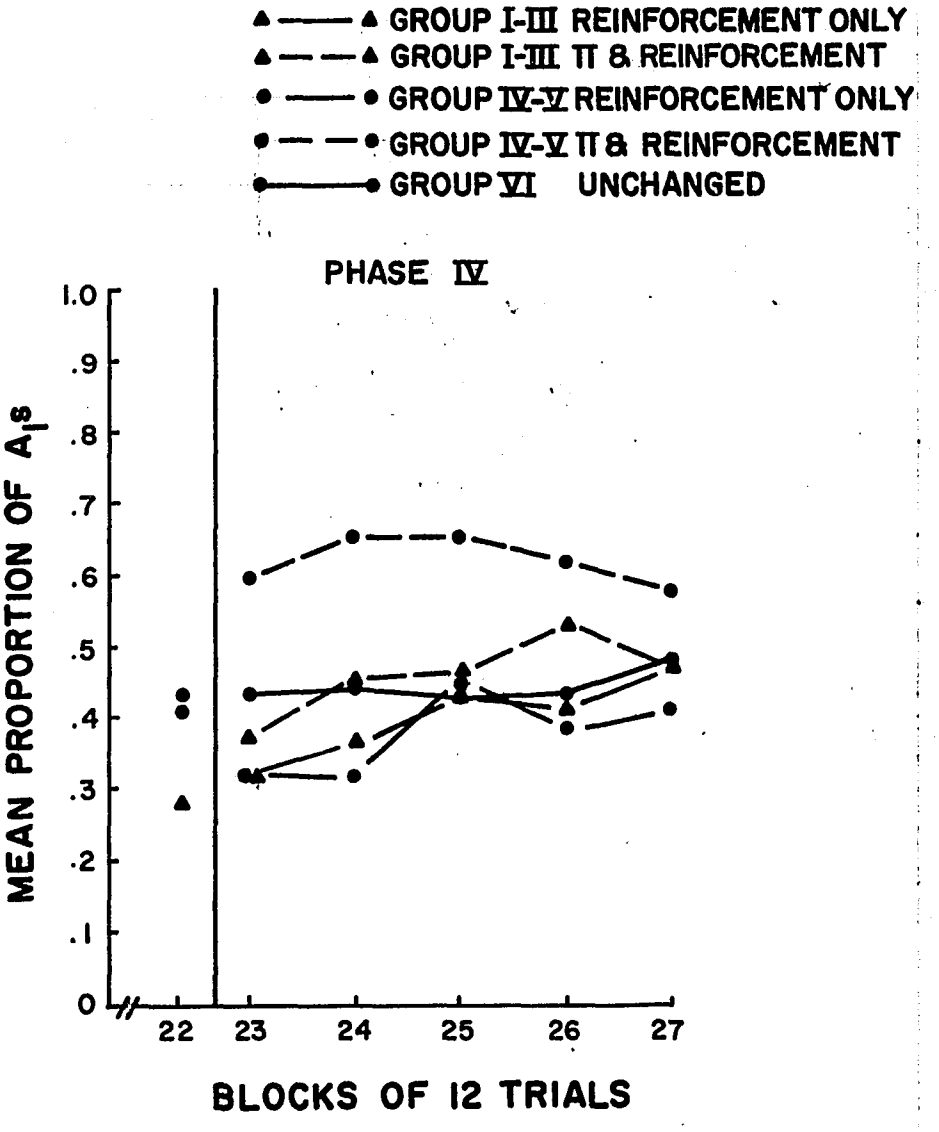

▲——▲ GROUP I-III REINFORCEMENT ONLY
▲— —▲ GROUP I-III II & REINFORCEMENT
●——● GROUP IV-V REINFORCEMENT ONLY
●— —● GROUP IV-V II & REINFORCEMENT
●——● GROUP VI UNCHANGED
PHASE IV
MEAN PROPORTION OF A_1s
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
22
23
24
25
26
27
BLOCKS OF 12 TRIALS

Figure 10 - Mean Proportion of A_1s as a Function of Blocks of Twelve Trials for Groups I-VI over Phase IV of Experiment I.

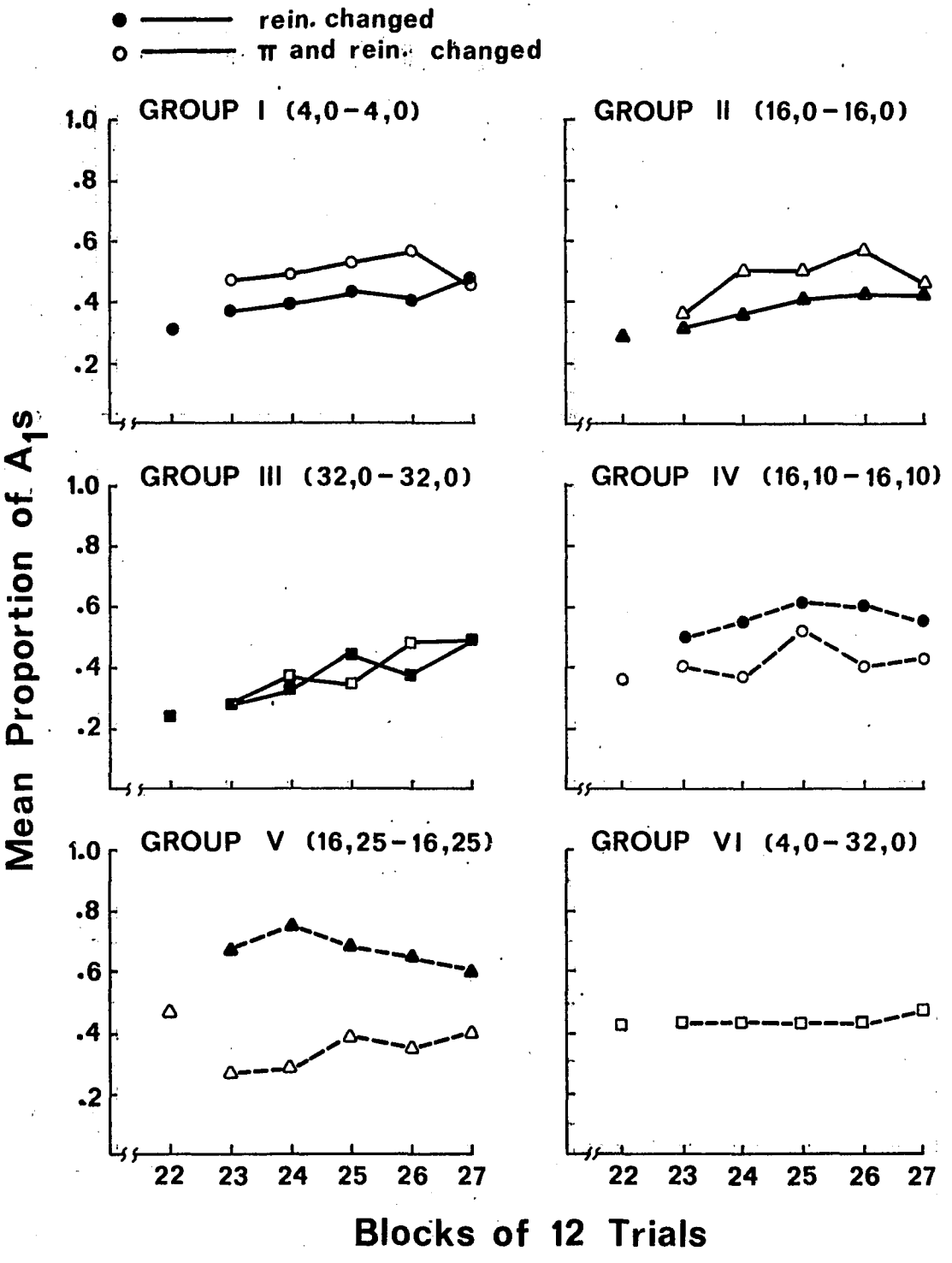

● —— rein. changed
o —— π and rein. changed
GROUP I (4,0-4,0)
GROUP II (16,0-16,0)
GROUP III (32,0-32,0)
GROUP IV (16,10-16,10)
GROUP V (16,25-16,25)
GROUP VI (4,0-32,0)
Mean Proportion of A1s
1.0
.8
.6
.4
.2
22
23
24
25
26
27
Blocks of 12 Trials

Table 17a - Analysis of Variance Based on Mean Reciprocal Latency ($\bar{1}$/sec.) as a Function of A_1 Side over Phase I for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Left vs. Right	0.205	1	0.205	0.266
Group	9.899	8	1.237	1.605
L. vs. R. x Group	8.9386	8	1.117	1.449
Error	42.4114	55	0.7711	

Table 17b - Analysis of Variance Based on Mean Reciprocal Latency ($\bar{1}$/sec.) as a Function of Shift over Phase I for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Shift	0.281	1	0.281	0.328
Group	9.754	8	1.219	1.425
Shift x Group	3.631	8	0.454	0.530
Error	47.047	55	0.855	

*$p < .05$

Table 18a - Analysis of Variance Based on Mean Reciprocal Choice Time ($\overline{10}$/sec.) as a Function of A_1 Side Over Phase I for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Left vs. Right	3.809	1	3.809	1.394
Group	52.682	8	6.585	2.409*
L. vs. R. x Group	13.142	8	1.643	0.601
Error	150.336	55	2.733	

Table 18b - Analysis of Variance Based on Mean Reciprocal Choice Time ($\overline{10}$/sec.) as a Function of Shift over Phase I for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Shift	2.479	1	2.479	1.093
Group	52.587	8	6.573	2.898*
Shift x Group	19.411	8	2.426	1.070
Error	124.725	55	2.268	

*$p < .05$

Table 19a - Analysis of Variance Based On Mean Reciprocal Committed Time ($\bar{1}$/sec.) as a Function of A_1 Side over Phase I for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Left vs. Right	0.564	1	0.564	3.291
Group	6.853	8	0.857	4.998*
L. vs. R. x Group	1.190	8	0.149	0.868
Error	9.427	55	0.171	

Table 19b - Analysis of Variance Based on Mean Reciprocal Committed Time ($\bar{1}$/sec.) as a Function of Shift over Phase I for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Shift	0.942	1	0.942	5.296*
Group	7.018	8	0.877	4.933*
Shift x Group	2.062	8	0.258	1.50
Error	9.780	55	0.178	

*$p < .05$

Table 20a - Analysis of Variance Based on Mean Reciprocal Latency ($\bar{1}$/sec.) as a Function of A_1 Side over Blocks 17-22 for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Left vs. Right	0.794	1	0.794	1.620
Group	17.216	8	2.152	4.392*
L. vs. R. x Group	7.239	8	0.905	1.847
Error	26.949	55	0.490	

Table 20b - Analysis of Variance Based on Mean Reciprocal Latency ($\bar{1}$/sec.) as a Function of Shift over Blocks 17-22 for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Shift	0.065	1	0.065	0.115
Group	17.608	8	2.201	3.876*
Shift x Group	2.950	8	0.369	0.649
Error	31.230	55	0.568	

*$p < .05$

Table 21a - Analysis of Variance Based on Mean Reciprocal Choice Time ($\overline{10}$/sec.) as a Function of A_1 Side over Blocks 17-22 for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Left vs. Right	8.869	1	1.869	1.164
Group	392.375	8	49.047	6.440*
L. vs. R. x Group	74.524	8	9.315	1.223
Error	418.885	55	7.616	

Table 21b - Analysis of Variance Based on Mean Reciprocal Choice Time ($\overline{10}$/sec.) as a Function of Shift over Blocks 17-22 for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Shift	58.857	1	58.857	8.572*
Group	383.848	8	47.981	6.988*
Shift x Group	80.168	8	10.021	1.460
Error	377.626	55	6.866	

*$p < .05$

Table 22a - Analysis of Variance Based on Mean Reciprocal Committed Time ($\overline{1}$/sec.) as a Function of A_1 Side over Blocks 17-22 for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Left vs. Right	0.39	1	0.390	0.120
Group	21.380	8	2.672	8.284*
L. vs. R. x Group	1.537	8	0.192	0.595
Error	17.744	55	0.323	

Table 22b - Analysis of Variance Based on Mean Reciprocal Committed Time ($\overline{1}$/sec.) as a Function of Shift over Blocks 17-22 for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Shift	0.890	1	0.890	2.762
Group	21.193	8	2.650	9.266*
Shift x Group	1.322	8	0.165	0.578
Error	15.724	55	0.286	

*$p < .05$

Since all the Groups were equally represented over the two significant shifts these effects were ignored. Therefore in all later analyses both the left and right sides and shifts 1 and 2 were combined. For Group IX all time measures were obtained from the 10 forced trials of each block as there were too few free trials upon which to get stable time measures.

Latency

Figures 11a and b show the overall latency measures for Groups I-IX over Blocks 1-22 while Figure 12 presents the latency measure separately for A_1 and A_2 responses for each Group. Inspection of Figures 11a and b shows the delay Groups IV, V and VIII, to be slightly below the other Groups during both the initial and asymptotic blocks. The analyses found in Tables 23-24 showed that only the asymptotic difference between the Groups was significant. Comparison of all pairs of means by the F-ratio procedure (Winer, 1971, P. 602) revealed only the differences between Groups IV and V to be significantly different from Groups I, II, III, VI, VII and IX ($p < .05$). Group VIII is not different from any Group ($p > .05$). For both the initial and asymptotic blocks there is no difference in latency for the A_1 or A_2 responses (Tables 23-24).

Choice Time

Figures 13 a and b present the mean reciprocal choice time for Groups I-IX while Figure 14 shows the choice time as a function of A_1 and A_2 responses for each Group. The delay Groups IV, V and VIII were again slower than the other Groups. For the choice measure there was a significant Group difference over both the initial and asymptotic blocks as the analyses in Tables 25-26 showed. The Phase I individual

Figure 11a- Mean Reciprocal Latency ($\overline{1}$/sec.) as a Function of Blocks of Twelve Trials over Phases I-III for Groups I-V of Experiment I.

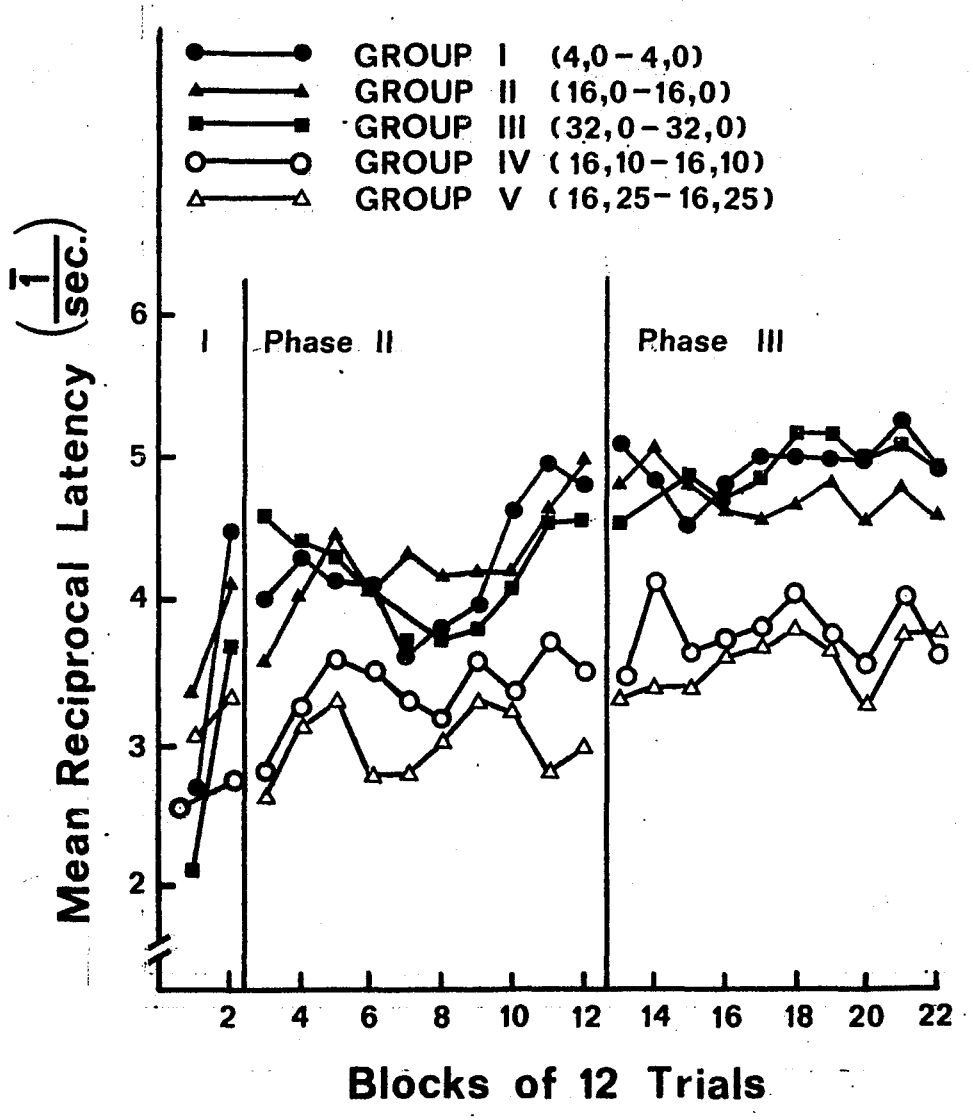

GROUP I (4,0-4,0)
GROUP II (16,0-16,0)
GROUP III (32,0-32,0)
GROUP IV (16,10-16,10)
GROUP V (16,25-16,25)
Mean Reciprocal Latency (1/sec.)
Phase I
Phase II
Phase III
6
5
4
3
2
2
4
6
8
10
12
14
16
18
20
22
Blocks of 12 Trials

Figure 11b - Mean Reciprocal Latency ($\bar{1}$/sec.) as a Function of Blocks of Twelve Trials over Phases I-II for Groups VI-IX of Experiment I.

