

69-7608

ROBBINS, Janet, 1940-
PROBABILITY LEARNING IN THE CORRECTION
T-MAZE.

The City University of New York, Ph.D., 1969
Psychology, experimental

University Microfilms, Inc., Ann Arbor, Michigan

PROBABILITY LEARNING IN THE CORRECTION T-MAZE

By

JANET ROBBINS

A dissertation submitted to the
Graduate Faculty in Psychology in
partial fulfillment of the require-
ments for the degree of Doctor of
Philosophy, The City University of
New York

1968

This manuscript has been read and accepted for the University Committee in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

July 16, 1968
date

Solomon Weinstock
Chairman of Examining Committee

July 15, 1968
date

Donald Roshier
Executive Officer

Solomon Weinstock
Eino E. Heinemann
William F. Reynolds
Supervisory Committee

The City University of New York

ACKNOWLEDGEMENTS

Grateful acknowledgement is made to the members of the thesis committee, Prof. Eric G. Heinemann, Prof. William Reynolds, and especially to Prof. Solomon Weinstock whose guidance and cooperation were an essential part of this thesis.

Acknowledgement is also made to my husband, Donald Robbins, for his patience, understanding and encouragement throughout the course of these studies.

Special thanks are due to the staff at the Brooklyn College Computer Center, especially to Mr. Howard Givner and to Mr. Martin Cohen, who wrote and re-wrote the computer programs used and who displayed tremendous self-control in dealing with a novice in the use of computers.

Finally, acknowledgement is made to the various institutions whose support enabled this research to be carried out: specifically, National Institutes of Mental Health (Grant number 13955 and a pre-doctoral fellowship), Sigma Xi Research Fund and The City University of New York.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	iii
LIST OF TABLES	v
LIST OF FIGURES	viii
GENERAL INTRODUCTION	1
EXPERIMENT 1	
Introduction	8
Method	15
Results	
Empirical Analyses	19
Theoretical Analyses	29
Discussion	59
EXPERIMENT 2	
Introduction	62
Method	65
Results	
Empirical Analyses	70
Theoretical Analyses	84
Discussion	122
GENERAL DISCUSSION	125
SUMMARY	136
REFERENCES	140
APPENDIX	142
AUTOBIOGRAPHICAL STATEMENT	155

LIST OF TABLES

Table	Page
1. Analysis of Variance Based on Mean A_1 Frequency For the Eight Blocks of Ten Trials for Groups 60 and 70 of Experiment 1	21
2. Frequencies of A_1 Responses in the "Asymptotic Block" (Trials 62-81) for Real and Stat Rats in Experiment 1	27
3. Frequencies of Responding to the "Absorbed" Side During the 19 Trials When Reinforce- ment Was Available Only on the Non-Absorbed Side for Real and Stat Rats in Experiment 1 . .	28
4. Generation of Stat Rats	30
5. Maximum Likelihood Parameter Estimates Based on Trials 1-81 For the Four Linear Models for Experiment 1	31
6. Analyses of Variance Based on Mean A_1 Frequency For the Eight Blocks of Ten Trials for the Equal θ Model Comparison for Experiment 1 . . .	35
7. Analyses of Variance Based on Mean A_1 Frequency For the Eight Blocks of Ten Trials for the 2θ Model Comparisons for Experiment 1	38
8. Analyses of Variance Based on Mean A_1 Frequency For the Eight Blocks of Ten Trials for the ID Model Comparisons for Experiment 1	40
9. Analyses of Variance Based on Mean A_1 Frequency For the Eight Blocks of Ten Trials for the BW Model Comparisons for Experiment 1	43

Table	Page
10. Number of Rats Making Their First Response to the Non-Absorbed Side During the Last 19 Trials When Reinforcement Was Available Only On the Non-Absorbed Side for Real and BW Stat Rats for Experiment 1	45
11. Comparison of 1-Element Model to Real Rats for Groups 60 and 70 On Some Asymptotic Conditional Response Probabilities for Experiment 1	47
12. Analyses of Variance Based on the Mean A_1 Frequency For the Eight Blocks of Ten Trials for the PM Comparisons for Experiment 1	50
13. Means and Standard Deviations (sd) for Real and BW Stat Rats for Experiment 1	53
14. Analysis of Variance Based on Mean A_1 Frequency For the Eleven Blocks of Ten Trials for Groups C67 and C80 in Experiment 2	73
15. Analysis of Variance Based on the Mean A_1 Frequency During the Last 20 Trials for Groups C67, I and L in Experiment 2	74
16. Frequencies of A_1 Responses During the "Asymptotic Block" for Real and Stat Rats in Experiment 2	80
17. Maximum Likelihood Parameter Estimates for the Four Linear Models for Experiment 2	85
18. Group by Blocks Analyses of Variance Based on Mean A_1 Frequency for the Equal θ Model Comparisons for Experiment 2	89
19. Frequencies of "Preferred" or "Absorbed" Responses During the Last 12 Trials (112-123) for Groups C67 and C80 and Stat Rats When π Changed From .67 and .80 to $\pi(n) = .20 + .03n$, $n = 1, \dots, 12$ for Groups C67 and C80, Respectively in Experiment 2	93