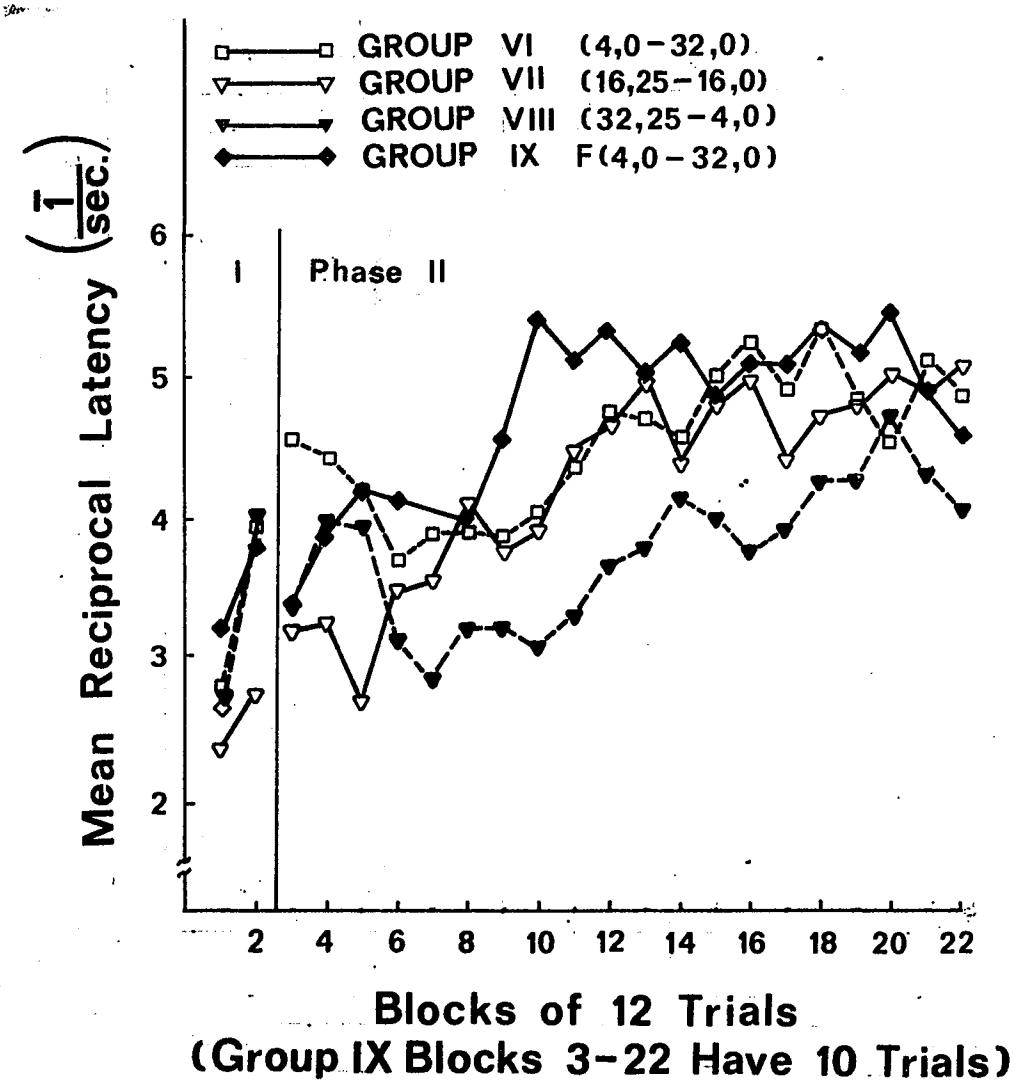
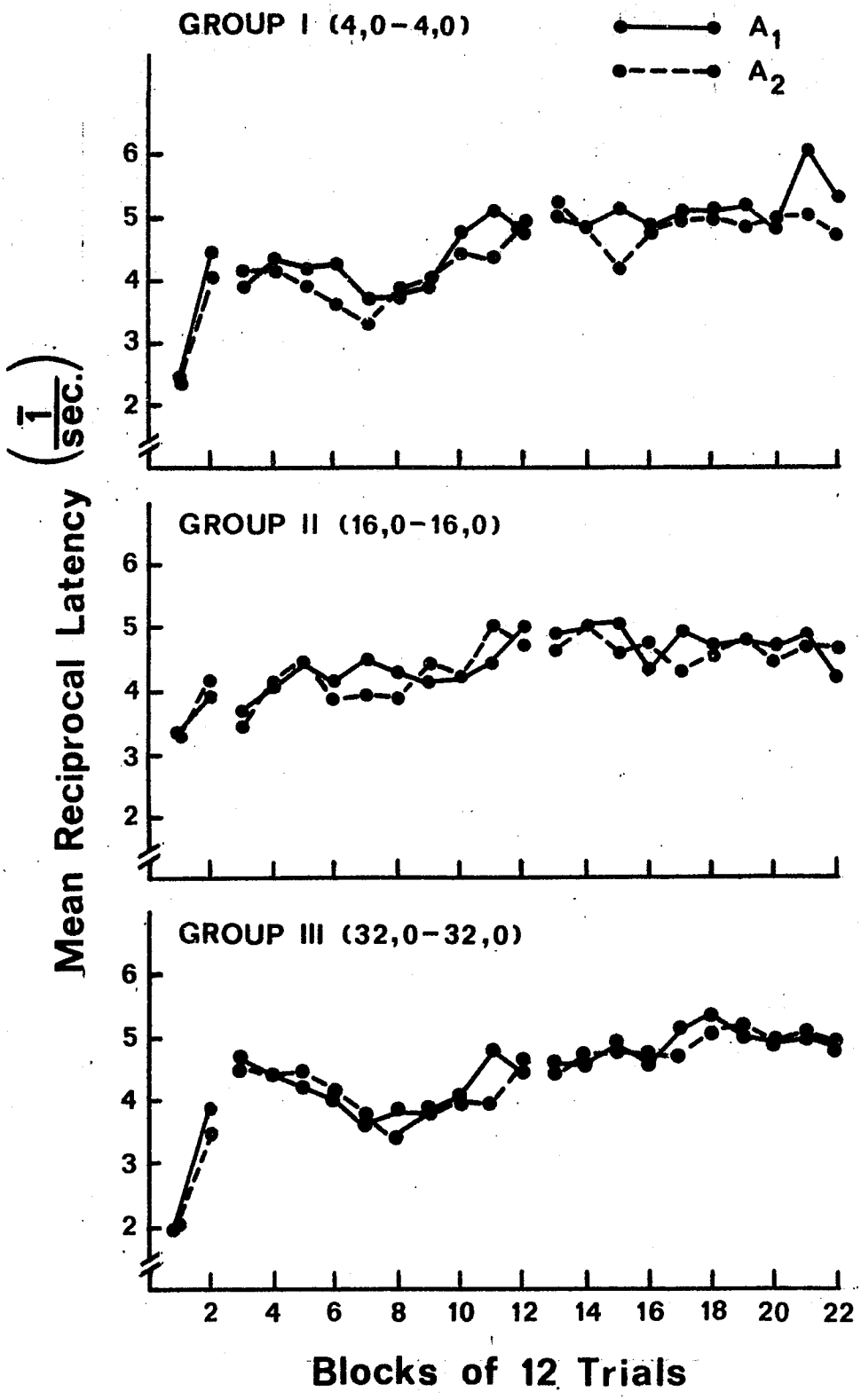
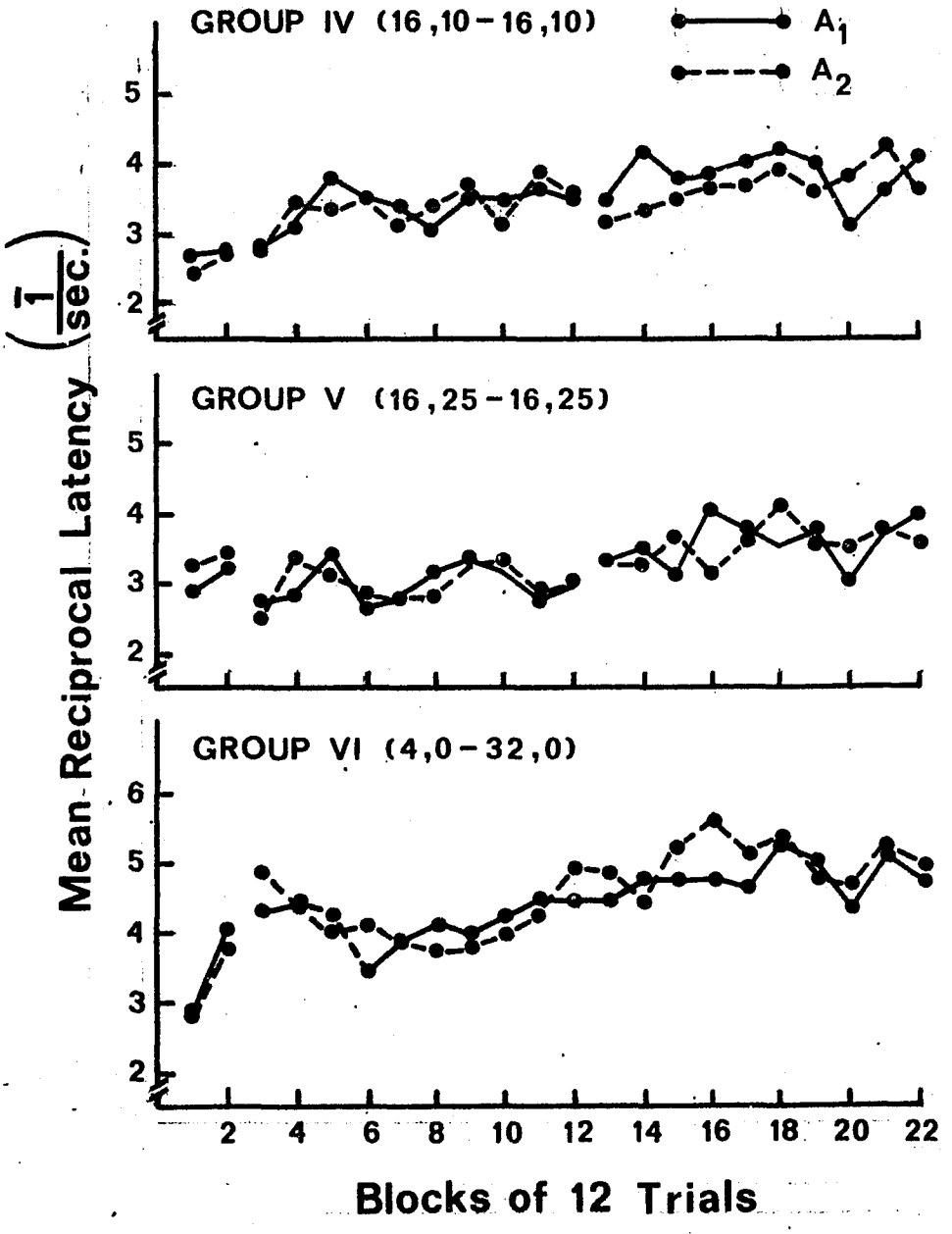

GROUP VI (4,0-32,0)
GROUP VII (16,25-16,0)
GROUP VIII (32,25-4,0)
GROUP IX F(4,0-32,0)
Phase I
Phase II
Mean Reciprocal Latency (1/sec.)
6
5
4
3
2
2 4 6 8 10 12 14 16 18 20 22
Blocks of 12 Trials
(Group IX Blocks 3-22 Have 10 Trials)

Figure 12 - Mean Reciprocal Latency ($\overline{1}$/sec.) According to A_1 and A_2 Responses as a Function of Blocks of Twelve Total Trials over Phases I-III for Groups I-IX of Experiment I.


GROUP I (4,0-4,0)
A1
A2
GROUP II (16,0-16,0)
GROUP III (32,0-32,0)
Mean Reciprocal Latency (1/sec.)
2
3
4
5
6
2 4 6 8 10 12 14 16 18 20 22
Blocks of 12 Trials


GROUP IV (16,10-16,10)
A1
A2
GROUP V (16,25-16,25)
GROUP VI (4,0-32,0)
Mean Reciprocal Latency (1/sec.)
Blocks of 12 Trials
2
4
6
8
10
12
14
16
18
20
22

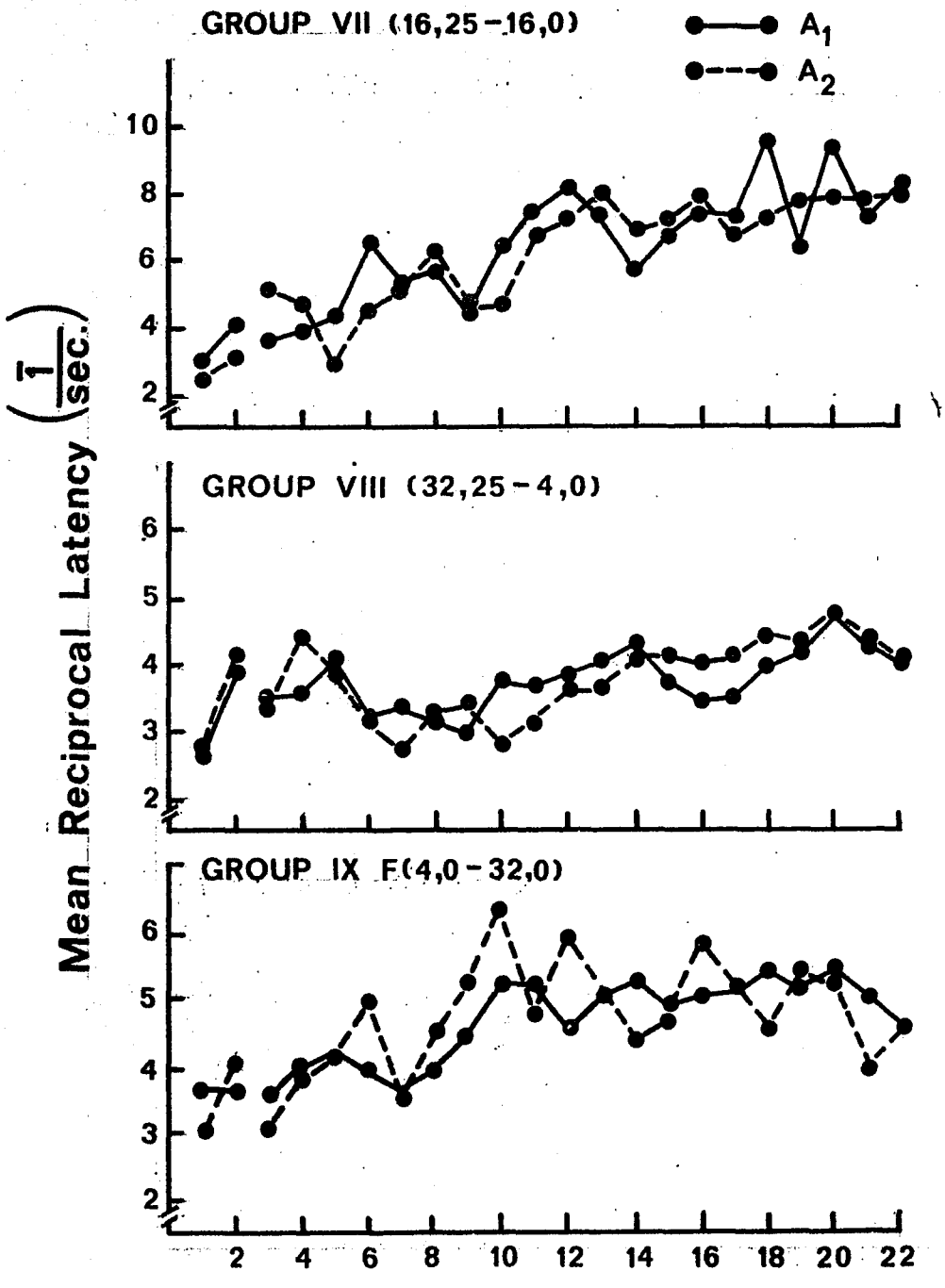

GROUP VII (16,25-16,0)
A1
A2
GROUP VIII (32,25-4,0)
GROUP IX F(4,0-32,0)
Mean Reciprocal Latency (1/sec.)
Blocks of 12 Trials
Group IX Blocks 3-22 Have 10 Trials

Table 23 - Analysis of Variance Based on Mean Reciprocal Latency ($\overline{1}$/sec.) over Phase I for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Group	20.356	8	2.545	1.516
Error	107.407	64	1.678	
Choice	0.071	1	0.071	0.240
Group x Choice	1.503	8	0.188	0.628
Error	19.151	64	.299	

*p < .05

Table 24 - Analysis of Variance Based on Mean Reciprocal Latency ($\bar{1}$/sec.) over Asymptotic Blocks 17-22 for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Group	42.530	8	5.316	4.843*
Error	70.106	64	1.095	
Choice	1.646	1	1.646	0.115
Group x Choice	0.796	8	0.010	0.696
Error	9.145	64	0.143	

*$p < .05$

Figure 13a- Mean Reciprocal Choice Time ($\overline{10}$/sec.) as a Function of Blocks of Twelve Trials over Phases I-III for Groups I-V of Experiment I.

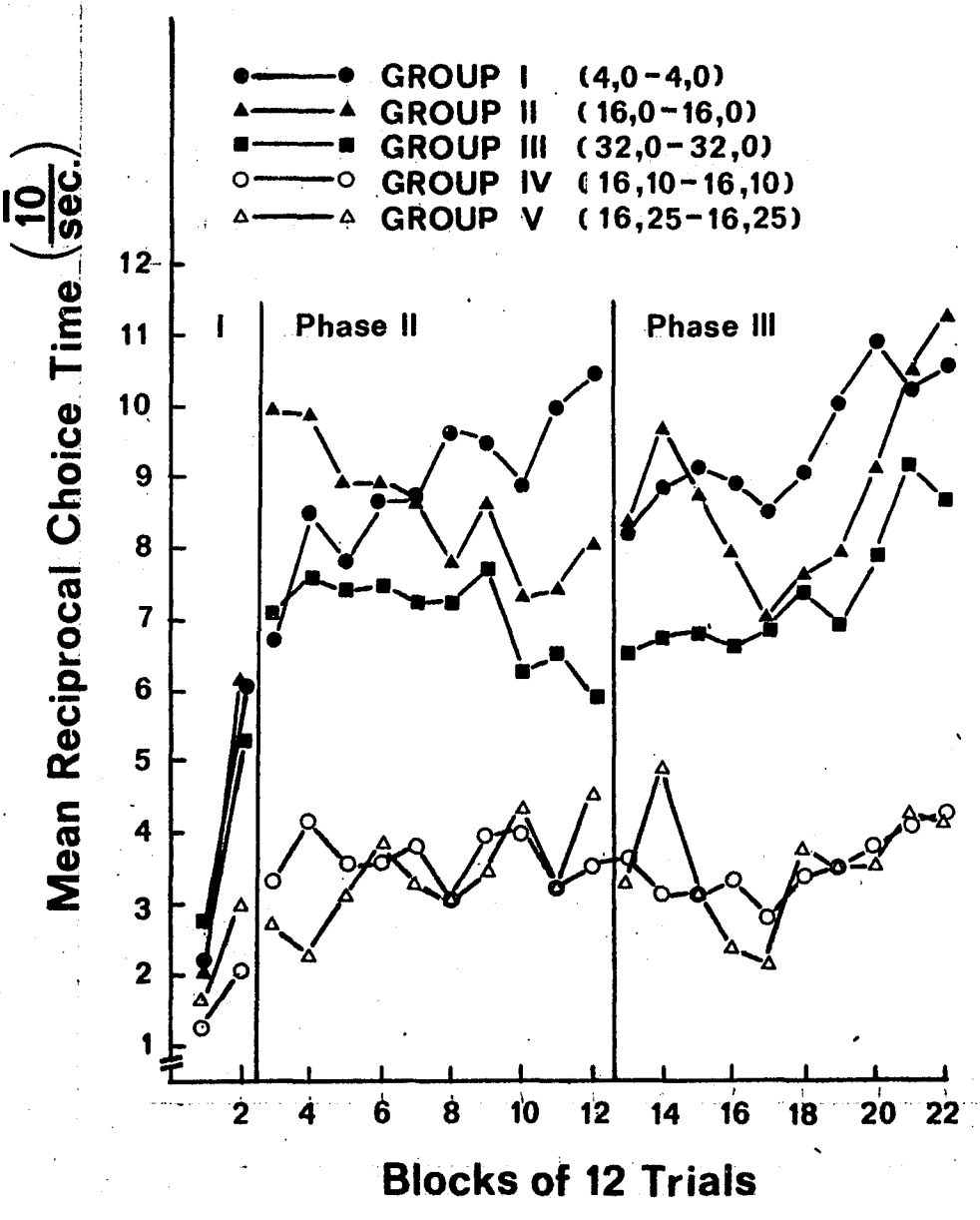

GROUP I (4,0-4,0)
GROUP II (16,0-16,0)
GROUP III (32,0-32,0)
GROUP IV (16,10-16,10)
GROUP V (16,25-16,25)
Mean Reciprocal Choice Time (10/sec.)
Phase I
Phase II
Phase III
Blocks of 12 Trials

Figure 13b - Mean Reciprocal Choice Time ($\overline{10}$/sec.) as a Function of Blocks of Twelve Trials over Phases I-II for Groups VI-IX of Experiment I.