Table	Page
20. Group by Blocks Analyses of Variance Based on Mean A_1 Frequency for the 2Q Model Comparisons for Experiment 2	96
21. Group by Blocks Analyses of Variance Based on Mean A_1 Frequency for the ID Model Comparisons for Experiment 2	98
22. Group by Blocks Analyses of Variance Based on Mean A_1 Frequency for the BW Model Comparisons for Experiment 2	100
23. Group by Blocks Analyses of Variance Based on Mean A_1 Frequency for the PM Comparisons for Experiment 2	107
24. Means and Standard Deviations (sd) of Real and Stat Rats for BW and PM for Experiment 2 .	111
25. Comparison of Real and Stat Rats for BW and PM on Some Asymptotic Conditional Response Probabilities for Experiment 2	121

LIST OF FIGURES

Figure	Page
1. Mean Proportion of A_1 s Over Blocks of Ten Trials for the Two Groups of Experiment 1 (Block 10 has 9 Trials)	20
2. Mean Proportion of A_1 s Over Blocks of Ten Trials for Individual S s in Group 60 of Experiment 1 (Block 10 has 9 Trials)	24
3. Mean Proportion of A_1 s Over Blocks of Ten Trials for Individual S s in Group 70 of Experiment 1 (Block 10 has 9 Trials)	25
4. Mean Proportion of A_1 s Over Blocks of Ten Trials for the Equal θ Model Stat Rats for Groups 60 and 70 of Experiment 1	34
5. Mean Proportion of A_1 s Over Blocks of Ten Trials for the 2 θ and ID Model Stat Rats for Groups 60 and 70 of Experiment 1	37
6. Mean Proportion of A_1 s Over Blocks of Ten Trials for the BW Model Stat Rats for Groups 60 and 70 of Experiment 1	41
7. Mean Proportion of A_1 s Over Blocks of Ten Trials for the PM Stat Rats for Groups 60 and 70 for Experiment 1	49
8. Mean Proportion of A_1 s Over Blocks of Ten Trials for Groups C67, C80, I and L in Experiment 2 (The Last Block for Groups I and L Contains 11 Trials)	71
9. Mean Proportion of A_1 s Over Blocks of Ten Trials for Individual S s in Group C67 in Experiment 2 (Block 12 has 12 Trials)	76

Figure	Page
10. Mean Proportion of A_1 s Over Blocks of Ten Trials for Individual S s in Group C80 in Experiment 2 (Block 12 has 12 Trials)	77
11. Mean Proportion of A_1 s Over Blocks of Ten Trials for Individual S s in Group I in Experiment 2 (Block 12 has 11 Trials)	78
12. Mean Proportion of A_1 s Over Blocks of Ten Trials for Individual S s in Group L in Experiment 2 (Block 12 has 11 Trials)	79
13. Proportion of A_1 s as a Function of Trials for Trials 102-123 for Groups C67 and C80, Respectively. During Trials 112-123, π Ranged from .23 to .56 as Determined by the Function $\pi(n) = .20 + .03n$, $n = 1, \dots, 12$	81
14. Mean Proportion of A_1 s Over Blocks of Ten Trials for the Equal θ Model Stat Rats for Groups C67, C80, I and L of Experiment 2	88
15. Proportion of A_1 s Over Trials 112-123 for the Equal θ Model Stat Rats for Groups C67 and C80 in Experiment 2	91
16. Mean Proportion of A_1 s Over Blocks of Ten Trials for the 2 θ and ID Model Stat Rats for Groups C67, C80, I and L for Experiment 2	95
17. Mean Proportion of A_1 s Over Blocks of Ten Trials for the BW Model Stat Rats for Groups C67, C80, I and L in Experiment 2	99,
18. Proportion of A_1 s Over Trials 112-123 for the BW Model Stat Rats for Groups C67 and C80 in Experiment 2	102
19. Mean Proportion of A_1 s Over Blocks of Ten Trials for the PM Stat Rats for Groups C67 and C80 for Experiment 2	105
20. Proportion of A_1 s over Trials 112-123 for the PM Stat Rats for Groups C67 and C80 for Experiment 2	108

Historically two broad strategies have been adopted to gain an understanding of maze behavior. The first developed out of the early data on maze learning. The data were gathered on complex mazes, such as the human-sized maze at Kew Gardens, and usually focused on the total number of errors. Theoretical accounts of the data, not surprisingly, became correspondingly complex and met with little success. This trend culminated in a paper by Tolman (1938) that was taken by most workers in the field as a confession of failure, and this, in turn, led to the abandonment of the complex maze in learning research.

After the abandonment of complex mazes and the corresponding theoretical strategy of constructing complex theories, there was a movement to gain an understanding of simple learning situations and to "compound" the laws of simple learning to deal with more complex learning situations. This strategy is best represented by the work of Hull (1943, 1952). Hull's earlier work concentrated on developing theory for "simple learning" situations, those involving a single stimulus, and a single response, while his later work

extended the theory to choice situations such as the T-maze. By 1952 Hull and his associates had worked through the T-maze up to linear mazes with four choice points.

While Hull's work on the maze involved the compounding of his theoretical laws for simple learning, this strategy may be carried through in a non-theoretical fashion by using empirical laws. In a sense the work of Bush and Mosteller (1955) is such an approach for they assume merely that appropriate learning operators will be applied following reinforcement or non-reinforcement, respectively, of a choice without elaborating a theory of simple learning. The compounding of empirical laws for simple learning is well illustrated by the work of Weinstock, North, Brody and LoGuidice (1965). It had been found that non-reinforced trials in a partial reinforcement situation under widely spaced trials led to virtually no decrement in responding. This led to the use of an "identity operator" model, in which non-reinforced trials leave the probability of choice unchanged, for probability learning situations in the non-correction T-maze. The resulting model predicts 100% responding to one or the other side of the maze with the proportion of subjects choosing each side depending on the learning rate on reinforced trials and the probabilities of reward. Weinstock et al. (1965) provided a nice confirmation

of this model and, in general, there is little or no controversy on an empirical level for the non-correction case.

Unfortunately, there are contradictions in the results for learning in the T-maze under correction procedures. Many studies have been run, utilizing a 100:0 reinforcement schedule. This is not maximally useful for theoretical purposes since rats usually learn very rapidly and as a result make very few errors. Therefore, there are not enough correction trials to be evaluated as compared with directly reinforced (no correction) trials. In order to obtain enough correction trials probabilistic reinforcement schedules have been used and probability learning in the T-maze has become most important for theoretical purposes.

Examination of the data for probability learning in the correction T-maze reveals many apparent contradictions. Some investigators report "matching" at asymptote, $P_{\infty}(A_1) = \pi$, where π = the probability of reinforcement of an A_1 , (Brunswik, 1939; Estes, 1957a; Parducci and Polt, 1958), although it is not clear that the behavior was asymptotic in all cases. Others report "overshooting" at asymptote, $P_{\infty}(A_1) > \pi$ but less than 1, (Weinstock, unpublished; Wright, 1967), or "absorption," $P_{\infty}(A_1) = 1$, (Bitterman, 1965).

The major goal of the present research is to clear

up the contradictions in studies on probability learning in the correction T-maze. To this end, two groups of rats were given (Experiment 1) the conventional correction procedure which allows the rat to retrace the entire length of the incorrect arm. The results indicated that Ss tended toward absorption at asymptote. Since the Estes (1957a) study used correction at the choice point, the effect of arm length was investigated in Experiment 2. Two groups of Ss were allowed to penetrate 11 or 22 in. into the incorrect arm and two other groups were given correction at the choice point.

In generalizing from the runway to the correction T-maze, the theoretical problem arises of how to treat correction trials. There are a number of assumptions one can make about the effects of a correction trial. One can assume that the increase in $P(A_1)$, when an A_1 is reinforced on a correction trial is (a) equal to the increase in $P(A_1)$ when S goes directly to the A_1 (reinforced) side, which leads to the Estes (1957b) "matching" model or the Bush and Mosteller (1955, p. 287) equal θ model; or (b) less than the increase in $P(A_1)$ when S goes directly to the A_1 (reinforced) side, which leads to the two θ case of the Bush and Mosteller (1955, p. 289) model; or (c) that there is an increase in probability to the side initially chosen,

regardless of which side is reinforced, which leads to the Bush and Wilson (1956) "secondary reinforcement" model. A fourth possibility is that correction trials have no effect on $P(A_1)$ which leads to the identity operator model. This model was considered since parameter estimates for the two θ model revealed values close to zero for the learning parameter on correction trials, thereby suggesting an identity operator.