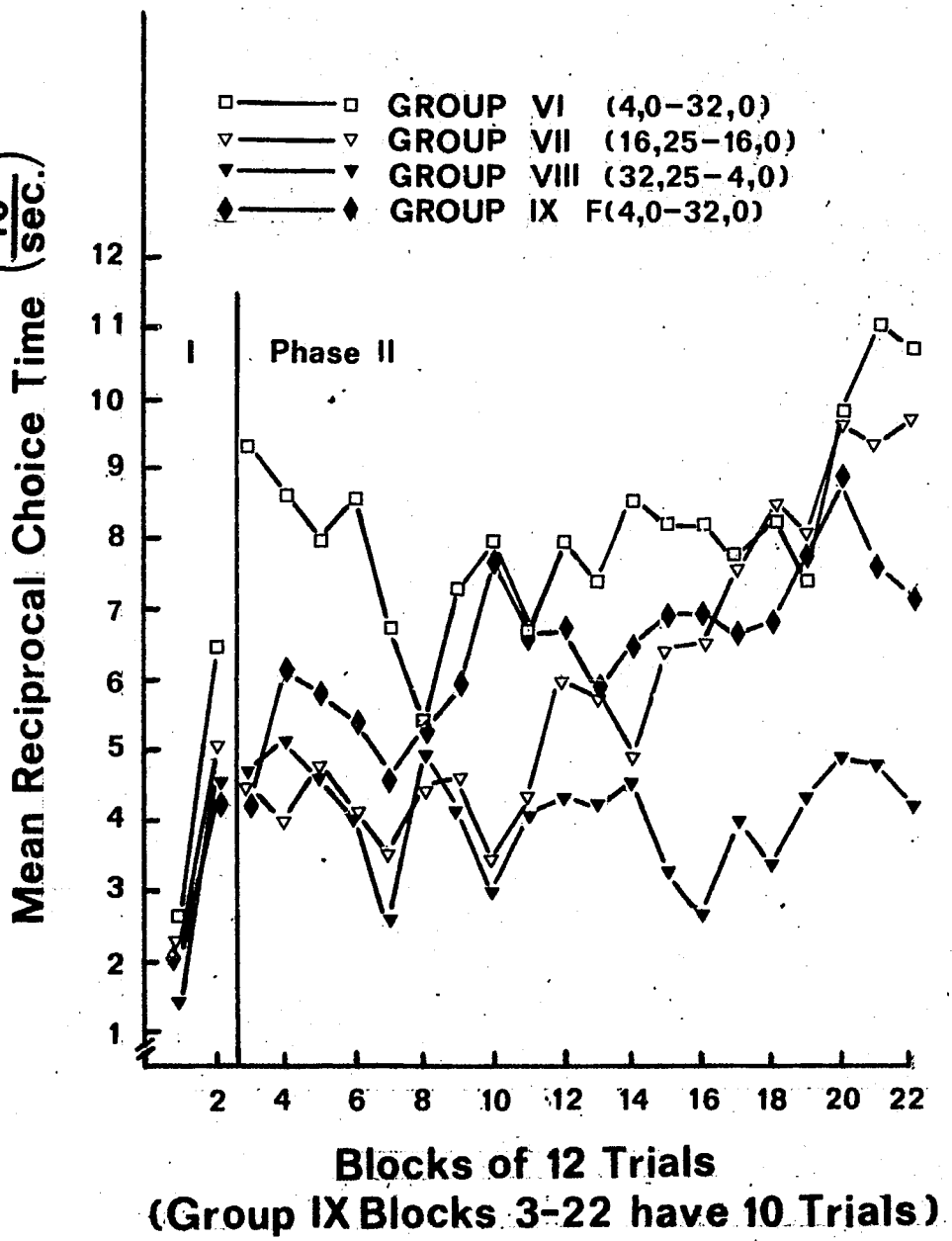
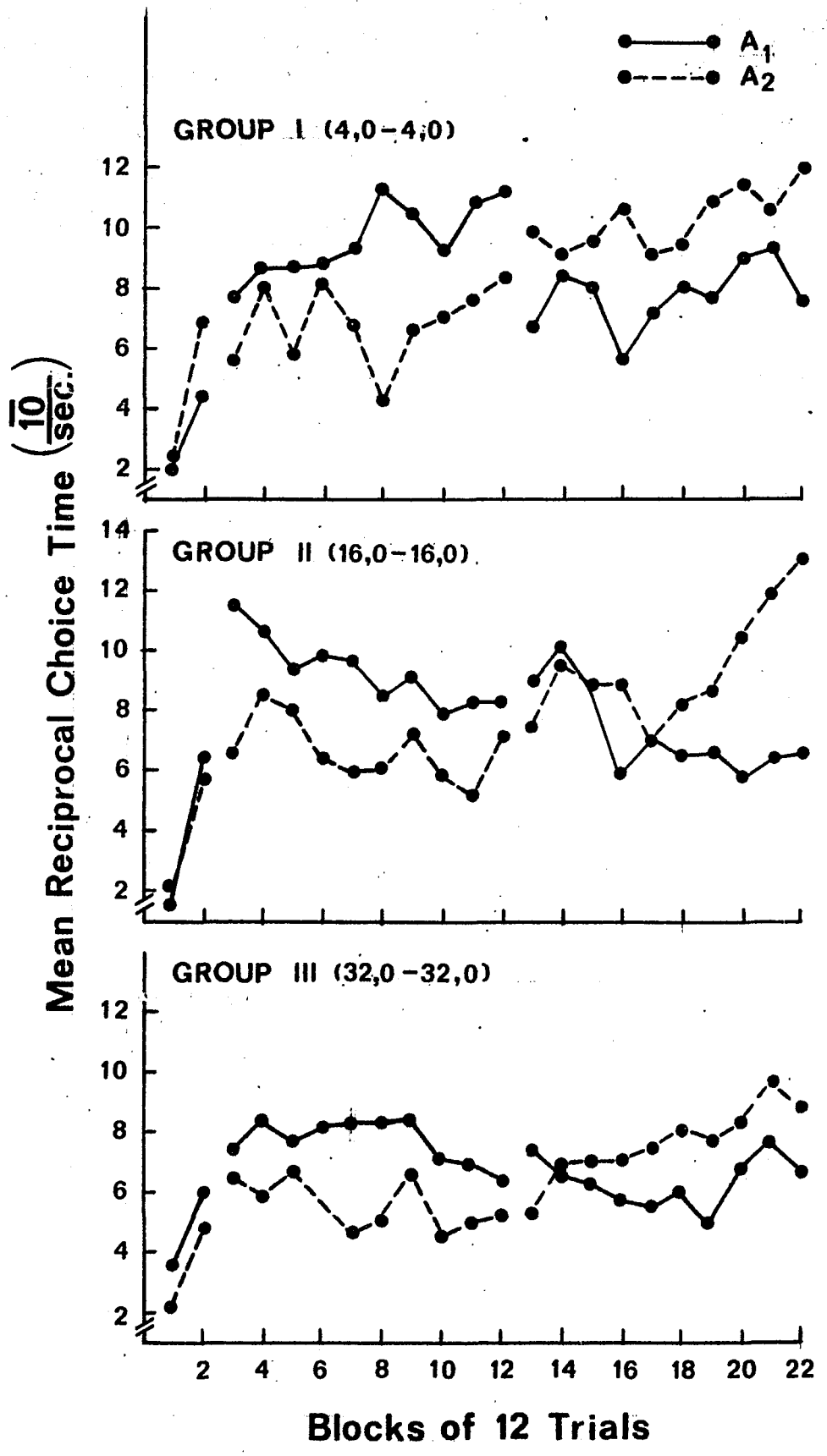
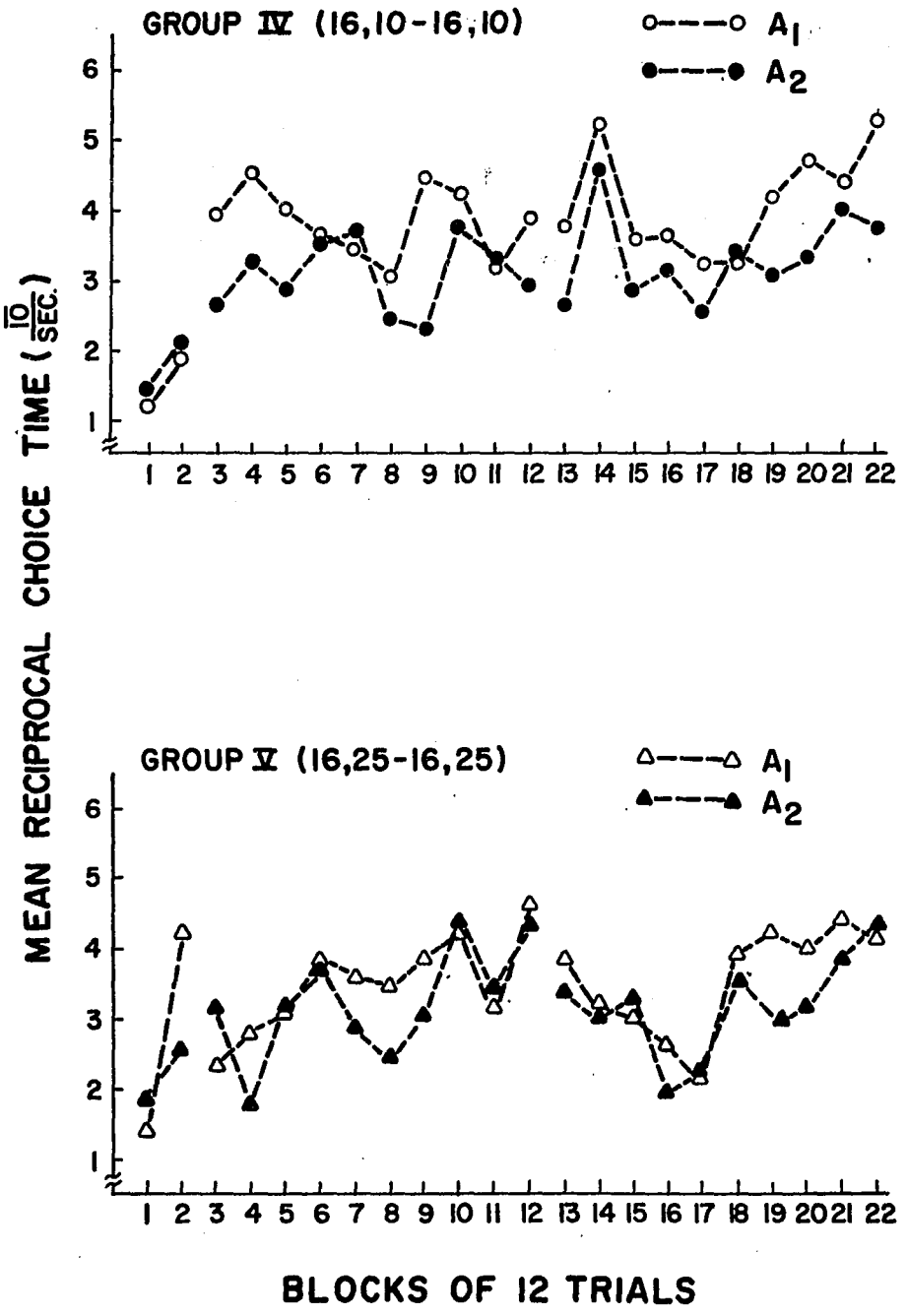
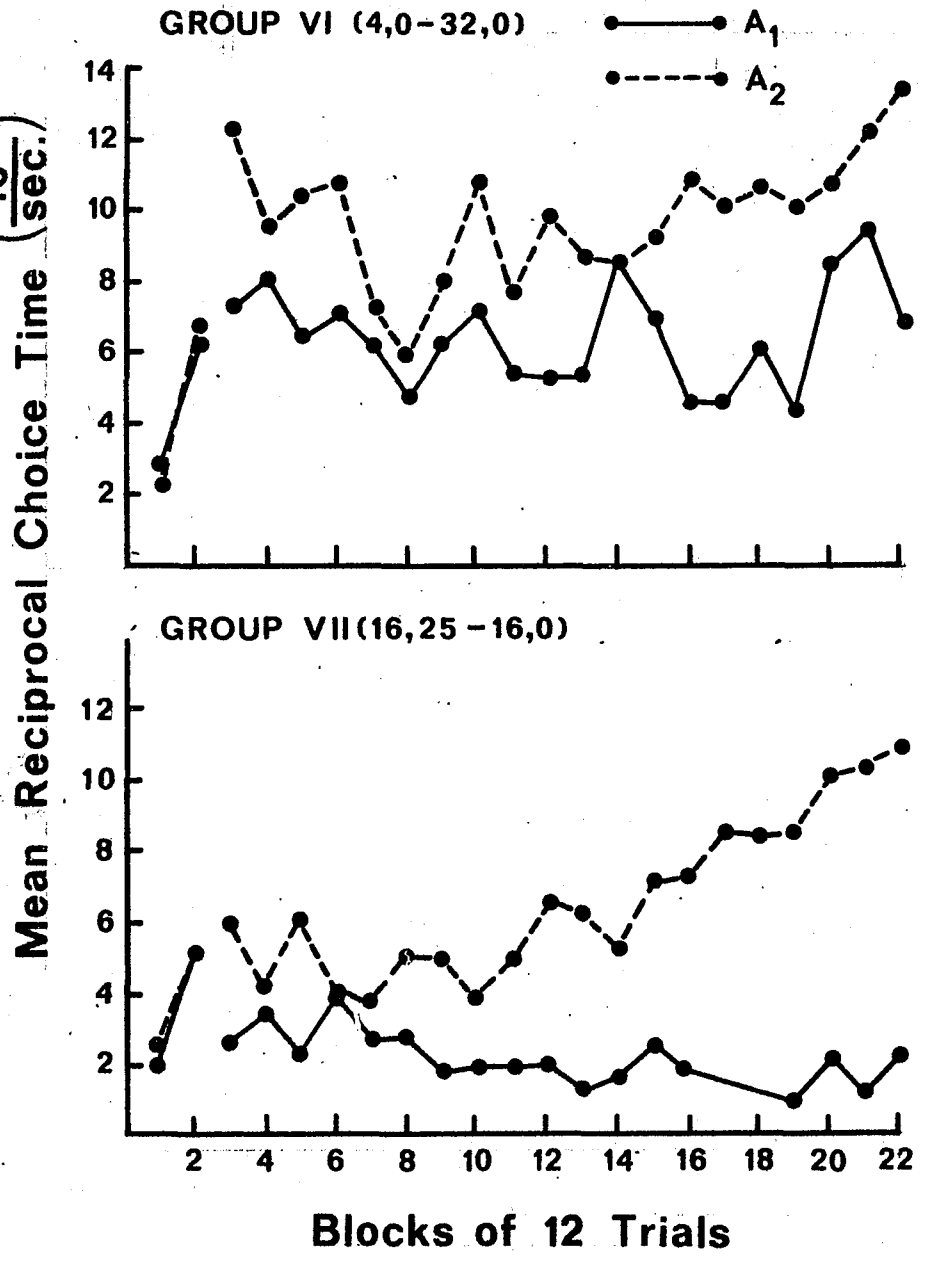

GROUP VI (4,0-32,0)
GROUP VII (16,25-16,0)
GROUP VIII (32,25-4,0)
GROUP IX F(4,0-32,0)
Mean Reciprocal Choice Time (10/sec.)
I
Phase II
12
11
10
9
8
7
6
5
4
3
2
1
2
4
6
8
10
12
14
16
18
20
22
Blocks of 12 Trials
(Group IX Blocks 3-22 have 10 Trials)

Figure 14 - Mean Reciprocal Choice Time ($\overline{10}$/sec.) According to A_1 and A_2 Responses as a Function of Blocks of Twelve Trials over Phases I-III for Groups I-IX of Experiment I.


A1
A2
GROUP I (4,0-4,0)
GROUP II (16,0-16,0)
GROUP III (32,0-32,0)
Mean Reciprocal Choice Time (10/sec.)
Blocks of 12 Trials
2
4
6
8
10
12
14
16
18
20
22


GROUP IV (16,10-16,10)
A1
A2
GROUP V (16,25-16,25)
A1
A2
MEAN RECIPROCAL CHOICE TIME (10/SEC.)
1 2 3 4 5 6
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
BLOCKS OF 12 TRIALS


GROUP VI (4,0-32,0)
A1
A2
GROUP VII(16,25-16,0)
Mean Reciprocal Choice Time (10/sec.)
Blocks of 12 Trials

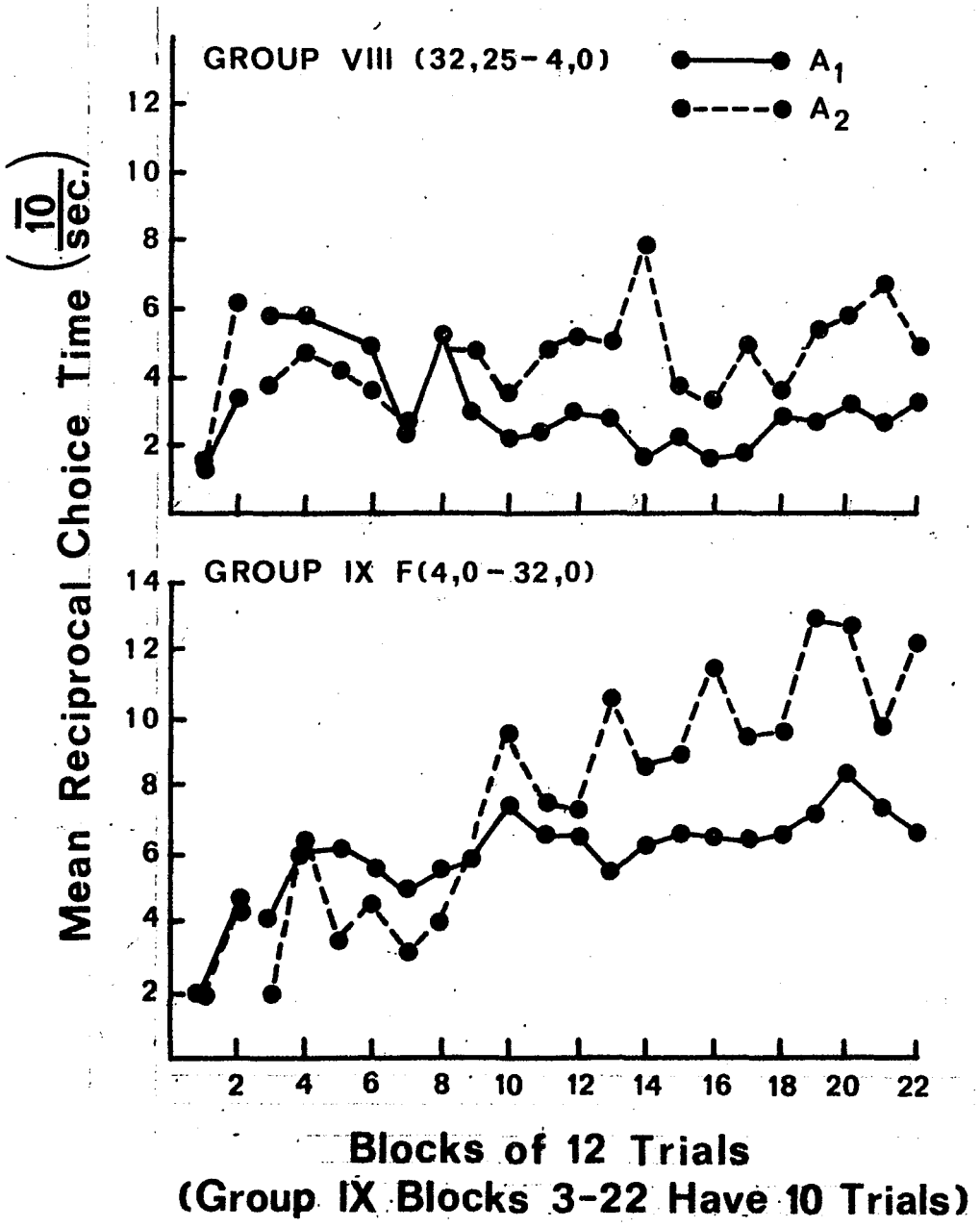

GROUP VIII (32,25-4,0)
A1
A2
GROUP IX F(4,0-32,0)
Mean Reciprocal Choice Time (10/sec.)
Blocks of 12 Trials
(Group IX Blocks 3-22 Have 10 Trials)

Table 25 - Analysis of Variance Based on Mean Reciprocal Choice Time ($\overline{10}$/sec.) over Phase I for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Groups	134.482	8	16.810	5.694*
Error	188.931	64	2.952	
Choice	0.921	1	0.921	0.509
Group x Choice	19.128	8	2.391	1.321
Error	115.846	64	1.810	

*$p < .05$

Table 26 - Analysis of Variance Based on Mean Reciprocal Choice Time ($\overline{10}$/sec.) over Asymptotic Blocks 17-22 for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Group	756.069	8	94.509	7.766*
Error	778.884	64	12.170	
Choice	159.590	1	159.590	26.378*
Group x Choice	144.403	8	18.050	2.983*
Error	387.215	64	6.050	

*$p < .05$

F-ratio comparisons between all pairs of means again showed Groups IV and V to be significantly different from Groups I, II, III, VI, VII and IX, ($p < .05$). The difference between Groups IV and VII was also significant ($p < .05$) while none of the other comparisons were ($p > .05$).

Inspection of Figure 13a also revealed differences between the mean reciprocal choice times of Groups I-III over Blocks 7-12 of Phase II and Blocks 17-22 of Phase III. Separate analyses of variance performed for each Phase were not significant ($p > .05$) (Tables 27a-27b).

Over the asymptotic Blocks (17-22) there were also significant differences between choice time to the A_1 and A_2 sides and a significant Group and Choice interaction (Table 26). Inspection of Figure 14 clearly shows the interaction effect. Groups I-III for both original and reversal learning (Phases II and III), show faster speeds to the side with the larger proportion of reinforcement (larger π side). Speeds to the A_1 and A_2 side are more similar for Groups IV and V. While for Groups VI-IX we find faster speeds to the A_2 side, i.e. the smaller π side which is the side which receives the more "positive" of the contrasted reinforcement conditions (i.e. either greater duration or less of a delay of reinforcement).

Because of the significant interaction effect separate analyses were calculated for both A_1 and A_2 responses for Groups I-IX (Tables 28a and 28b). There was a significant difference between the Groups for both A_1 and A_2 responses. The individual comparisons of all pairs of means using the Tukey (b) procedure, can be found in Tables 29 a and b for the A_1 and A_2 choice responses respectively. These comparisons generally support the graphs showing Groups IV, V and VIII to be slower than the other Groups with not all of the specific comparisons significant.

Table 27a - Analysis of Variance Based on Mean Reciprocal Choice Time ($\overline{10}$/sec.) over Asymptotic Blocks 7-12 for Groups I-III of Experiment I.

Source	SS	DF	MS	F
Between	21.873	2	10.936	0.707
Within	417.501	27	15.463	
Total	439.374	29		

Table 27b - Analysis of Variance Based on Mean Reciprocal Choice Time ($\overline{10}$/sec.) over Asymptotic Blocks 17-22 for Groups I-III of Experiment I.

Source	SS	DF	MS	F
Between	22.800	2	11.400	1.036
Within	297.185	27	11.007	
Total	319.985	29		

*$p < .05$

Table 28a - Analysis of Variance Based on Mean Reciprocal A_1 Choice Time ($\overline{10}$/sec.) over Asymptotic Blocks 17-22 for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Between	263.228	8	32.904	6.062*
Within	347.362	64	5.428	
Total	610.591	72		

Table 28b - Analysis of Variance Based on Mean Reciprocal A_1 Choice Time ($\overline{10}$/sec.) over Asymptotic Blocks 17-22 for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Between	718.155	8	89.769	6.518*
Within	674.456	64	10.538	
Total	1392.611	72		

*$p < .05$

Table 29a - Individual Comparisons of Pairs of Means for the Mean Reciprocal A_1 Choice Time ($\overline{10}$/sec.) over Asymptotic Blocks 17-22 for Groups I-IX of Experiment I.

	$\overline{X}_1$	$\overline{X}_9$	$\overline{X}_6$	$\overline{X}_2$	$\overline{X}_3$	$\overline{X}_4$	$\overline{X}_5$	$\overline{X}_8$	$\overline{X}_7$
$\overline{X}_1$	--	1.134	1.657	1.711	2.276	4.191*	4.546*	5.342*	6.182*
$\overline{X}_9$		--	0.523	0.577	1.142	3.057	3.412	4.208*	5.048*
$\overline{X}_6$			--	0.054	0.619	2.534	2.889	3.685	4.525*
$\overline{X}_2$				--	0.565	2.480	2.835	3.631	4.471*
$\overline{X}_3$					--	1.915	2.270	3.066	3.906
$\overline{X}_4$						--	0.355	1.151	1.991
$\overline{X}_5$							--	0.796	1.636
$\overline{X}_8$								--	0.840
$\overline{X}_7$									--

* $p < .05$

Table 29b - Individual Compairsons of Pairs of Means for the Mean Reciprocal A_2 Choice Time ($\overline{10}$/sec.) over Asymptotic Blocks 17-22 for Groups I-IX of Experiment I.

	$\bar{X}_9$	$\bar{X}_6$	$\bar{X}_2$	$\bar{X}_7$	$\bar{X}_1$	$\bar{X}_3$	$\bar{X}_8$	$\bar{X}_5$	$\bar{X}_4$
$\bar{X}_9$	--	0.226	0.226	1.634	1.876	3.706	6.620*	7.715*	7.824*
$\bar{X}_6$		--	0.000	1.409	1.650	3.481	6.395*	7.493*	7.598*
$\bar{X}_2$			--	1.409	1.650	3.481	6.395*	7.493*	7.598*
$\bar{X}_7$				--	0.241	2.072	4.986*	6.084*	6.189*
$\bar{X}_1$					--	1.831	4.745*	5.843*	5.948*
$\bar{X}_3$						--	2.914	4.012	4.117
$\bar{X}_8$							--	1.098	1.203
$\bar{X}_5$								--	0.105
$\bar{X}_4$									--

* $p < .05$

None of the comparisons between Groups I, III, VI, VII, and IX are significant for either A_1 or A_2 response.

Correlated t-tests between A_1 and A2 choice speeds for each Group showed only the differences for Group II ($t = 4.478$, df=9), Group VI ($t = 2.648$, df=5), Group VII ($t = 3.868$, df=4), and Group IX ($t = 2.751$, df=5) to be significant ($p < .05$). The non-significant t-tests were Group I ($t = 1.698$, df=9), Group III ($t = 1.263$, df=9), Group IV ($t = 1.074$, df=9), Group V ($t = 0.744$, df=9) and Group VIII ($t = 1.245$, df=5) ($p > .05$).

Committed Time

Figure 15a and b shows the mean reciprocal committed time or the time taken from the making of the choice time to the interruption of a photo-cell beam 2 in. from the water tube for Groups I-IX. Figure 16 shows this measure for A_1 and A_2 responses separately. Groups IV, V and VIII are again below the other Groups although for Group VIII the decrement did not develop until the middle of Phase II. For both Phase I and Blocks 17-22 there was a significant Group effect (Tables 30 and 31). Comparison of the individual pairs of means for Phase I employing the F ratio procedure shows Groups IV and V to be similar to each other and significantly different from all other Groups ($p < .05$). No other comparisons were significant ($p > .05$).

The committed time analysis over Blocks 17-22 also reveals a significant Choice x Group interaction effect. Inspection of Figure 16 shows Groups VII and VIII have faster A_2 speeds while the other Groups show similar speeds to both A_1 and A_2. Separate analyses were performed for the A_1 and for the A_2 responses for Groups I-IX (Tables 32a and 32b), and each yielded significant differences for the Group variable.

Figure 15a - Mean Reciprocal Committed Time ($\bar{1}$/sec.) as a Function of Blocks of Twelve Trials for Phases I - II for Groups I-V of Experiment I.

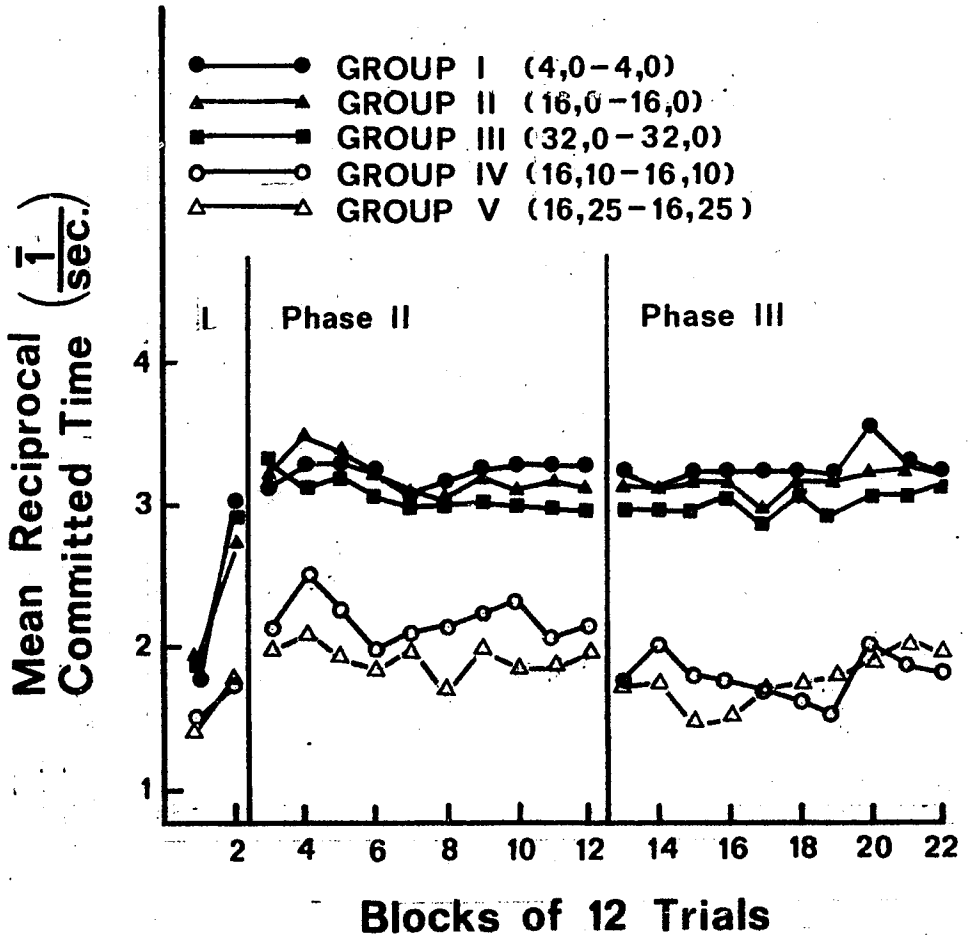

GROUP I (4,0-4,0)
GROUP II (16,0-16,0)
GROUP III (32,0-32,0)
GROUP IV (16,10-16,10)
GROUP V (16,25-16,25)
Phase II
Phase III
Mean Reciprocal Committed Time (1/sec.)
Blocks of 12 Trials

Figure 15b - Mean Reciprocal Committed Time ($\bar{1}$/sec.) as a Function of Blocks of Twelve Trials for Phases I-III for Groups VI-IX of Experiment I.