The equal θ case generates the prediction of "matching" at asymptote. The two θ model predicts an overshoot of the matching value. Finally, the Bush and Wilson secondary reinforcement model predicts that at asymptote $P_\infty(A_1) = 1$ or 0, as does the identity operator model. All four models assume a linear learning operator on directly reinforced trials, namely that

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

An alternative conception views $\underline{S}$ as responding to a mutually exclusive set of stimulus patterns (Estes, 1959), where one pattern is sampled per trial. Since a pattern is conditioned to only one response at any one time, the response conditioned to the sampled pattern must occur on that trial. As a result $P(A_1)$, the proportion of patterns conditioned to an A_1 response, can change only on error

(correction) trials and therefore, changes occur only in discrete steps of $1/N$, where N is the number of patterns. The probability of change on a correction trial is given by a conditioning parameter, C . The N -Pattern model generates an asymptotic $P_{\infty}(A_1) = \pi$ or matching, the same as the Estes "matching" model. However, the Pattern Model predicts considerably more asymptotic variability of $P_{\infty}(A_1)$ than that generated by the Estes linear operator model. Both Experiments 1 and 2, then seek to resolve the empirical controversy and to enable a choice of an appropriate model for probability learning in the correction T-maze.

In summary, the experiments undertaken were as follows:

- Experiment 1. Probability learning in the correction T-maze with retracing of the entire length of the incorrect arm allowed.
- Experiment 2. Probability learning in the T-maze with varying distances of penetration allowed into the incorrect arm.

In both experiments trials were widely spaced. Massed trials have purposely been omitted because the use of a massed trial technique entails numerous theoretical problems: response probabilities may not be independent, alternation effects appear, and the after-effects of

reinforcement, stimulus-trace considerations, and differential drive stimuli further complicate the situation. A one trial per day procedure was utilized to eliminate these difficulties and more closely approximate theoretical assumptions (Estes, 1957b).

EXPERIMENT 1

Various correction procedures have been used in the correction T-maze. The standard procedure is to allow S to retrace the entire length of the incorrect arm in order to gain access to the "correct" or reinforced side. Using this procedure Parducci and Polt (1958) reported "matching" for groups given an 85:15 or a 50:50 reinforcement schedule. On the other hand, Weinstock (unpublished), using a 75:25 reinforcement schedule, and Wright (1967), using a 70:30 schedule, reported "overshooting" when this procedure was used.

Examination of the group curves of the Parducci and Polt study suggests that the Ss may not have reached asymptote. In addition, when these Ss were switched to a 30:70 reinforcement schedule, the group curves fell below the reinforcement probability ("undershooting"). Parducci and Polt reported that some Ss went 100% of the time to the high probability (.70) side after the schedule change. Similarly, in Wright's study two groups showed "overshooting" with many

individual Ss showing 100% responding. Both studies made use of a massed trial procedure and there are doubts, for Parducci and Polt, whether asymptote was reached. The present experiment was designed to remove ambiguities in experimental outcomes by presenting one trial per day for a considerable number of trials.

The apparent contradictions in the data must also be removed to enable the development of appropriate theoretical models. A large number of models have been developed both in the framework of Estes's (1950) stimulus sampling theory and of Bush and Mosteller's (1955) stochastic models for learning to deal with two-choice situations like the T-maze. Within both frameworks there is no controversy over the theoretical treatment of directly reinforced trials. Such trials may be assumed to result in an increment to the probability of responding to the reinforced side, or that

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

There are, however, a number of possibilities regarding the effects of a correction trial or a trial on which the organism responds to the A_2 side and then is given reinforcement on the A_1 side.

There are four main theoretical possibilities, in

linear operator terms:

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

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

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

$$(5) \quad P_{n+1}(A_1) = (1 - \theta_2)P_n(A_1).$$

The complete models may be specified by further assuming "symmetry" between reinforcement on the right and on the left, or for A_1 and for A_2 , of the $\underline{T}$ -maze. Four types of trials are possible. If we let E_1 stand for reinforcement presented on the A_1 and E_2 on the A_2 sides, respectively, 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) and of Estes (1957b). Here we apply the following linear learning operators on the four types of trials, namely

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

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

which is equivalent to

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

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

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

or, equivalently

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

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

$$(10) \quad P_{\infty}(A_1) = \pi,$$

if θ , the learning rate parameter, is less than 1.