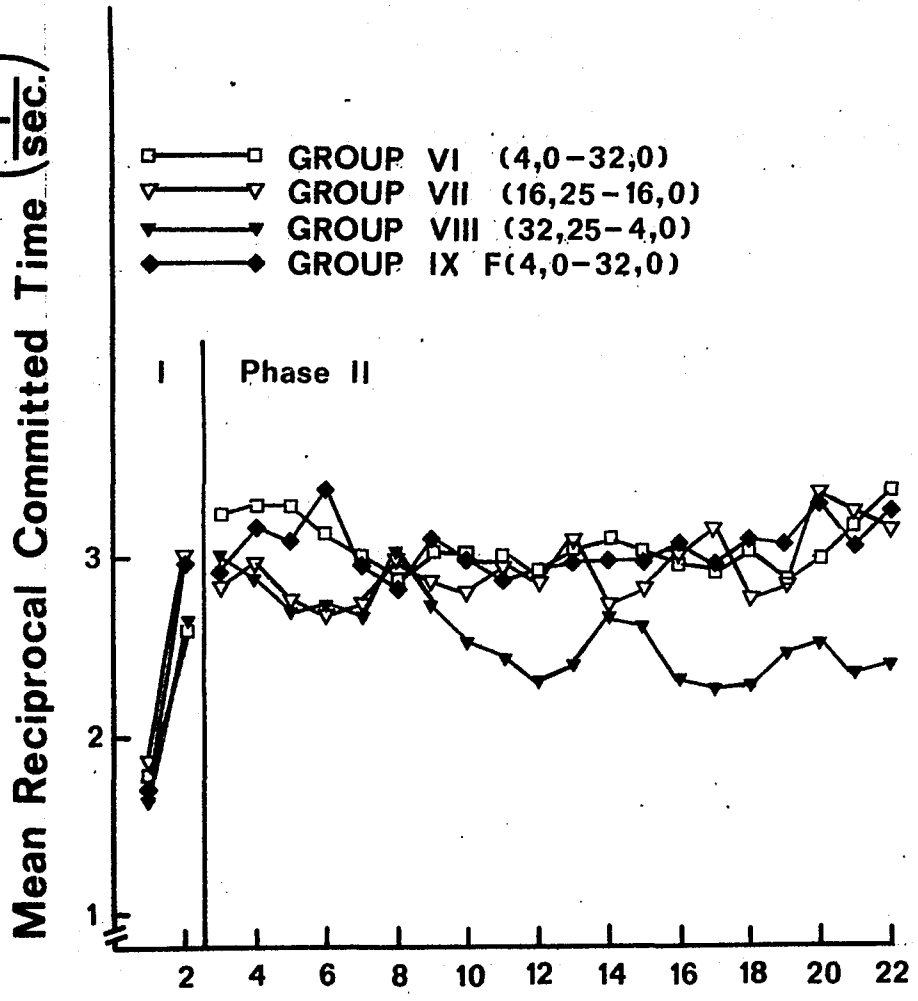
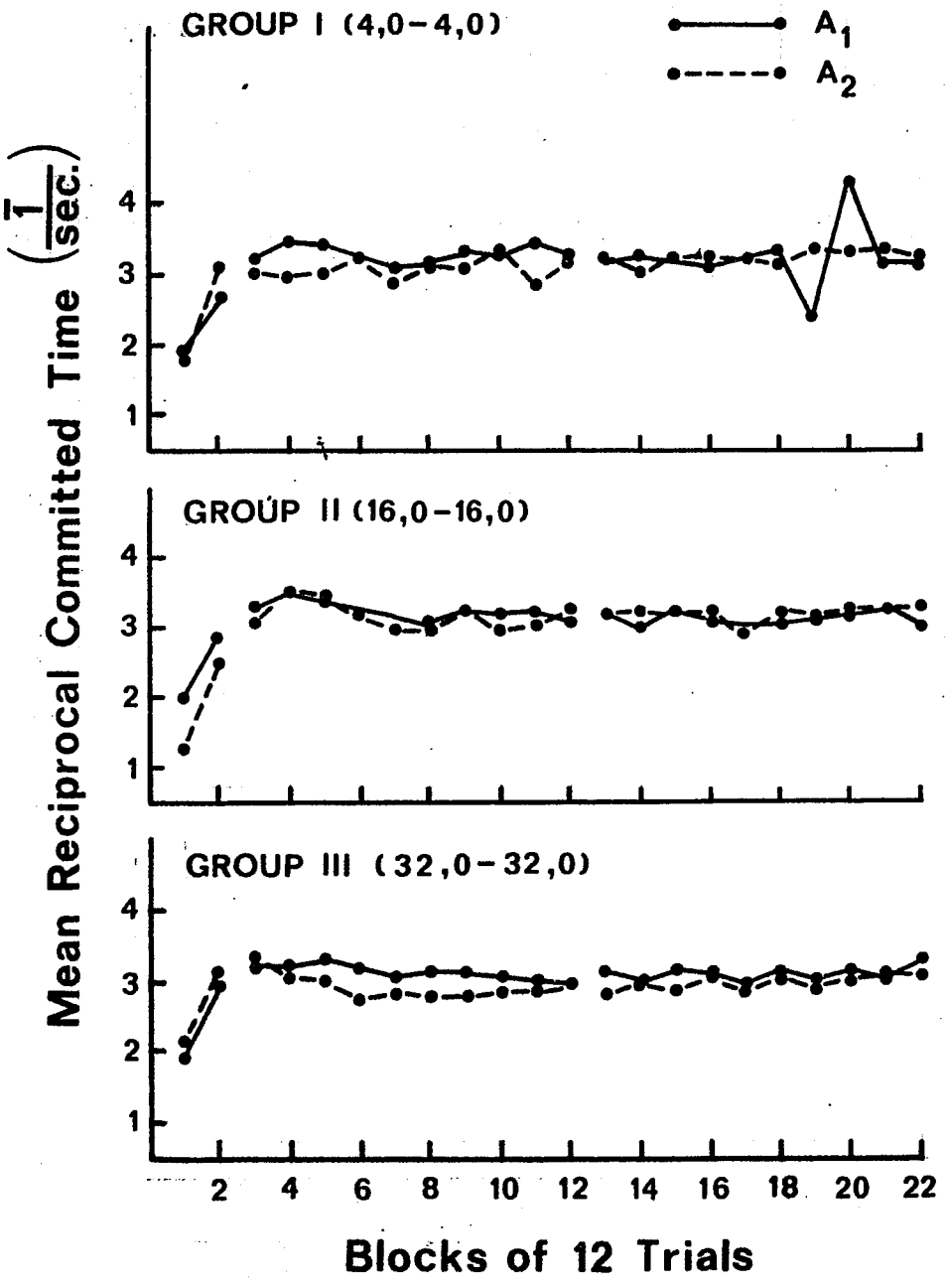
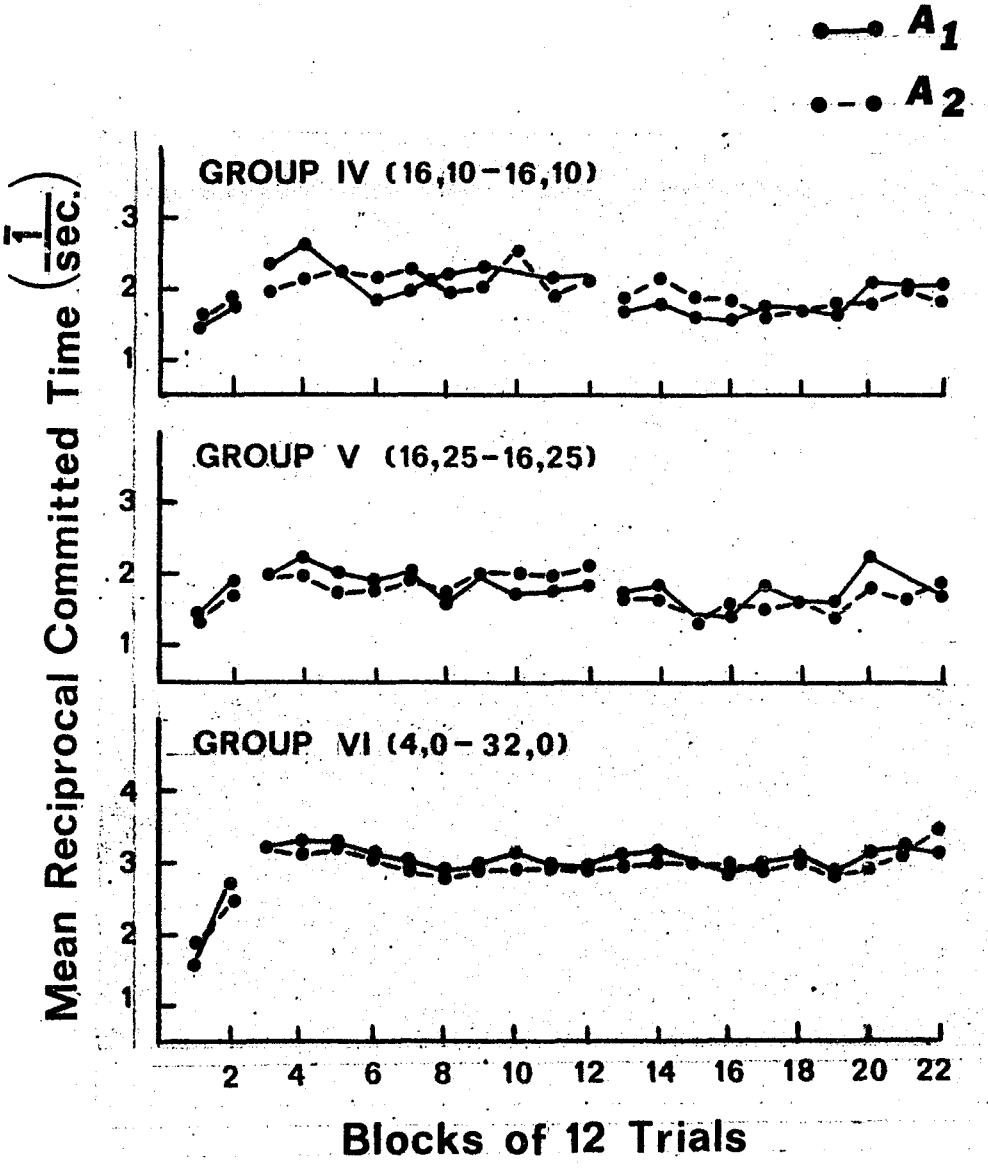

Mean Reciprocal Committed Time $\left(\frac{1}{\text{sec.}}\right)$
GROUP VI (4,0-32,0)
GROUP VII (16,25-16,0)
GROUP VIII (32,25-4,0)
GROUP IX F(4,0-32,0)
I
Phase II
1
2
3
2
4
6
8
10
12
14
16
18
20
22
Blocks of 12 Trials
(Group IX Blocks 3-22 Have 10 Trials)

Figure 16 - Mean Reciprocal Committed Time (1/sec.) According to A_1 and A_2 Responses as a Function of Blocks of Twelve Trials for Phases I-III for Groups I-IX of Experiment I.


GROUP I (4,0-4,0)
A1
A2
GROUP II (16,0-16,0)
GROUP III (32,0-32,0)
Mean Reciprocal Committed Time (1/sec.)
1
2
3
4
2
4
6
8
10
12
14
16
18
20
22
Blocks of 12 Trials


A1
A2
GROUP IV (16,10-16,10)
GROUP V (16,25-16,25)
GROUP VI (4,0-32,0)
Mean Reciprocal Committed Time (1/sec.)
Blocks of 12 Trials
2 4 6 8 10 12 14 16 18 20 22

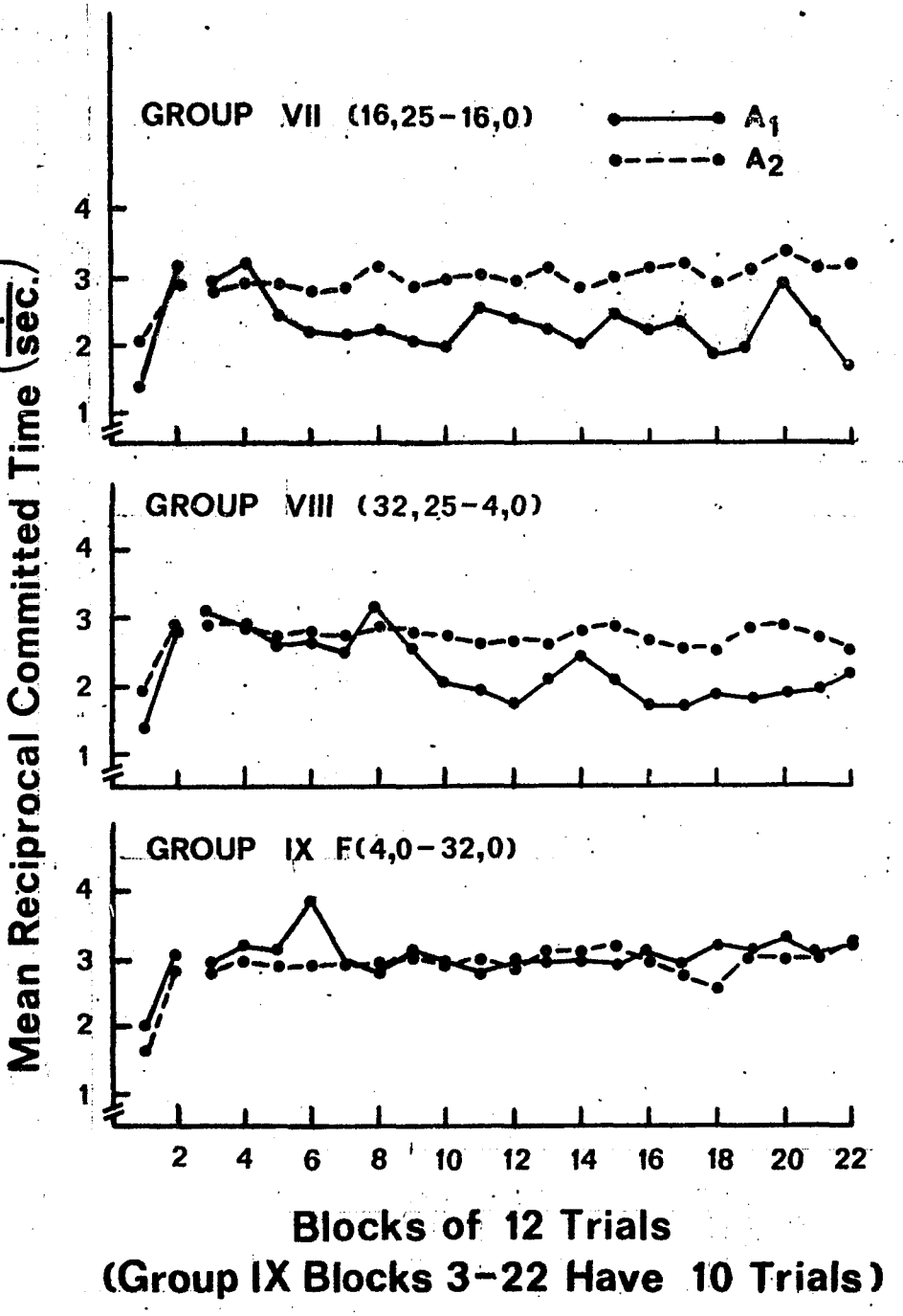

GROUP VII (16,25-16,0)
A1
A2
GROUP VIII (32,25-4,0)
GROUP IX F(4,0-32,0)
Mean Reciprocal Committed Time (1/sec.)
1
2
3
4
2 4 6 8 10 12 14 16 18 20 22
Blocks of 12 Trials
(Group IX Blocks 3-22 Have 10 Trials)

Table 30 - Analysis of Variance Based on Mean Reciprocal Committed Time ($\overline{1}$/sec.) over Phase I for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Groups	17.472	8	2.184	6.025*
Error	23.200	64	0.362	
Choice	0.0008	1	0.0008	0.005
Group x Choice	2.112	8	0.264	1.508
Error	11.206	64	0.175	

*$p < .05$

Table 31 - Analysis of Variance Based on Mean Reciprocal Committed Time ($\bar{1}$/sec.) over Asymptotic Blocks 17-22 for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Groups	52.309	8	6.5386	10.932*
Error	38.319	64	.599	
Choice	0.167	1	0.167	1.504
Group x Choice	2.969	8	0.371	3.335*
Error	7.120	64	0.111	

*p < .05

Table 32a - Analysis of Variance Based on Mean Reciprocal A_1 Committed Time ($\bar{1}$/sec.) over Blocks 17-22 for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Between	27.144	8	3.393	8.565*
Within	25.353	64	0.396	
Total	52.497	72		

Table 32b - Analysis of Variance Based on Mean Reciprocal A_2 Committed Time ($\bar{1}$/sec.) over Blocks 17-22 for Groups I-IX of Experiment I.

Source	SS	DF	MS	F
Between	28.108	8	3.514	11.178*
Within	20.117	64	0.314	
Total	48.226	72		

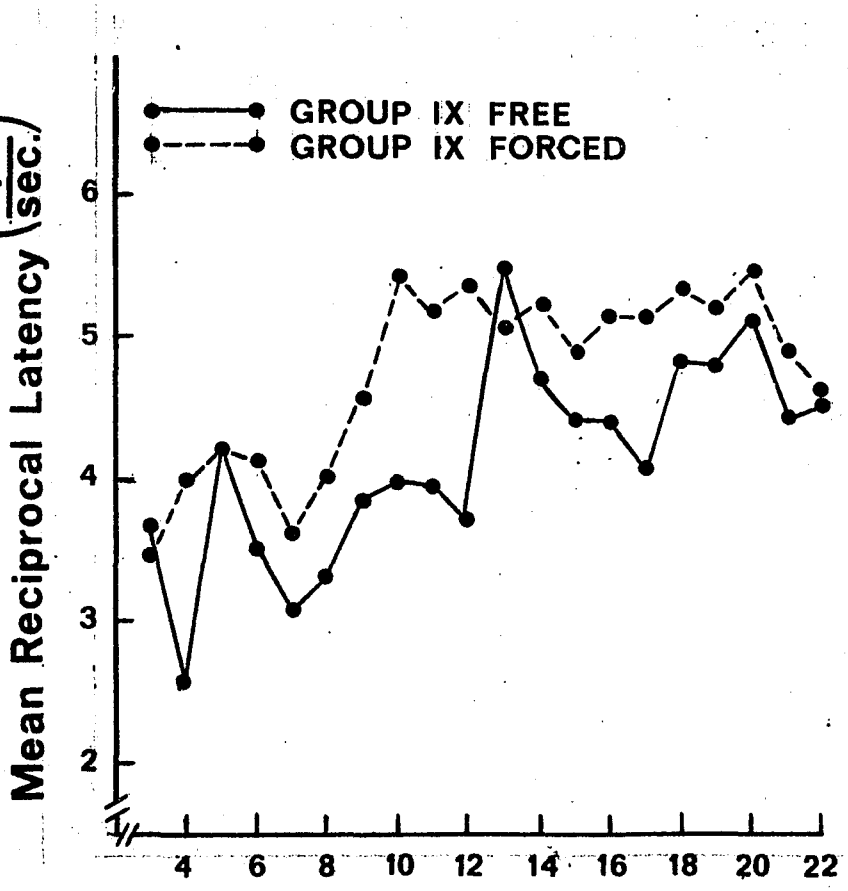
*$p < .05$

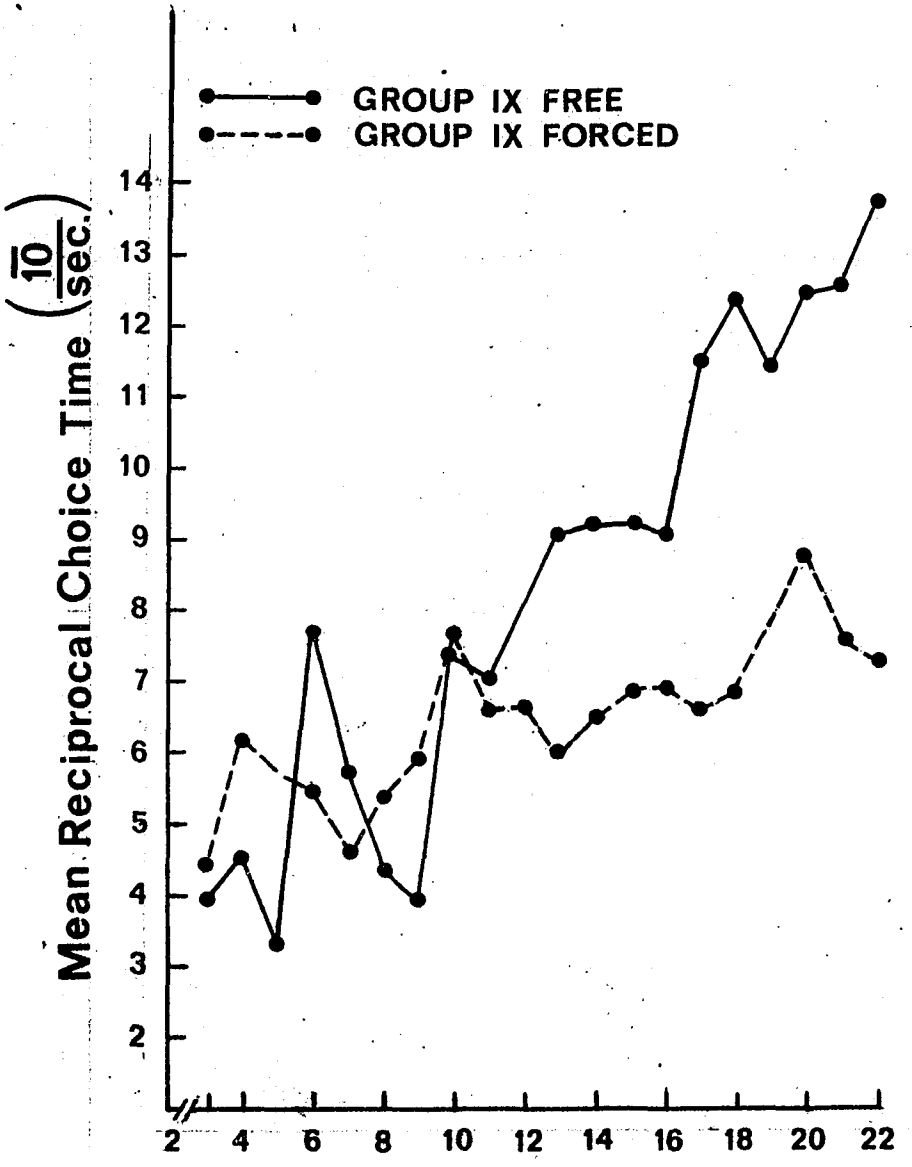
Individual comparisons (Tukey (b)) between Groups I, II, III, VI and IX, versus Groups IV, V and VIII were all significant ($p>.05$). Comparisons for the A_2 response showed Groups IV and V to be significantly different from all other Groups ($p<.05$) while none of the other comparisons were significant ($p>.05$).

Correlated t-tests between A_1 and A_2 responses were performed for Groups VII and VIII only. Both were not significant $t = 2.199$ ($p<.05$, $df=4$), and $t = 2.386$ ($p<.05$, $df=5$), respectively, for the two Groups.

Group IX Free and Forced Trials: Figure 17 shows the three speed measures for the free and forced trials of Group IX while Figure 18 shows the three speed measures as a function of A_1 and A_2 responses for the free trials. No statistical analyses were performed as there were too few free trials and in addition over Blocks 17-22 there were no free responses to the A_1 side. Forced trial speeds for the latency measure were generally faster than those on the free trials while free trial speeds for the choice measure were generally faster than those on the forced trials. There was no difference for the committed time measure. The choice time data are compatible with the observations that Ss started toward the A_2 side and then stopped at the closed A_2 door before responding to the A_1 side. This is supported by the faster A_2 when compared to the A_1 speed for the forced trials (Figure 14).

Figure 17 - Mean Reciprocal Latency ($\overline{1}$/sec.) Choice ($\overline{10}$/sec.) and Committed $\overline{1}$/sec.) Time According to A_1 or A_2 Responses as a Function of Blocks of Two Trials for the Free Trials of Group IX F(4.0-32,0) of Experiment I.


GROUP IX FREE
GROUP IX FORCED
Mean Reciprocal Latency $\left(\frac{1}{sec.}\right)$
2
3
4
5
6
4
6
8
10
12
14
16
18
20
22
Blocks of 2 Trials
(Group IX Free Trials)
Blocks of 10 Trials
(Group IX Forced Trials)


GROUP IX FREE
GROUP IX FORCED
Mean Reciprocal Choice Time $\left(\frac{10}{\text{sec.}}\right)$
14
13
12
11
10
9
8
7
6
5
4
3
2
2
4
6
8
10
12
14
16
18
20
22
Blocks of 2 Trials
(Group IX Free Trials)
Blocks of 10 Trials
(Group IX Forced Trials)

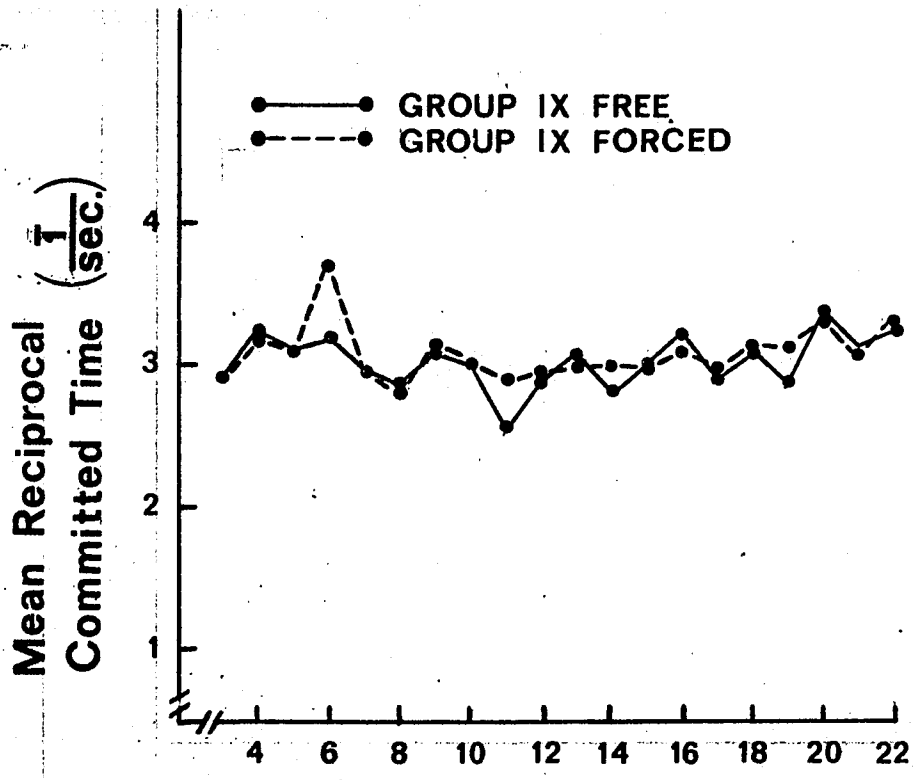
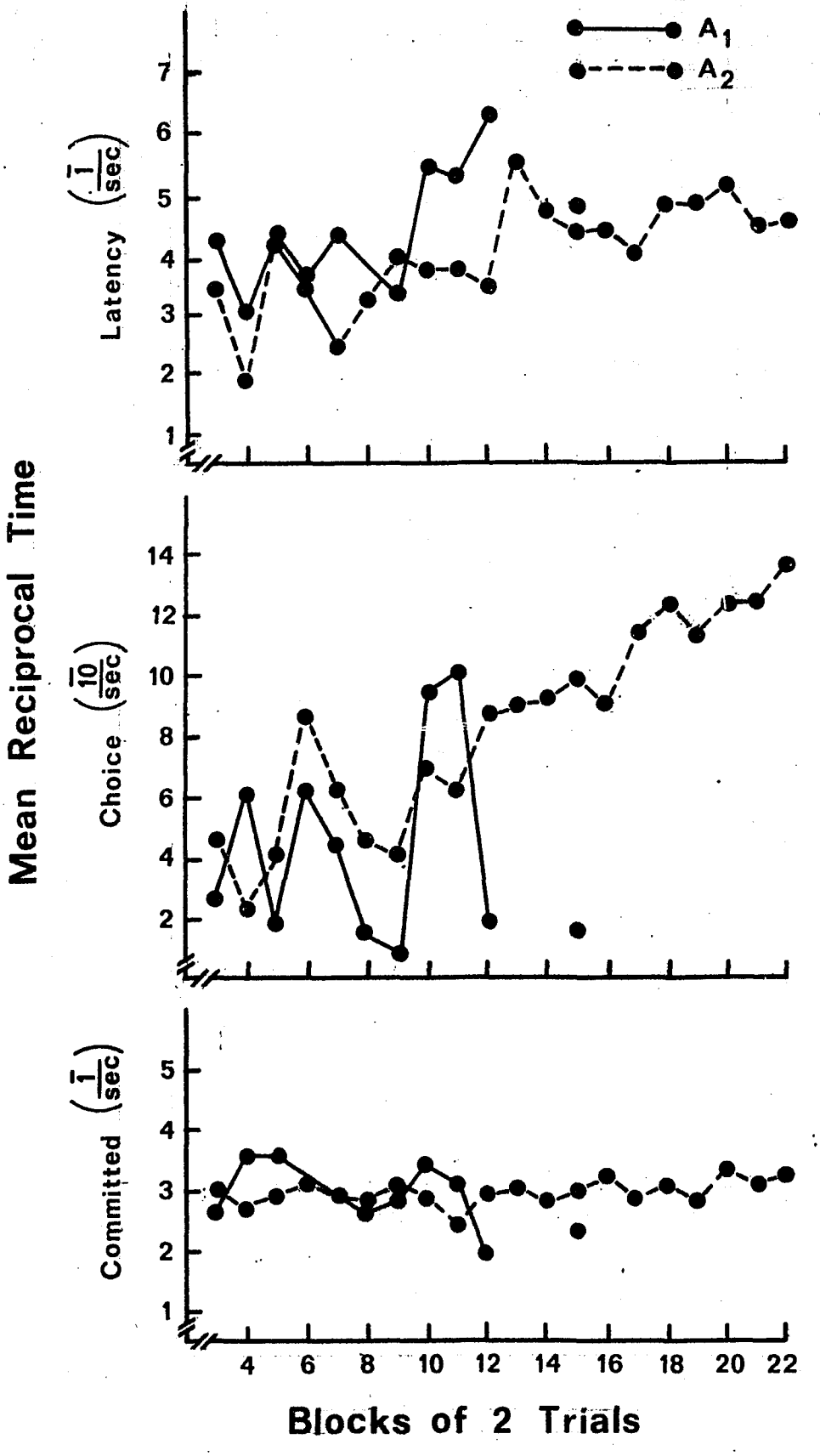

GROUP IX FREE
GROUP IX FORCED
Mean Reciprocal Committed Time $\left(\frac{1}{\text{sec.}}\right)$
1
2
3
4
4
6
8
10
12
14
16
18
20
22
Blocks of 2 Trials
(Group IX Free Trials)
Blocks of 10 Trials
(Group IX Forced Trials)

Figure 18 - Mean Reciprocal Latency ($\overline{1}$/sec.) Choice ($\overline{10}$/sec.) and Committed ($\overline{1}$/sec.) for Free and Forced Trials of Phase II of Group IX F(4,0-32,0) of Experiment I.


A1
A2
Mean Reciprocal Time
Latency (1/sec)
Choice (10/sec)
Committed (1/sec)
Blocks of 2 Trials

Discussion

The major positive finding in the present study was the non-monotonicity of the choice probability learning curve for Group VI which received 4 sec. duration under 0 sec. delay on the A_1 side and 32 sec. duration and 0 sec. delay on the A_2 side. The early data of this Group were similar to that of the equal reinforcement Groups in that they approached the "matching" asymptote. The effects of unequal reinforcement for the two alternatives set in later and produced a bend in the curve to the ultimate asymptotic choice probability of an A_1 of .42. This Group had an *n* of only 6 and the result is, therefore, open to question. Should it prove to be replicable, it suggests the operation of a two-phase theory of reinforcement, at least in the T-maze. The operation of a two-phase theory of reinforcement received additional support from the results of Phase IV. Here both the reversed and non-reversed *Ss* of Group V also showed non-monotonicity after immediate reinforcement was introduced. Since Experiment II is directed at replicating the results and exploring the variables affecting it, further discussion will be postponed.

The following other main results to be discussed are: a) for the choice data -- the absence of learning rate differences among Groups I-III which differed in duration of reinforcement, evidence that the equal reinforcement Groups "undershot" the theoretical asymptote, and the comparisons made to evaluate the adequacy of the equal θ model for the non-correction rerun procedure: b) for the time data -- the absence of a magnitude of reinforcement effect on the three speed measures and the effect of A_1 and A_2 response on speed. Since the discussion of the other results depends on the adequacy of the

procedure and the evaluation of the theoretical model these results will be discussed first.

The most significant feature of the present choice data is reflected in the similarity and the stability of the individual Ss learning curves within each of the Groups. This demonstrated that the group learning curves, for all Groups, were representative and not an artifact of averaging across Ss who were performing differently. The results of Groups I-III showed that the identity operator failed to hold tightly for the rerun or "error" trials with the Ss making too few error runs of length greater than two. These results replicate those of Weinstock, Robbins and Chen (1972). It can be accounted for by assuming that following non-reinforcement the Ss sampled new stimulus components which became conditioned over trials to the opposite response. Put otherwise, following non-reinforcement there are discriminitive cues present whichccarry over to the next run and lead to an increase in probability of a correct response after an error.

In principle there should be no discriminative cues present on the first run of a trial and the model may be expected to hold for the first run data. Asymptotic first choice responses of Groups I-III over Phases II and III show a reasonable approximation to the "matching" result of the equal θ model except for a small, but statistically significant, undershooting of the theoretical asymptote. If the obtained rather that the theoretical asymptote is used to calculate a number of fine statistics of the data we again find reasonable qualitative agreement between the obtained and expected values. The present results are in general agreement with previous research and further demonstrate the overall success of linear operator models in predicting behavior in

the probability T-maze (J. Robbins, 1969, Weinstock et al, 1972).

However, the equal θ model should have produced different learning rates, or θ-values, for the different duration of reinforcement Groups. Since θ is the only parameter available in the class of models which may vary with reinforcement variables, the failure to find differences among Groups I-III in both Phases II and III of the present experiment indicates that the class of models cannot be extended to deal with the effects of duration of reinforcement. The fact that the θ-values were the same leads to the further prediction of "matching" by Group VI which received durations of 32 sec. for the A_2 and 4 sec. for the A_1 sides. This group reached an asymptote of .42 which was far from the matching asymptote of .75 for the probability of an A_1. In addition the non-monotonicity shown was clearly counter to any predictions that might be generated by specializing the class of linear learning operators. All in all the data of the present experiment lead to the conclusion that the class of linear learning models cannot be extended to duration of reinforcement effects.

The performance of Groups VII and VIII which differed in delay of reinforcement are more difficult to assess. One of the estimation Groups (Group V) showed no learning and remained at .5 throughout. In view of this one cannot properly draw theoretical conclusions from this part of the experiment.

Finally the forced trial procedure produced marked differences in both the early and asymptotic portions of the learning curve, during Phase II, of Groups VI and IX. The assumption has been made that forced and free trials resulting in reinforcement of the same choice

response have the same effect. This assumption is clearly wrong for the present data. Further experimental work is necessary to determine whether and where the assumption does hold. One interpretation of the results of Group IX, which showed absorbtion on the 32 sec. side, is that the Ss discriminated strongly between free and forced trials. If we regard the free trials alone as constituting the experiment the Ss were performing under a non-correction model for which the theoretical expectation is absorbtion. In any case, the present data serve as a warning signal to those who use forced trial procedures to answer theoretical questions. From this point of view, the forced trials had no effect on the free trial choice response probabilities.

The latency, choice and committed time results were surprising in that different durations of reinforcement did not lead to asymptotic differences in speed of response. Generally, it was only the delay Groups IV, V and VIII which were slower than the other Groups for the asymptotic trials over the three measures taken. Additionally the latency and committed measures showed no difference between speeds for A_1 and A_2 responses. An interesting aspect of the choice point time measure was found in the significant difference between A_1 and A_2 speeds and the significant Group x Choice interaction. These results suggested that Ss were not "set" at the start of a trial to make a specific response but, rather, engaged in a "decision" in the choice area. Support of this hypothesis can be found in the relatively longer time spent in the choice area. As the n in each Group was small further discussion of the time measures will be postponed until Experiment II in which a larger n was employed.

Experiment II

The results of Experiment I were unexpected in that different durations of reinforcement, specifically 4 and 32 sec., lead to the same rate of learning while contrasted reinforcement values of 4 and 32 sec. affected asymptotic choice behavior. One possibility was that the latter was simply a function of the presentation of more than a single reinforcement value to an S. Thus in this Experiment one Group received equal reinforcement conditions with two different reinforcement durations utilized for each response alternative.

A second major finding of Experiment I was the non-monotinicity of the early portion of the learning curve for the unequal reinforcement Group which received durations of 4 and 32 sec. The initial rise to roughly the "matching" value and the subsequent change in direction of the curve to an asymptote of .42 suggested a two phase learning process. It may be suggested that Phase I is related to the presence or absence of reinforcement. A threshold value of reinforcement may have to be exceeded to "trigger" this Phase. After some number of trials, presumably well after S's consummatory behavior has developed, Phase II begins. Apparently only in this Phase do the various reinforcement parameters become effective. Since the "contrasted" reinforcement Group in Experiment I had an n of only 6, one Group in the present experiment is devoted to replicating the findings of Experiment I.

Of particular interest are the variables which might affect the point at which Phase II begins and those which determine asymptotic performance. Three variables may be suggested: (1) the size of the

difference between the contrasted reinforcement values, (2) whether the larger duration was given on the high or low π side, and (3) the utilization of two different reinforcement durations for a side. Asymptotic choice performance should be determined by the following: (1) the size of the differences between the reinforcement durations employed for the two sides, and (2) whether the larger duration is given on the high or low π side. The point at which Phase II begins might be influenced by the number of comparisons S can make between the reinforcement durations used. This comparison process may or may not be independent of the size of the differences between the durations of reinforcement given. Three Groups of the present Experiment were designed to extend the findings of Experiment I with the above hypotheses in mind.

Method

Subjects

Ninety-six female albino rats, 70-80 days old at the beginning of the experiment were received from Carworth, Rockland, New York.

Apparatus

The apparatus used and the response measures recorded were the same as in Experiment I.

Procedure

The gentling and adaptation to the deprivation procedure used were the same as that in Experiment I. Ss were split into two running shifts of 48 animals each and maintained on approximately a 20 hr. water deprivation schedule. Ss in both shifts were randomly assigned to one of five groups. Group I had 32 Ss while Groups I-V had 16 Ss each.

All Groups were given reinforcement on a 75-25 probability schedule with the high probability side (the A_1 side) being right and left respectively for half of the Ss in each group. Reinforcement schedules were randomly assigned in blocks of 16 trials with the restriction that each block have reinforcements in the ratio of 12:4.

Each shift was run at approximately the same time each day, but within each shift the Ss were run in a new random order each day. Each S had 4 runs a day with a minimum half hour ITI. The order of running each S within a day was fixed.

Table 33 presents the reinforcement durations employed. Wherever two reinforcement durations are shown for a side they were presented equally often according to a random schedule. The duration of reinforce-

Table 33 - Reinforcement Durations for the A_1 and A_2 Sides for Groups I-V of Experiment II

Group	A_1 Side	A_2 Side	Group Designation
I	4,32	4,32	4,32-4,32
II	4	32	4-32
III	32	4	32-4
IV	4	8	4-8
V	4	4,32	4-4,32

ment refers to the length of time S had to engage in drinking behavior.

All Groups were run under the same non-correction rerun procedure employed in Experiment I including the 30 sec. confinement in the goal box on all error trials.

Initially each shift was run for 3½ hrs. per day until the Ss were brought up to 4 runs per day. This took approximately 2½ weeks. All Ss started the 75-25 probability training with the appropriate reinforcement conditions from trial 1. Eight blocks of 16 trials were run so that Ss had approximately the same number of trials as the Ss under Phase II training in Experiment I.

One S in Group I and 4 Ss in Group IV died during the experiment and their data were excluded from all analyses.

Results of Experiment II

Choice Data

The side on which the larger proportion of reinforcement was available for each S was defined to be the A_1 side. Following the procedure of Experiment I all tests of significance based on proportion of A_1s were performed after applying an arc sine transformation to the choice data for each S over the trials being analyzed. Separate analyses of variance were performed to determine if there were any "side preferences" and whether the two "shifts" differed. No significant differences were found due to "side" or "shift" (Tables 34-35). Therefore the left and right sides and shifts one and two were combined to give the proportion of A_1 responses as the basis measure in all later analyses.

Inspection of Figure 19, which shows the learning curves for Groups I-V, reveals that all of the Groups showed an increase in the proportion of A_1s for the first two blocks at which point they began to show differences. This was confirmed by the non-significant results of the analysis of variance based on the total number of A_1 responses for Blocks 1-2 (Table 36).

Comparison of the learning curves of Group II and Group VI of Experiment I (replotted here in Blocks of 16 trials) reveals that, by and large, Group II replicated the results of Group VI. An analysis of variance performed on the A_1 frequency for each of the eight blocks (Table 37) revealed no significant Group difference or Group x Block interaction although a significant Block effect was found. The statistical tests used here for Block effects and for the Group x Block interactions assumes that the scores are independent. This is not the case

Table 34 - Analysis of Variance Based on Mean A_1 Proportion as a Function of "Side" for the Eight Blocks of Sixteen Trials for Groups I-V of Experiment II.

Source	SS	DF	MS	F
A_1 Side	0.074	1	0.074	0.005
Groups	1724.824	4	431.206	28.799*
A_1 Side x Group	16.084	4	4.021	0.269
Error	1212.829	81	14.973	

*$p < .05$

Table 35 - Analysis of Variance Based on Mean A_1 Proportion as a Function of "Shift" for the Eight Blocks of Sixteen Trials for Groups I-V of Experiment II.

Source	SS	DF	MS	F
Shift	12.716	1	12.716	0.873
Group	1762.250	4	440.562	30.260*
Shift x Group	35.797	4	8.949	0.615
Error	1179.310	81	14.559	

*$p < .05$

Figure 19 - Mean Proportion of A_1s over Blocks of Sixteen Trials for Groups I-V of Experiment II and Group VI of Experiment I. Group VI Includes Trials 25-152.

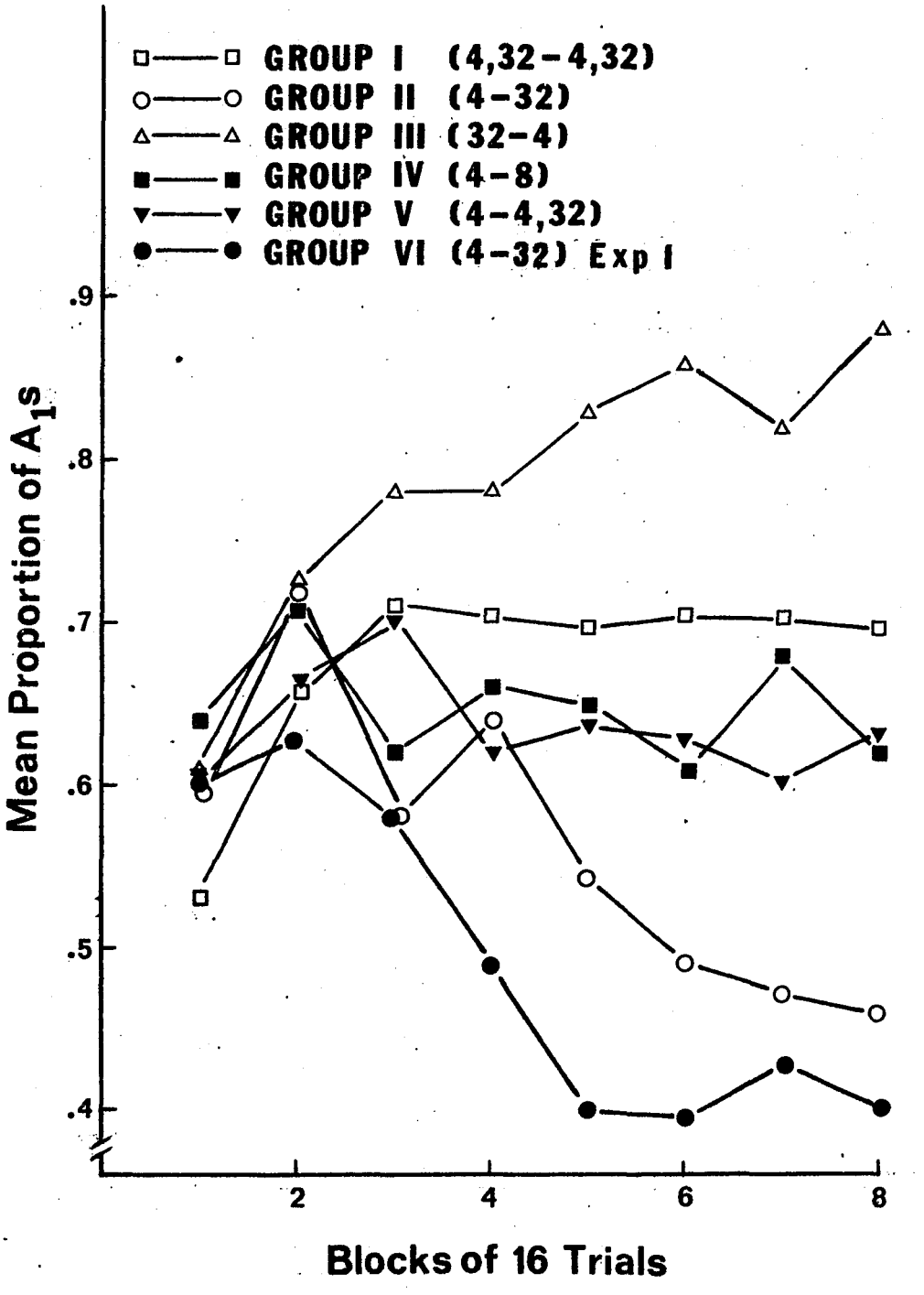

GROUP I (4,32-4,32)
GROUP II (4-32)
GROUP III (32-4)
GROUP IV (4-8)
GROUP V (4-4,32)
GROUP VI (4-32) Exp I
Mean Proportion of A1s
.9
.8
.7
.6
.5
.4
2
4
6
8
Blocks of 16 Trials

Table 36 - Analysis of Variance Based on Number of A_1 Responses for Blocks 1-2 for Groups I-V of Experiment II.

Source	SS	DF	MS	F
Between	60.121	4	15.030	1.799
Within	718.407	86	8.354	
Total	778.527	90		

*$p < .05$

Table 37 - Analysis of Variance Based on the Frequency of A_1 Responses for the Eight Blocks of Sixteen Trials for Group II of Experiment II and Group VI of Experiment I.

Source	SS	DF	MS	F
Group	38.640	1	38.640	1.757
Error	439.792	20	21.990	
Block	128.728	7	18.380	5.188*
Group x Block	24.772	7	3.539	0.995
Error	496.250	140	3.545	

*$p < .05$

since we have repeated measurements on each S. Greenhouse and Geisser (1959) suggest a procedure which adjusts the number of d.f.s. in order to remove possible correlations between these scores, thereby avoiding the theoretically appropriate multivariate analysis of variance. The correction was not applied here to the Block effect, since, in the present study it simply demonstrated learning.

Separation of the Groups from the reference Group (Group I) occurred at Block 3 except for Group V which occurred at Block 4. This was confirmed by the significant analysis of variance based on the total number of A_1 responses for Blocks 3-4 (Table 38). Comparisons between all pairs of means employing the Tukey (b) procedure showed Group I to be significantly different from Groups II, III and IV while Group III was different from Groups II, IV and V ($p < .05$). No other comparisons were significant ($p > .05$). The finding that Group V, which was the only Group to receive two reinforcement values for only one of the alternatives (4 - 4,32), continued (to show an increase in the proportion of A_1s for the third block) with Group I suggests that the point at which differences in the durations of reinforcement became effective depended on the frequency of exposure to the different durations and not on the absolute values. This was also indicated by the performance of Groups II (4-32), III (32-4) and IV (4-8), which diverged from each other at Block 3 even though they all reached different asymptotes (Blocks 5-8 in Figure 19).

The mean proportion of A_1 responses for Groups I-V for the asymptotic blocks were .7025, .4893, .8525, .6350 and .6250 respectively. The analysis of variance found in Table 39 showed these differences to be significant ($p < .05$). Comparison of the individual pairs of

Table 38 - Analysis of Variance Based on Number of A_1 Responses for Blocks 3-4 for Groups I-V of Experiment II.

Source	SS	DF	MS	F
Between	385.496	4	96.374	10.586*
Within	782.944	86	9.104	
Total	1168.440	90		

*$p < .05$

Table 39 - Analysis of Variance Based on Mean Proportion of A_1 Responses over Asymptotic Blocks 5-8 for Groups I-V of Experiment II.

Source	SS	DF	MS	F
Between	4388.486	4	1097.121	35.613*
Within	2649.402	86	30.807	
Total	7037.888	90		

*$p < .05$

means (Tukey b) revaled non-significant differences between Groups I and IV and Groups IV and V ($p > .05$) while all other comparisons were significant ($p < .05$).

Group I (4,32-4,32) showed a slight, but significant, undershooting of the expected .75 asymptote $t = 2.967$ ($df = 30$, $p < .05$), as had Groups I-III of Experiment I. Estimations of the $\underline{\theta}$-value for Group I is complicated because there are two types of E_1 and E_2 outcomes, i.e. both large and small reinforcement durations are given half the time for each side. Inspection of Table 40, which shows the conditional probabilities for Groups I-V over Blocks 5-8, showed that for small duration of reinforcement trials $P(A_1|E_1) = .7210$ and $P(A_1|E_2) = .5571$. For large duration of reinforcement trials $P(A_1|E_1) = .7412$ and $P(A_1|E2) = .6797$. The conditional probabilities revealed a difference between $P(A_1|E_2)$ for large and small duration of reinforcement. Following a small duration of reinforcement E_2 there was a lower probability of responding to the A_1 side. Estimating the $\underline{\theta}$-values from the difference between $P(A_1|E_1)$ and $P(A_1|E_2)$ for each magnitude we find that θ_S (small duration) equalled .1739 and θ_L (large duration) equalled .0615. This result is unexpected in that large duration of reinforcement should lead to faster conditioning, i.e., larger $\underline{\theta}$-values. Because of the above differences no theoretical curve was generated. In general the conditional probabilities of Groups I and V seemed to indicate that the $\underline{Ss}$ responded differently depending on the duration of reinforcement given.

General qualitative tests of the model for Groups I employed comparisons between the obtained error run lengths of 0-5 with the theoretical values (Table 41) and the comparison between the obtained

Table 40 - The Conditional Probabilities $P(A_1|E_1)$ and $P(A_1|E_2)$ Over Asymptotic Blocks 5-8 for Groups I-V of Experiment II. Given are the Values for Each Duration of Reinforcement and Their Combined Value if More than One Reinforcement Duration is Given on a Side.

Group		$P(A_1\|E1)$	$P(A_1\|E_2)$
I	32 sec. dur.	.7412	.6797
	4 sec. dur.	.7210	.5571
	combined	.7311	.6184
II		.5106	.4563
III		.8889	.7540
IV		.6667	.5938
V	32 sec. dur.	----	.5476
	4 sec. dur.	----	.5000
	combined	.6422	.5156

Table 41 - Expected and Obtained Mean Proportion of Error Run Lengths 0 Through 5 to the A_1 and A_2 Sides over the Asymptotic Blocks for Group I of Experiment II. The Expected Proportions are Derived Employing the Empirical Asymptote of .7025 for Group I.

Error Run Length	Expected		Obtained	
0	A_1	A_2	A_1	A_2
0	.5269	.0744	.5267	.0798
1	.0700	.0890	.0884	.1894
2	.0492	.0265	.0510	.0278
3	.0346	.0079	.0237	.0025
4	.0243	.0023	.0040	.0005
5	.0171	.0007	.0025	.0000

and theoretical pairs and triplets of all A_1 and A_2 response sequences (Table 42). The theoretical statistics for both the error run lengths and the sequential statistics were derived using the empirical .7025 asymptotic proportion of A_1 responses. Inspection of Table 41 shows too few error run lengths of greater than 3 to the A_1 side and too many error runs of length 1 to the A_2 side. Most of the sequential statistics, Table 42, show agreement within 3% of the expected values. The discrepancies reveal too few runs of A_{11}, A_{22}, A_{111} and A_{222} while the sequences involving both A_1 and A_2 responses are somewhat above the expected values.

Finally, inspection of Figure 20, which shows the individual Ss learning curves for Groups I-V as cumulative frequency of A_1 responses over blocks of 16 trials, reveals essentially parallel learning curves which indicate that the Ss were responding similarly. The graphs start with the S with the lowest cumulative frequency and the starting point of each additional S is stepped up by 10 on the Y-axis.

Time Data

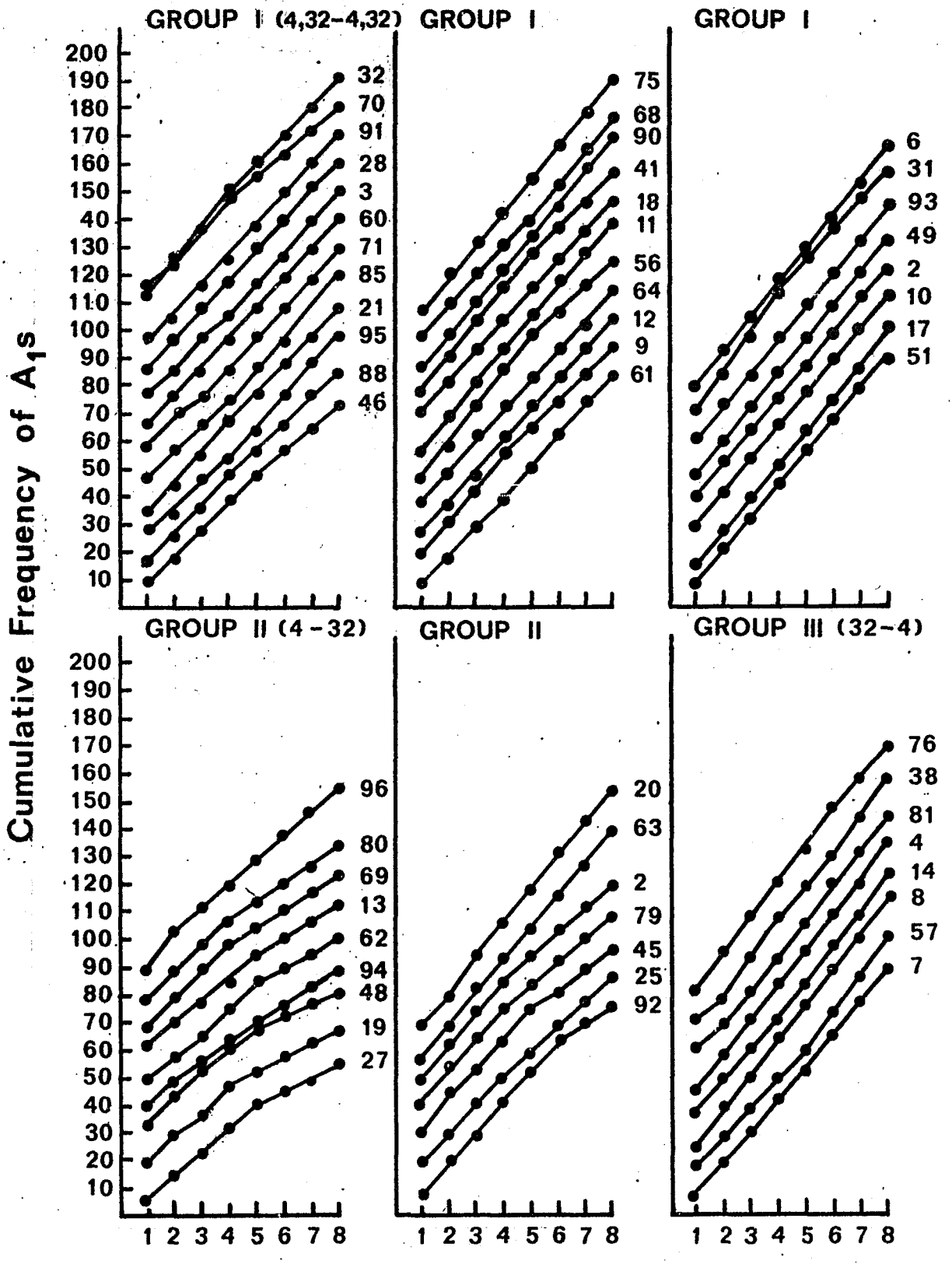
Latency, choice time, and committed time were converted to reciprocals (1/sec., 10/sec., 1/sec. respectively) throughout.

Separate analyses of variance were performed to determine if there were any "side preferences" and whether the two "shifts" differed for any of the time measures. No significant differences were found due to "side" (Tables 43-45) and so the left and right sides were combined to give the basic time measures in all later analyses. All of the "shift" analyses were significant (Tables 46-48). Inspection of Table 49, which shows the means for each Group and shift for the latency, choice and committed measures, revealed shift 2 to be slightly faster than shift 1. The data for both shifts were still combined in all later analyses as

Table 42 - Sequential Statistics: Expected and Obtained Mean Proportion of Pairs and Triplets of A_1 and A_2 Responses Over the Asymptotic Blocks for Group I of Experiment II. The Expected Proportions are Derived Employing the Empirical .7025 Asymptote of Group I.

Sequence	Expected	Obtained
A_{11}	.4935	.4675
A_{12}	.2090	.2340
A_{21}	.2090	.2361
A_{22}	.0885	.0624
A_{111}	.3467	.3078
A_{112}	.1468	.1568
A_{121}	.1468	.1807
A_{211}	.1468	.1568
A_{221}	.0622	.0542
A_{212}	.0622	.0818
A_{122}	.0622	.0536
A_{222}	.0263	.0083

Figure 20 - Cumulative Frequency of A_1 Responses as a Function of Blocks of Sixteen Trials for Individual Ss in Groups I-V of Experiment II. The Starting Point for Each S is Stepped Up by 10 Units on the Y-Axis.


GROUP I (4,32-4,32)
GROUP I
GROUP I
GROUP II (4-32)
GROUP II
GROUP III (32-4)
Cumulative Frequency of A_1s
Blocks of 16 Trials
32 70 91 28 3 60 71 85 21 95 88 46
75 68 90 41 18 11 56 64 12 9 61
6 31 93 49 2 10 17 51
96 80 69 13 62 94 48 19 27
20 63 2 79 45 25 92
76 38 81 4 14 8 57 7

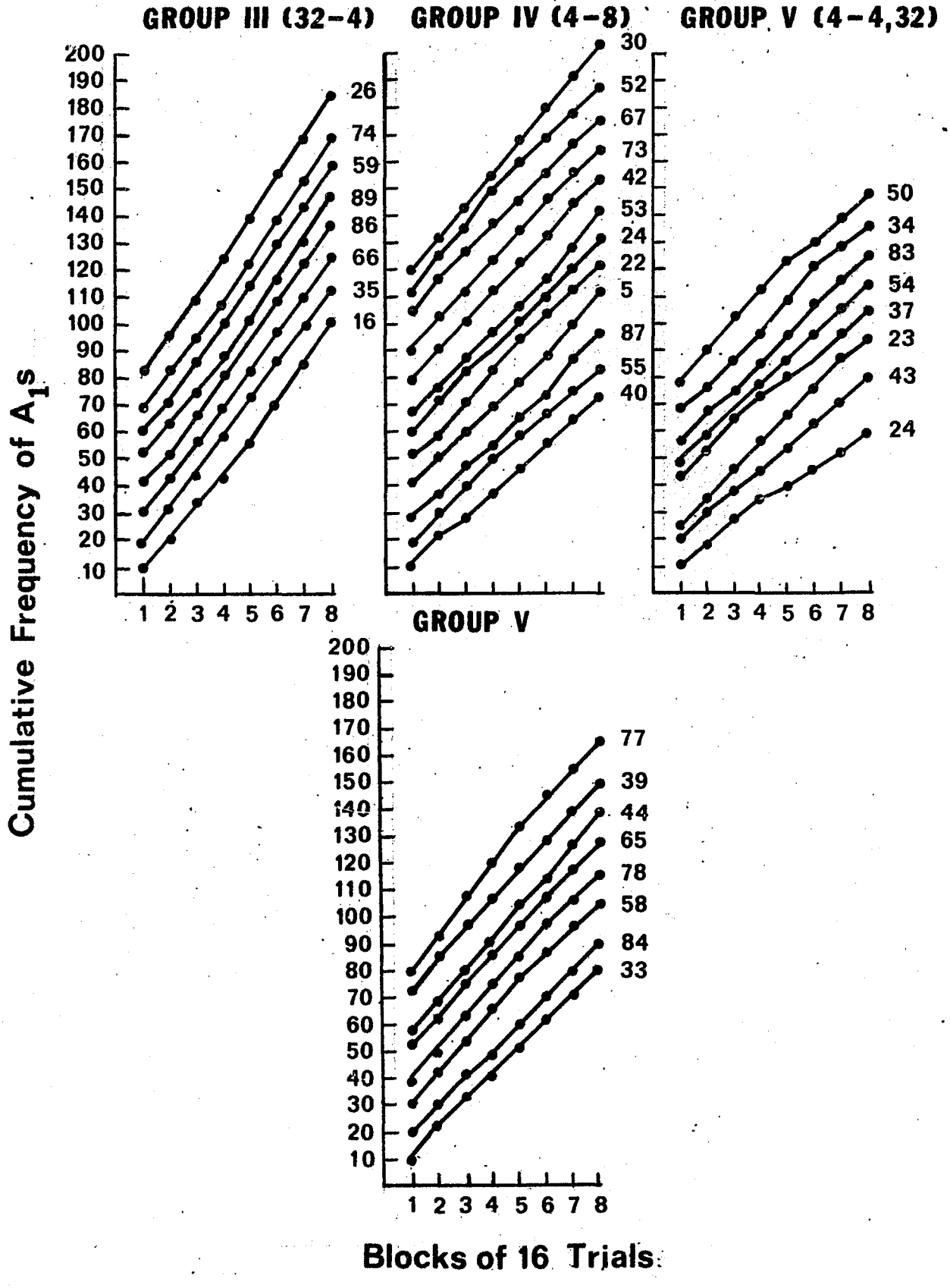

GROUP III (32-4)
GROUP IV (4-8)
GROUP V (4-4,32)
GROUP V
Cumulative Frequency of A_1s
Blocks of 16 Trials
26 74 59 89 86 66 35 16
30 52 67 73 42 53 24 22 5 87 55 40
50 34 83 54 37 23 43 24
77 39 44 65 78 58 84 33

Table 43 - Analysis of Variance Based on Mean Reciprocal Latency ($\overline{1}$/sec.) as a Function of "Side" for the Eight Blocks of Sixteen Trials for Groups I-V of Experiment II.

Source	SS	DF	MS	F
A_1 Side	0.236	1	0.236	0.310
Group	1.171	4	0.293	0.385
A_1 Side x Group	1.573	4	0.393	0.516
Error	61.668	81	0.761	

*p < .05

Table 44 - Analysis of Variance Based on Mean Reciprical Choice Time ($\overline{10}$/sec.) as a Function of "Side" for the Eight Blocks of Sixteen Trials for Groups I-V.

Source	SS	DF	MS	F
A_1 Side	14.370	1	14.370	1.516
Group	76.530	4	19.133	2.018
A_1 Side x Group	23.937	4	5.984	0.631
Error	767.798	81	9.479	

*p < .05

Table 45 - Analysis of Variance Based on Mean Reciprocal Committed Time ($\overline{1}$/sec.) as a Function of "Side" for the Eight Blocks of Sixteen Trials for Groups I-V of Experiment II.

Source	SS	DF	MS	F
A_1 Side	0.125	1	0.125	0.593
Group	0.572	4	0.143	0.681
A_1 Side x Group	1.098	4	0.274	1.306
Error	17.021	81	0.210	

*$p < .05$

Table 46 - Analysis of Variance Based on Mean Reciprocal Latency ($\overline{1}$/sec.) as a Function of "Shift" for the Eight Blocks of Sixteen Trials for Groups I-V of Experiment II.

Source	SS	DF	MS	F
Shift	7.469	1	7.469	11.585*
Group	1.216	4	0.304	0.471
Shift x Group	1.722	4	0.430	0.668
Error	52.221	81	0.645	

*$p < .05$

Table 47 - Analysis of Variance Based on Mean Reciprocal Choice Time ($\overline{10}$/sec.) as a Function of "Shift" for the Eight Blocks of Sixteen Trials for Groups I-V.

Source	SS	DF	MS	F
Shift	125.687	1	125.687	15.286*
Group	69.233	4	17.308	2.105
Shift x Group	11.022	4	2.755	0.335
Error	665.982	81	8.222	

*$p < .05$

Table 48 - Analysis of Variance Based on Mean Reciprocal Committed Time ($\overline{1}$/sec.) as a Function of "Shift" for the Eight Blocks of Sixteen Trials for Groups I-V of Experiment II.

Source	SS	DF	MS	F
Shift	2.291	1	2.291	12.655*
Group	0.463	4	0.116	0.639
Shift x Group	0.255	4	0.064	0.352
Error	14.663	81	0.181	

*$p < .05$

Table 49 - Mean Reciprocal Latency ($\overline{1}$/sec.), Choice Time ($\overline{10}$/sec.) and Committed Time ($\overline{1}$/sec.) for Shifts 1 and 2 for Groups I-V of Experiment II.

Latency

Groups	I	II	III	IV	V
Shift 1	3.785	4.613	4.342	4.347	3.916
Shift 2	4.574	4.749	4.778	4.466	4.818

Choice Time

Groups	I	II	III	IV	V
Shift 1	5.354	5.095	5.458	3.520	3.884
Shift 2	6.957	7.368	8.985	5.424	6.994

Committed Time

Groups	I	II	III	IV	V
Shift 1	2.359	2.453	2.592	2.454	2.499
Shift 2	2.865	2.683	2.901	2.664	2.909

each Group was equally represented within both shifts.

Inspection of Figures 21-23 showing the Group learning curves for the latency, choice and committed measures reveal the typical negatively accelerated learning curves for each. The results of separate analyses of variance performed on the mean reciprocal latency, choice and committed measures over the asymptotic Blocks (5-8), Tables 50-52 respectively, showed that only the choice time measure yielded a significant Group effect. Individual Group comparisons employing the Tukey (b) procedure revealed only the difference between Groups III and IV to be significant ($p < .05$).

The latency, choice and committed time measures were further analyzed as a function of choice, i.e., whether the response terminated on the A_1 or A_2 alternative. Figure 24 shows this graphically for Groups I-V while Tables 53-55 show the corresponding analyses of variance for the asymptotic blocks. The statistical tests used here (Tables 53-55) assume that the scores are independent. This is not the case since we have repeated measures on each S. The conservative Greenhouse and Geisser (1959) d.f. correction procedure was applied only when the Group x Choice interaction was significant under the original technique. Whenever this was done the corrected number of d.f.s was put in parentheses in the analysis of variance table. If the F was still significant with the adjusted d.f. this was indicated by an asterik, otherwise it was left blank. This procedure was followed for all repeated measure analyses of variance.

The latency analysis yielded no significant differences. The Group effect for the choice time measure was not significant, though previously a significant Group effect was found (Table 51). This

Figure 21 - Mean Reciprocal Latency ($\overline{1}$/sec.) in Blocks of 16 Trials for Groups I-V of Experiment II.

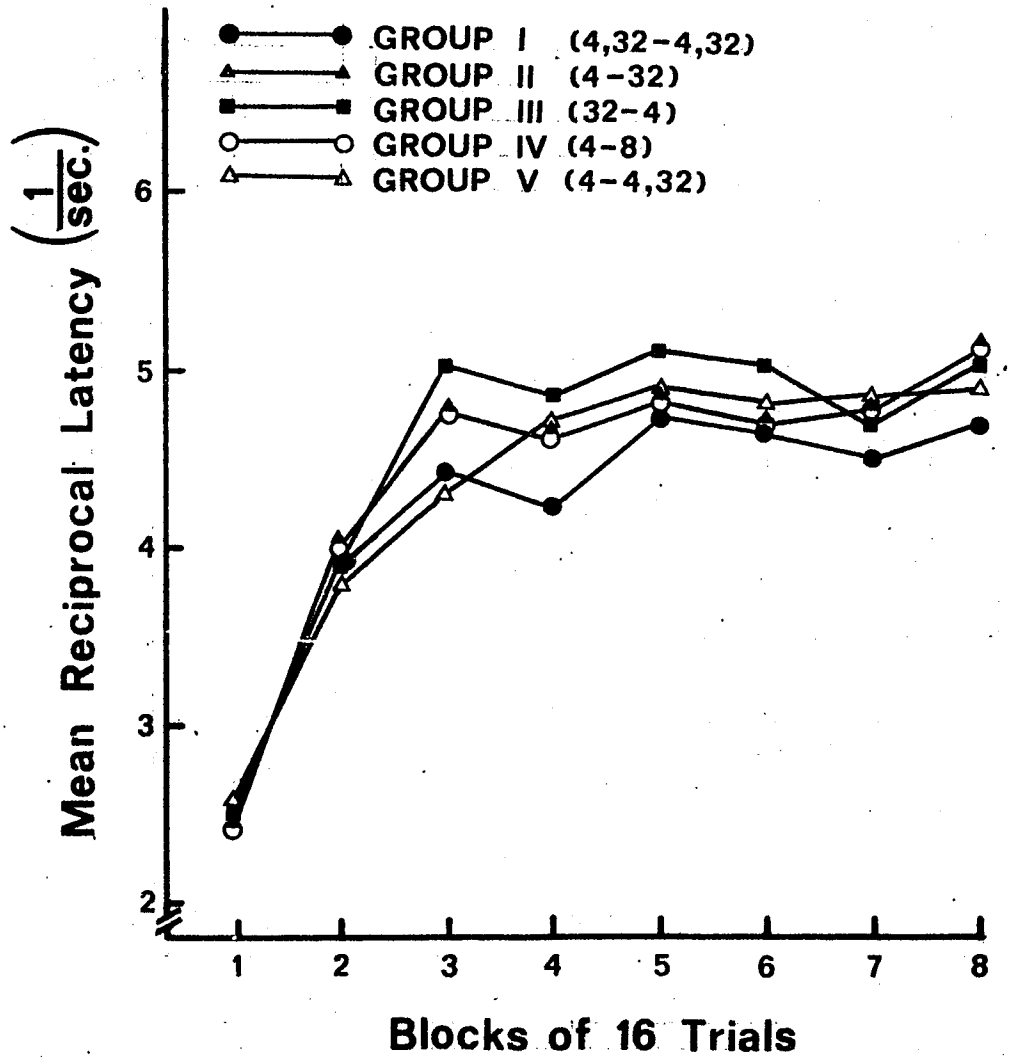

GROUP I (4,32-4,32)
GROUP II (4-32)
GROUP III (32-4)
GROUP IV (4-8)
GROUP V (4-4,32)
Mean Reciprocal Latency (1/sec.)
6
5
4
3
2
1
2
3
4
5
6
7
8
Blocks of 16 Trials

Figure 22 - Mean Reciprocal Choice Time ($\overline{10}$/sec.) in Blocks of 16 Trials for Groups I-V of Experiment II.

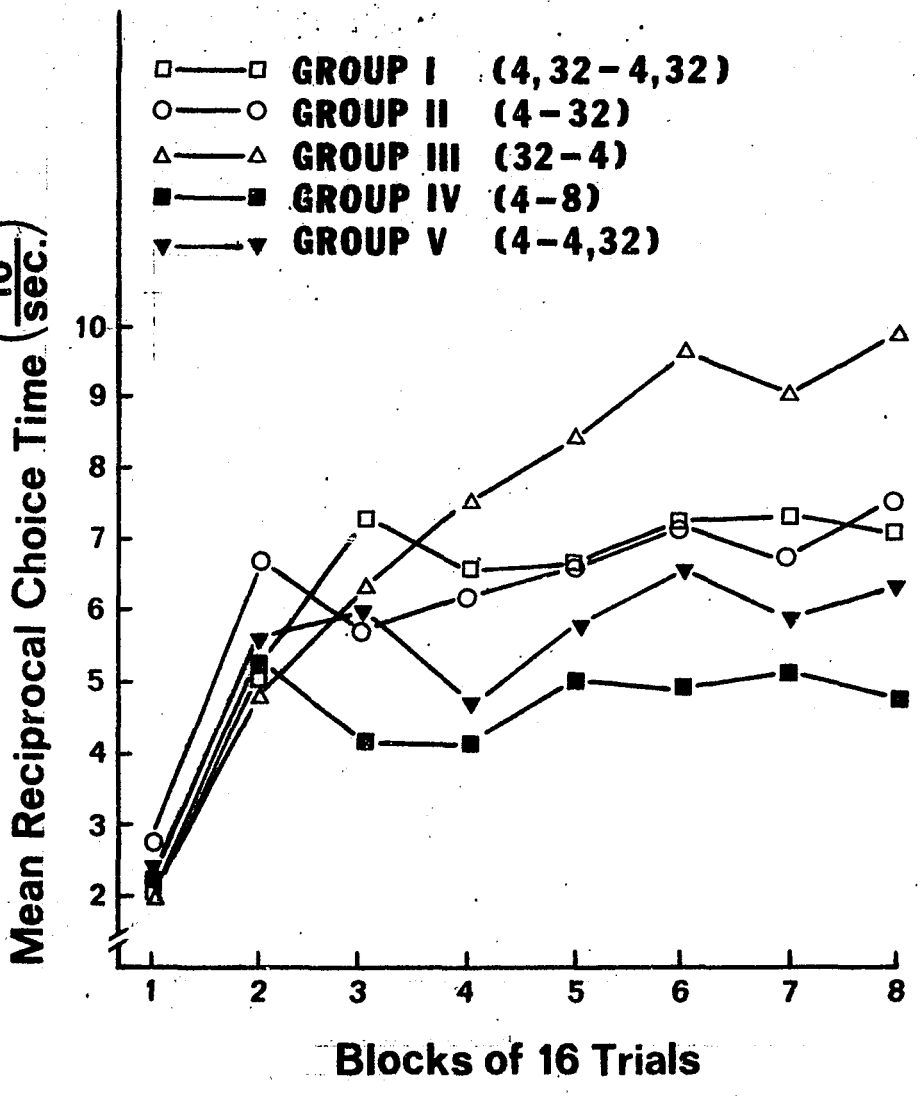

GROUP I (4,32-4,32)
GROUP II (4-32)
GROUP III (32-4)
GROUP IV (4-8)
GROUP V (4-4,32)
Mean Reciprocal Choice Time (10/sec.)
10
9
8
7
6
5
4
3
2
1
2
3
4
5
6
7
8
Blocks of 16 Trials

Figure 23 - Mean Reciprocal Committed Time ($\overline{1}$/sec.) in Blocks of 16 Trials for Groups I-V of Experiment II.

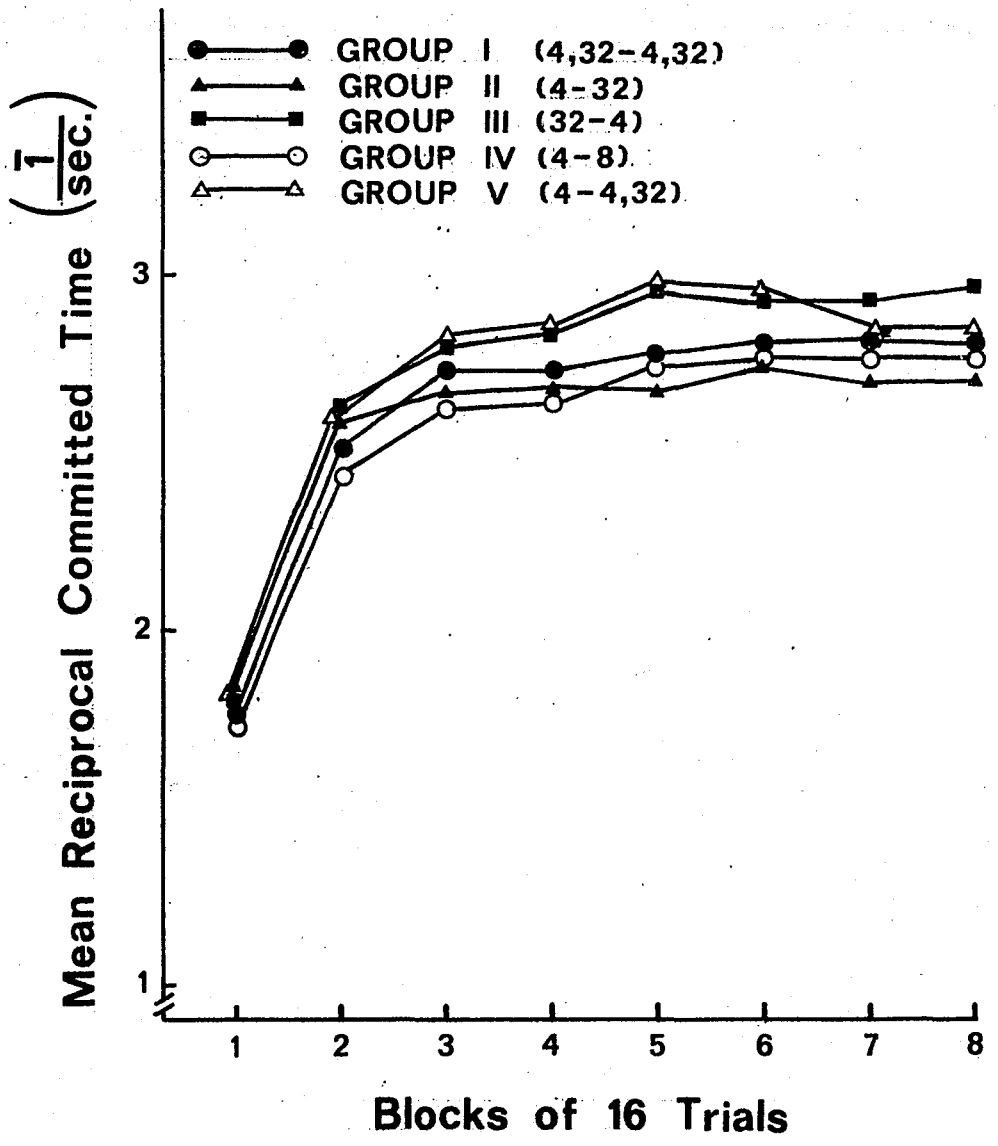

GROUP I (4,32-4,32)
GROUP II (4-32)
GROUP III (32-4)
GROUP IV (4-8)
GROUP V (4-4,32)
Mean Reciprocal Committed Time (1/sec.)
3
2
1
1
2
3
4
5
6
7
8
Blocks of 16 Trials

Table 50 - Analysis of Variance Based on the Mean Reciprocal Latency ($\overline{1}$/sec.) over the Asymptotic Blocks 5-8 for Groups I-V of Experiment II.

Source	SS	DF	MS	F
Between	2.038	4	0.509	0.764
Within	57.311	86	0.666	
Total	59.349	90		

*p < .05

Table 51 - Analysis of Variance Based on the Mean Reciprocal Choice Time ($\overline{10}$/sec.) over the Asymptotic Blocks 5-8 for Groups I-V of Experiment II.

Source	SS	DF	MS	F
Between	151.548	4	37.887	2.813*
Within	1158.344	86	13.469	
Total	1309.893			

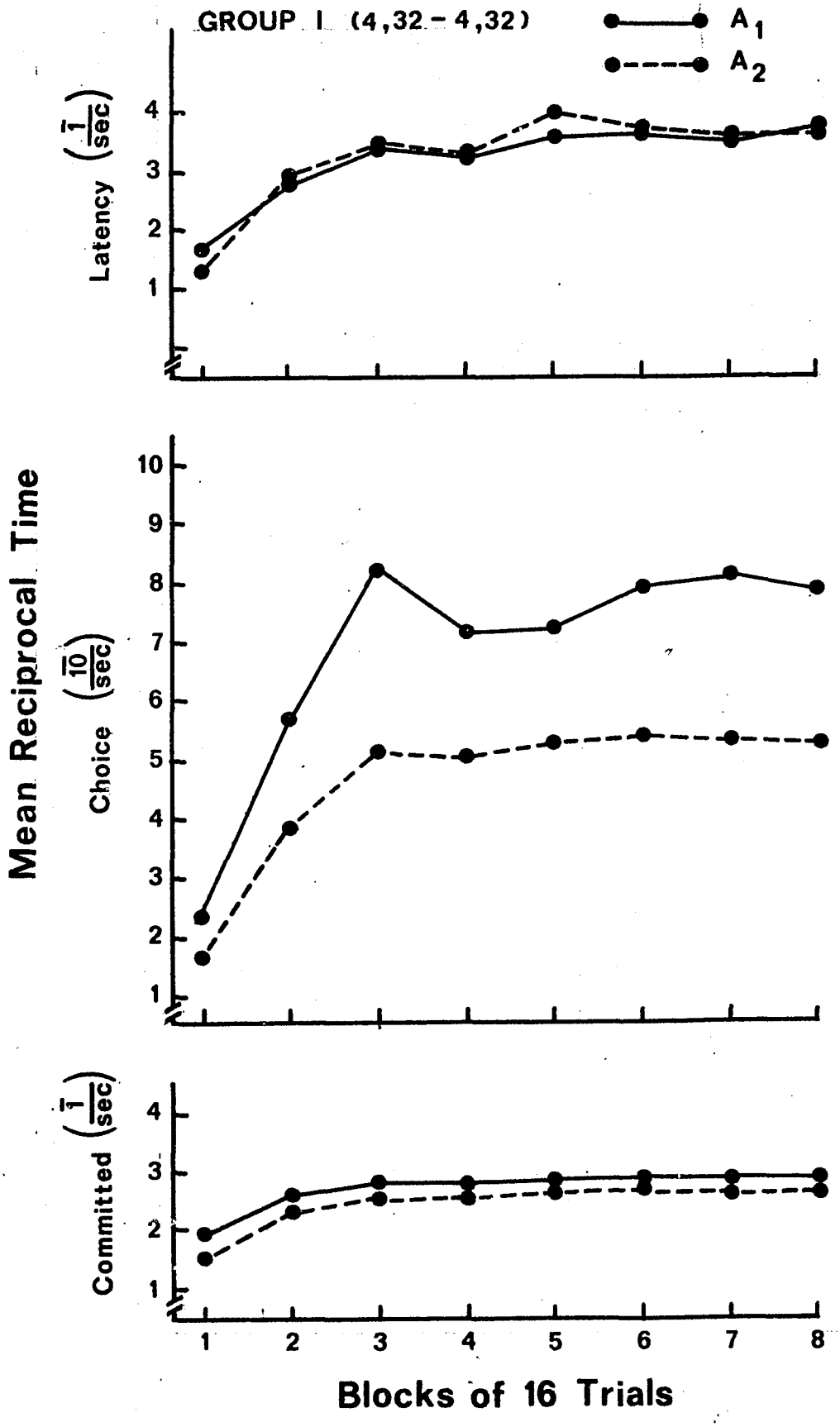
*p < .05

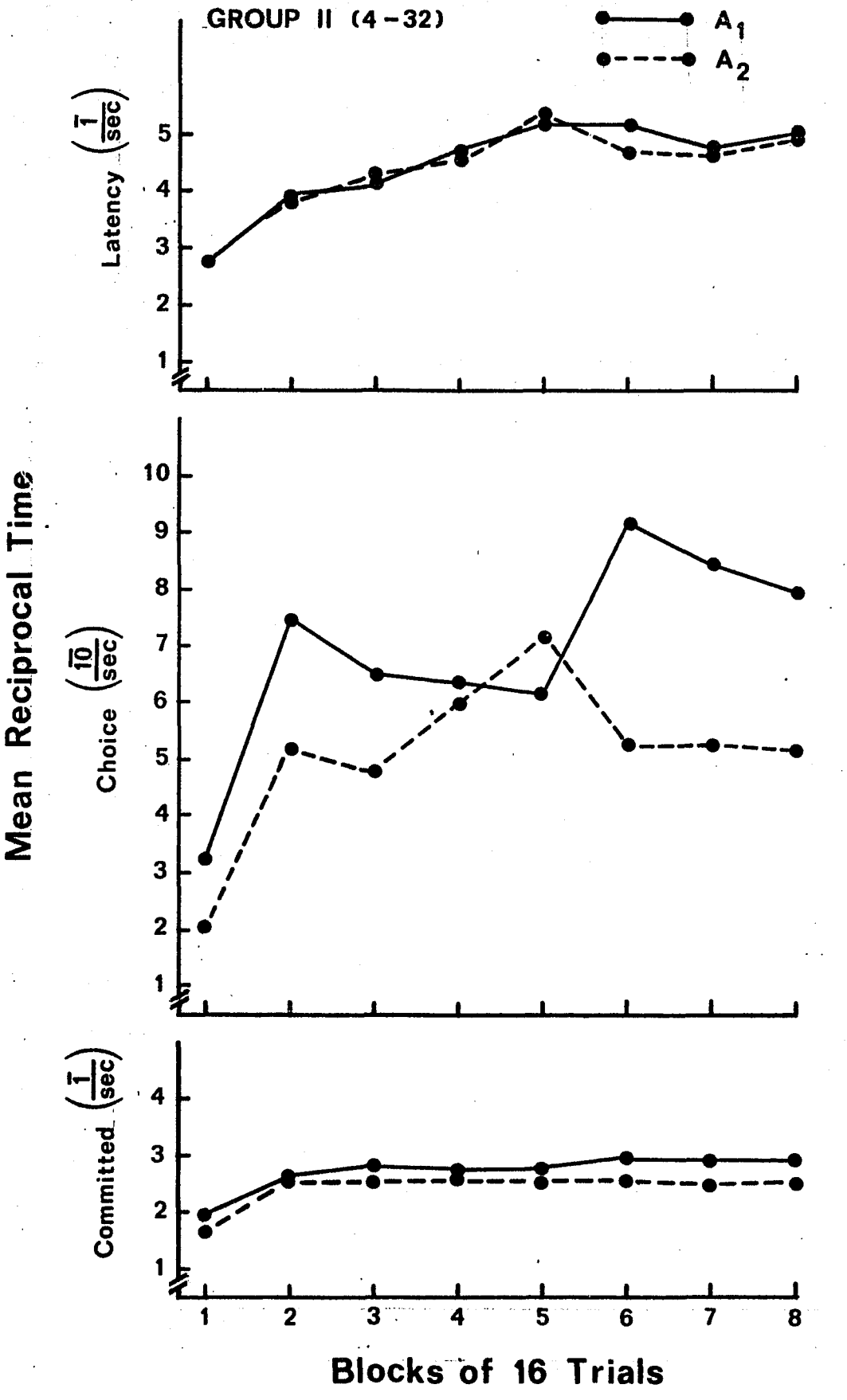
Table 52 - Analysis of Variance Based on the Mean Reciprocal Committed Time ($\overline{1}$/sec.) over the Asymptotic Blocks 5-8 of Groups I-V of Experiment II.

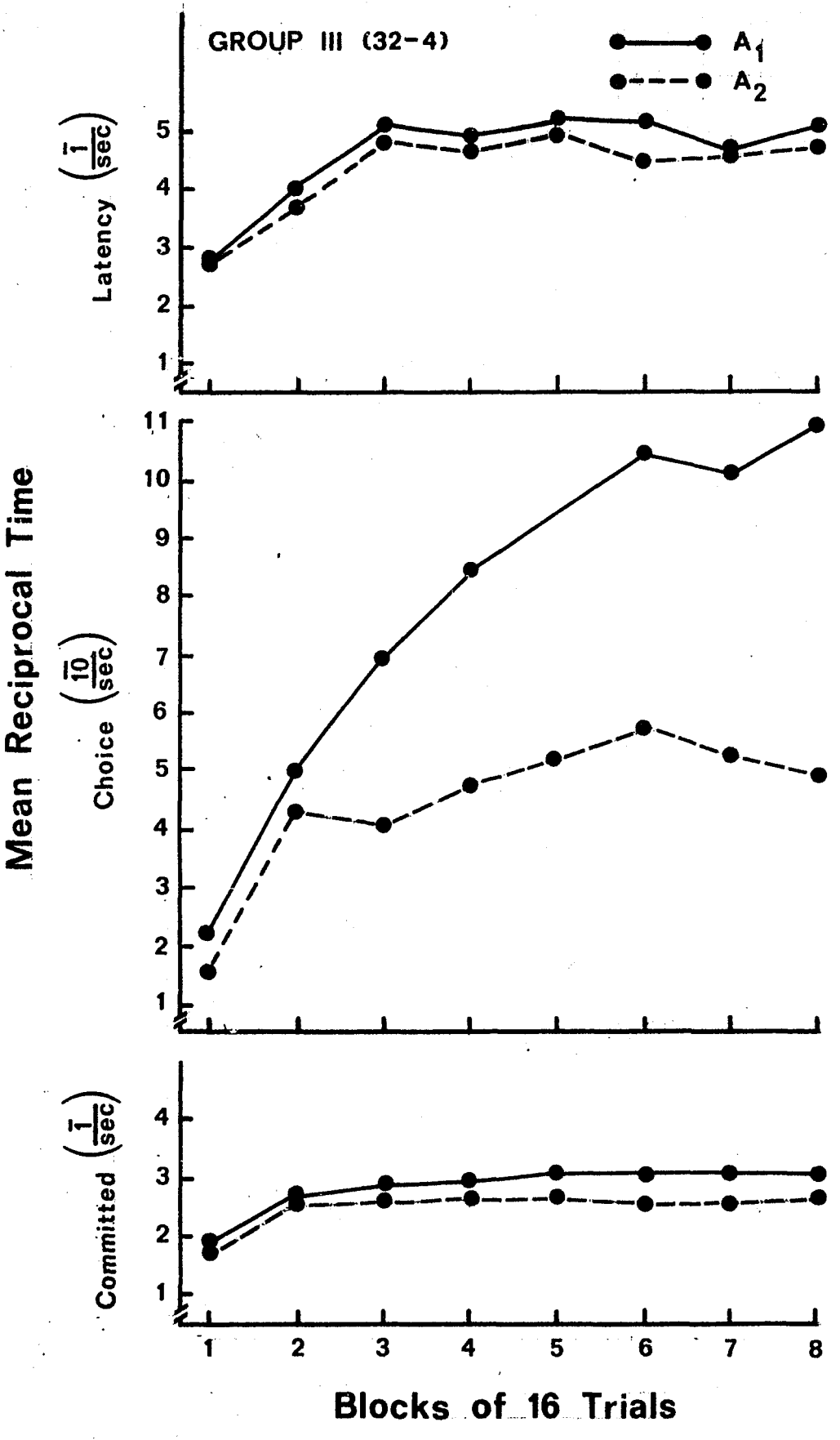
Source	SS	DF	MS	F
Between	0.659	4	0.165	0.619
Within	22.877	86	0.266	
Total	23.536	90		

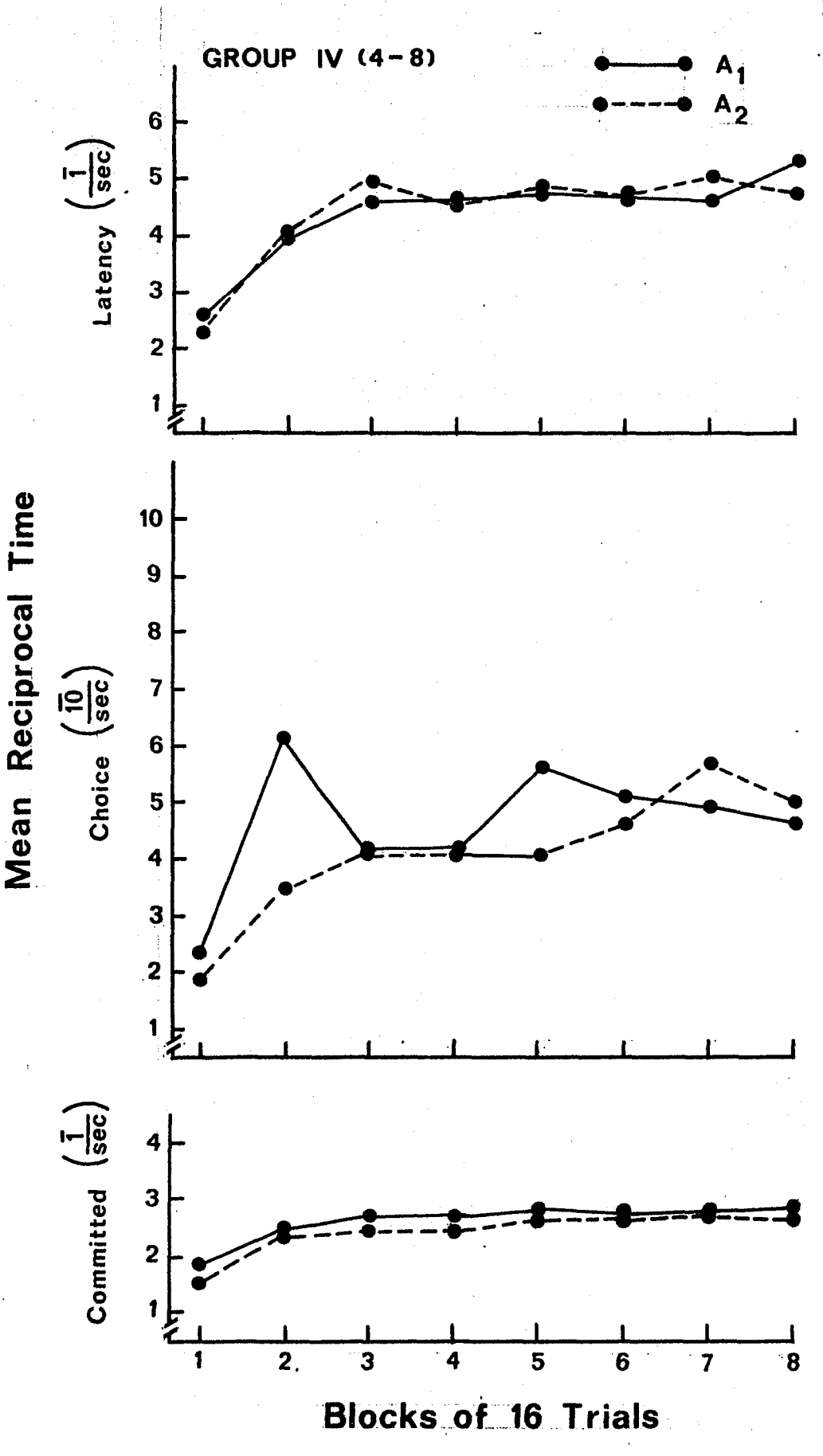
*p < .05

Figure 24 - Mean Reciprocal Latency ($\overline{1}$/sec.), Choice Time ($\overline{10}$/sec.) and Committed Time ($\overline{1}$/sec.) as a Function of A_1 and A_2 Responses over Blocks of Sixteen Total Trials for Groups I-V of Experiment II. (The Number of A_1 and A_2 Responses for each Block Totals 16).


GROUP I (4,32 - 4,32)
A1
A2
Latency (1/sec)
Choice (10/sec)
Committed (1/sec)
Mean Reciprocal Time
Blocks of 16 Trials


GROUP II (4-32)
A1
A2
Mean Reciprocal Time
Latency (1/sec)
Choice (10/sec)
Committed (1/sec)
Blocks of 16 Trials


GROUP III (32-4)
A1
A2
Mean Reciprocal Time
Latency (1/sec)
Choice (10/sec)
Committed (1/sec)
Blocks of 16 Trials


GROUP IV (4-8)
A1
A2
Mean Reciprocal Time
Latency (1/sec)
Choice (10/sec)
Committed (1/sec)
Blocks of 16 Trials

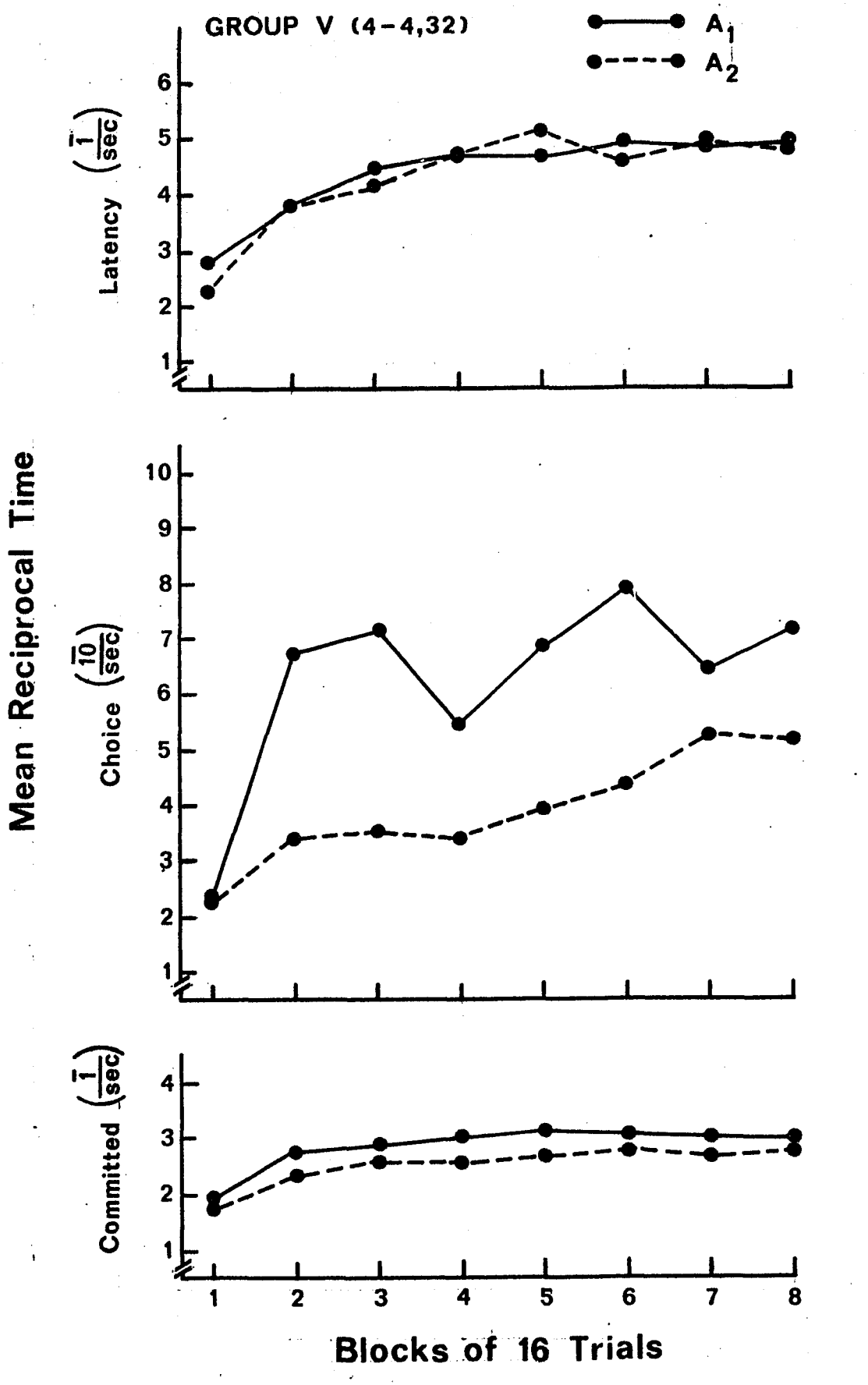

GROUP V (4-4,32)
A1
A2
Mean Reciprocal Time
Latency (1/sec)
Choice (10/sec)
Committed (1/sec)
Blocks of 16 Trials

Table 53 - Analysis of Variance Based on Mean Reciprocal Latency ($\overline{1}$/sec.) for Asymptotic Blocks 5-8 for Groups I-V of Experiment II.

Source	SS	DF	MS	F
Group	3.969	4	.992	0.646
Error	132.053	86	1.536	
Choice	.001	1	.001	0.018
Group x Choice	.209	4	.052	0.955
Error	9.415	172	.055	

*p < .05

Table 54 - Analysis of Variance Based on Mean Reciprocal Choice Time ($\overline{10}$/sec.) for Asymptotic Blocks 5-8 for Groups I-V of Experiment II.

Source	SS	DF	MS	F
Group	128.124	4	32.031	1.226
Error	2246.627	86	26.124	
Choice	200.38	1	200.38	110.830* (1/86)
Group x Choice	95.977	4	23.994	13.271* (4/86)
Error	311.009	172	1.808	

*$p < .05$

Table 55 - Analysis of Variance Based on Mean Reciprocal Committed Time ($\overline{1}$/sec.) for Asymptotic Blocks 5-8 for Groups I-V of Experiment II.

Source	SS	DF	MS	F
Group	.633	4	0.158	0.318
Error	42.794	86	0.498	
Choice	2.73	1	2.73	88.064* (1/86)
Group x Choice	0.100	4	0.025	0.806
Error	5.332	172	0.031	

*$p < .05$

discrepancy can be resolved by reference to the way in which the mean choice times are calculated for the one way analysis of variance and for the two way analysis of variance. The single classification analysis of variance is based on all trials over the asymptotic Blocks 5-8 while for the two way analysis the mean A_1 and A_2 times were calculated separately over the asymptotic blocks. There were a variable number of responses to the A_1 and A_2 sides for each block and each S. In particular, Group III had some Ss that made no A_2 responses over some of the later blocks. In the two way analysis the mean for a Group gives an equal weight to the A_1 and A_2 means while they should be weighted with their frequencies to get the appropriate over-all mean.

Due to the significant Group x Choice interactions (Table 54) the choice time measure was reanalyzed by calculating separate one way analyses for the A_1 and A_2 responses for Groups I-V (Tables 56-57). Only the difference between the A_1 responses were significant and here the only significant difference was between Groups III and IV ($p < .05$). In addition five separate correlated t-tests were calculated to determine which Groups had different A_1 and A_2 choice times because of the significant Group x Choice interaction (Table 54). For Groups I ($t=3.67$, $df=30$), III ($t=3.80$, $df=15$) and V ($t=2.30$, $df=15$), $p < .05$ the response to the A_1 alternative was faster. For Groups II ($t=0.28$, $df=15$), and IV ($t=0.94$, $df=11$) $p > .05$ the response to the A_1 and A_2 alternatives were not significantly different.

Due to the significant Choice effect for the committed time measure (Table 55) five separate correlated t-tests were performed

Table 56 - Analysis of Variance Based on the Mean Reciprocal A_1 Choice Time ($\overline{10}$/sec.) for the Asymptotic Blocks 5-8 for Groups I-V of Experiment II.

Source	SS	DF	MS	F
Between	182.907	4	45.747	2.506*
Within	1569.715	86	18.252	
Total	1752.702	90		

*$p < .05$

Table 57 - Analysis of Variance Based on the Mean Reciprocal A_2 Choice Time ($\overline{10}$/sec.) over the Asymptotic Blocks 5-8 for Groups I-V of Experiment II.

Source	SS	DF	MS	F
Between	41.108	4	10.277	1.028
Within	859.111	86	9.998	
Total	900.919	90		

*p < .05

to determine which Groups had different A_1 and A_2 committed times. The differences between A_1 and A_2 committed times were significant for all Groups. The *t*-tests were 5.93, 2.75, 2.68, 2.98 and 4.08 with df's = 30, 15, 15, 11 and 16 $p < .05$ for Groups I-V respectively.

To determine if there were any differences in the choice and committed time measures for the same durations of reinforcement the following *t*-tests were performed for: a) the 4 sec. duration -- II(A_1) - III(A_2), II(A_1) - IV(A_1) and III(A_1) - IV(A_1); and for b) the 32 sec. duration -- III (A_1) - II(A_2). All the comparisons for the choice time were not significant ($p > .05$), $t = 1.100$ (df=30), $t=1.169$ (df=26), $t=0.192$ (df=26), and $t=1.823$ (df=30), respectively. In addition all the committed time comparisons were not significant ($p > .05$), $t = 0.858$ (df=30), $t = -0.135$ (df=26), $t = -0.198$ (df=26) and $t = 1.836$ (df=30), respectively.

Discussion

As in Experiment I a significant feature of the present choice probability data is reflected in the similarity and stability of the individual learning curves within each of the Groups. Again, as in Experiment I, Group I which received equal reinforcement conditions for each alternative, showed a small but significant undershooting of the theoretical .75 asymptote. Weinstock, et al. (1972) employing an n of 9 also reported a small, but non-significant, undershooting of the theoretical asymptote. Thus the non-correction rerun procedure as presently employed apparently leads to a small but systematic departure from the theoretical model.

Qualitative comparisons of the fine detail of the data approximated the expected values of the equal θ model if the obtained asymptote of Group I was used for predictive purposes. The identity operator approximation, as in Experiment I and Weinstock, et al. (1972) did not hold tightly for non-corrected "runs". There were too few error run lengths of greater than three with too many error runs of length one. This discrepancy can again be accounted for by the introduction of new stimulus components due to nonreinforcement. They become conditioned over trials to the opposite response thereby increasing the probability of a correct response after an error.

The major positive finding of the present study was the non-monotonicity of the choice probability data of the unequal reinforcement Groups II-V which replicated the results of Group VI of Experiment I. The similarity in choice behavior of all of the Groups over the first two blocks of trials suggests that in early trials, all that matters is that reinforcement exceeds some threshold value. The absence of a

difference between Groups II (4-32) and III (32-4) was especially striking in this regard. The point at which the learning curves diverged was apparently independent of the duration of reinforcement employed since Groups II, III, and IV separated at the same point. Only Group V continued with the reference Group (Group I) for an additional block. One may presume that this is because it did not receive the same number of transitions in reinforcement conditions as the other Groups had.

The differences in durations of reinforcement given for the two alternatives became effective later in learning. Final asymptotic performance was clearly related to the differences in duration of reinforcement. The theoretical implications of these results for a two-process theory of reinforcement in the T-maze will be discussed later.

The present latency, choice and committed time measures, as in Experiment I, revealed the typical negatively accelerated learning curves. Specifically with the exception of the A_1 choice time measure for Group III, all time measures became asymptotic after three blocks of trials. Thus they do not exhibit the two phases apparently shown in the choice probability data. In addition, only the difference in the choice time between Groups III and IV showed a significant duration of reinforcement effect. Comparisons between Groups II, III and IV for the same duration of reinforcement, regardless of proportion of reinforcement, revealed no significant differences. The other comparisons that were significant were the differences between the A_1 and A_2 committed time within each of the Groups and the differences within Groups I, III and V for the choice time measure. The A_1 speeds were always the larger of the two even when a larger duration was given on

the A_2 side. All in all, it would appear that the time data mirrors the first Phase of the choice data but remains impervious throughout learning to the effects of duration of reinforcement. This finding is paradoxical and appears to run counter to the available theories of learning that might be applied to the T-maze situation.

The non-monotonicity of the learning curves for the unequal reinforcement Groups had led us to suggest that two phases of learning are involved. There are two theoretical approaches that are compatible with such an interpretation. One involves discrimination based on the "affereffects" of reinforcement while the other, due to Estes, is based on memory and S-S learning for differential reward. We shall examine the discrimination-aftereffects interpretation first.

We assume that varying the parameters of reinforcement leads to specific intraorganismic stimuli ("aftereffects") which may carry over from trial to trial. Here we may assume either that the "after-effects" decay in time without permanent storage if the intertrial interval is sufficiently large or we may assume permanent storage as does the sequential theory of Capaldi (1971). For the present experiment, which employed a minimum 30 min. ITI, these "aftereffects" at some point during the experiment become part of the total stimulus at the choice point and can thus affect the S's "decision". Presumably "aftereffects" of reinforcement stimulus components would not be available on the early trials of learning since they would depend on differential goal box behavior which would require some number of trials to develop.

We assumbe that the organism performs some sort of comparison or discrimination between the "aftereffects" on the two sides, and

perhaps through a mediating process, generates stimulus components all of which are conditioned to the larger duration side. The number or proportion of such components may be assumed to depend on the difference in the reinforcement parameters on the two sides. This approach enables us to generate asymptotic probabilities for A_1 and A_2 responses under the unequal reinforcement conditions of the present experiment. Specifically, if the larger duration is presented on the A_1 side, the proportion, α, of the choice point stimulus population will be completely condition to an A_1 response while the proportion $(1-\alpha)$ will divide according to the proportion of reinforcement, that is

(36) $P_\infty(A_1) = \alpha + (1-\alpha)\pi$.

Similarly, if the larger duration of reinforcement is presented on the A_2 side then

(37) $P_\infty(A_1) = (1-\alpha)\pi$.

In the present experiment two groups received the same π values and the same unequal durations of reinforcement. In one group the larger duration was presented on the A_1 and in the other on the A_2 side. Thus, a first check on the adequacy of the above notions can be had by estimating α from the data of one group and using that estimate to predict the asymptotic probability of the other group. Specifically, Group II received 32 sec. duration of reinforcement on the A_2 and 4 sec. duration on the A_1 side and reached an asymptotic probability of an A_1 response of .489. Group III, on the other hand, received 32 sec. on the A_1 and 4 sec. duration of reinforcement on the A_2 side and reached an asymptotic probability of an A_1 of .852. Since the .489 value is a more stable estimate of the "true" asymptotic probability we use it to estimate α, that is if we use the equation $P_\infty(A_1) = (1-\alpha)\pi = (1-\alpha)(.75) = .489$ and solve for α we get the

estimate $\hat{\alpha} = .348$. Inserting $\hat{\alpha}$ into the equation for the Group III asymptote we obtain $P_\infty(A_1) = \alpha + (1-\alpha)\pi = .348 + (1-.348)(.75) = .837$ which is in agreement with the obtained value of .852.

A deficiency in the present approach is to be found in its ad hod nature although it does suggest further research. Employing the same unequal reinforcement conditions for different groups but varying the π values should lead to an orderly progression in the final asymptotes. The population of unique elements (α) could be estimated from one group and then be employed to predict the results of the other π groups. A second problem with the present model concerns the unspecified nature of the "aftereffects" and the assumption that the organism will "attend" to these components only under conditions of differential reinforcement. This assumption, we note, is similar to those that typically appear in "attentional" theories of discrimination learning. Thus "aftereffects" components will play a role in determining choice behavior only under conditions of unequal reinforcement.

Suggestive of the above interpretation are the differences between the conditional probabilities, $P(A_1|E_1)$ and $P(A_1|E_2)$ for a given side within Groups I (4,32 - 4,32) and V (4 - 4,32) of Experiment II. The conditional probabilities varied depending on whether outcomes E_1 or E_2 were large or small reinforcement durations which indicated that Ss were responding to differences in reinforcement durations. Additional evidence for a discrimination interpretation derived from the similarity of the present choice probability learning curves and those learning curves found in discrimination studies using the same non-correction rerun procedure (Weinstock et al., 1972 and Wiur, unpublished data, 1973). Weinstock et al. employed two discrim-

ination groups which differed in the presentation ratios of the two discriminative stimuli, which were 50:50 and 75:25. The initial responses of the 50:50 Group "hung" at .5 for about 40 trials for both S_1 and S_2. The 75:25 Group showed an increase in $P(A_1|S_2)$ from .5 towards the π value of .75 for approximately 80 trials before decreasing to a value of .25. Wiur in a similar study specifically varied the presentation ratios of the two discriminative stimuli employing ratios of 50:50, 67:33 and 75:25 while adding a second 75:25 Group which received unequal reinforcement durations, with the larger reinforcement duration of the .75 side (A_1 side), for the two T-maze alternatives. The first few blocks showed an orderly progression in the degree of probability learning for each group from the initial hanging at .5 for both stimuli of the 50:50 Group to the over..70 responding to the A_1 side for both stimuli of the 75:25 unequal reinforcement Group. Both studies suggest that initial learning follows a probability learning paradigm. This implies a failure to attend the discriminative stimuli and supports two phase discrimination theories which take the development of attention to the relevant cues as phase I. The initial learning of our unequal reinforcement groups showed the same approach to the "matching" asymptote which, we now suggest, was due to the development of a discrimination following the two phase sequence just discussed.

A theoretical development similar to the one presented above has been developed by Estes (1969) using instead of "aftereffects", an equally vague "feedback" notion, different by implication from "aftereffects" in that Estes presents an "amplifier" interpretation of reinforcement in which choice behavior and not learning rate will depend on the reinforcement value associated with a particular

response. Within this interpretation, associations (long term storage in memory) may be established between S-R, S-O and R-O, where S,R and O denote stimulus, response and rewarding outcome, respectively. All that is needed for learning to occur is contiguity between the S,R or O. The reward values are simply viewed as information which the subject also has to learn. The principle function of rewards is to influence response selection when the subject scans his memory for the previous outcomes associated with particular stimuli or responses. The feedback from the outcomes can then be either faciliatory or inhibitory and thus lead to an overt response or inhibition of an overt response. In Estes' theory, the earlier associative stage follows the traditional mathematical models of learning with reward outcomes now part of what is learned. If applied to the present data the Estes' theory would also invoke discrimination learning or some similar process to account for the non-monotonicity of the unequal reinforcement groups.

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