The second model, obtained by the symmetry assumption coupled with equations (1) and (3), is the " 2θ model" of Bush and Mosteller. Here

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

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

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

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

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

$$(15) \quad P_{\infty}(A_1) > \pi.$$

The third model, obtained from equations (1) and (4), is Bush and Mosteller's "identity operator" model:

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

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

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

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

This model leads to the prediction that each organism will respond either 100% to the A_1 or 100% to the A_2 side at asymptote. The proportion of organisms "absorbed" on the two sides will depend, in this model, on the magnitude of θ and π . For small θ all organisms will be absorbed on the larger π side. For θ equal to 1, the proportion of the ss absorbed on the larger π side will be exactly equal to π . Finally, for intermediate values of θ it will lie between π and 1.

The last model, gotten from equations (1) and (5), is Bush and Wilson's (1956) "secondary reinforcement" model:

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

$$(21) \quad A_1-E_2: \quad P_{n+1}(A_1) = (1 - \theta_2)P_n(A_1) + \theta_2$$

$$(22) \quad A_2-E_1: \quad P_{n+1}(A_1) = (1 - \theta_2)P_n(A_1)$$

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

This model differs from the others in that reinforcement on the A_2 side following an A_1 response leads to strengthening of the tendency to make an A_1 response. Here, at asymptote, $P_{\infty}(A_1) = 1$ or $P_{\infty}(A_1) = 0$ with the proportion of organisms responding 100% to the A_1 side depending on θ_1 and θ_2 .

The model may be justified, theoretically, on the grounds that on an A_1-E_2 sequence the organism receives delay of reinforcement for an A_1 response. Further, the only choice

response, or turn, that the organism makes is its first choice under this correction procedure since it is not obliged to return to the stem of the maze and make a second choice response.

In addition to these four models there is a further case which arises from Estes' "pattern models" (1959). Here, $\underline{S}$ is viewed as responding to a mutually exclusive set of N stimulus patterns, where one pattern is sampled per trial. Since a pattern is conditioned to only one response at any one time, the response conditioned to the sampled pattern must occur on that trial. As a result the probability of an A_1 , which is simply the proportion of patterns conditioned to an A_1 , can only change on error (correction) trials. In addition, the $P(A_1)$ changes in discrete steps of $1/N$. Here too a "symmetry" assumption is made, except that here it is for the probability of change given a correction trial. The four types of trials for the N -Pattern model, using the same form as the other four models are:

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

$$(25) \quad A_1-E_2: \quad P_{n+1}(A_1) = P_n(A_1) - \frac{1}{N} \text{ with probability } = c$$

$$(26) \quad A_2-E_1: \quad P_{n+1}(A_1) = P_n(A_1) + \frac{1}{N} \text{ with probability } = c$$

$$(27) \quad A_2-E_2: \quad P_{n+1}(A_1) = P_n(A_1).$$

The N -Pattern model, like the "equal θ " model, generates a

prediction of "matching" at asymptote for individual organisms. However, considerably more variability in asymptotic responding is predicted by the pattern model than by the "equal θ " model. It is interesting to note that "2 θ " type models, comparable to those previously outlined, are not possible within this framework. This is because changes in $P(A_1)$ may occur only on A_1-E_2 and A_2-E_1 trials and not on A_1-E_1 and A_2-E_2 trials.

The major purpose of this experiment was to resolve the contradictions existing in the data and further to assess the competing possible models for the T-maze with correction. To this end two groups of rats were given 80 trials spaced at one trial per day under probability learning schedules of 70:30 and 60:40 respectively.

METHOD

Subjects

Sixty female albino rats, 100-120 days old at the start of the experiment were obtained from Albino Farms, Little Silver, New Jersey.

Apparatus

An enclosed T-maze painted flat gray and 5 in. high and 5 in. wide throughout was used. The start box was 9 in. long and the stem was 24 in. long. The cross piece including the choice area, was 41 in. long. A guillotine door separated the start box and the stem, while sliding doors separated each of the arms from the stem. The doors of the arms were mounted 18 in. from the end wall. The end walls were 8 in. long with a 3 x 5 in. recessed drinking area in the side walls closer to the start box. A drinking tube similar to those used in the home cages, was mounted on the wall and a slide could be inserted to prevent access to the tube. The apparatus was covered with hinge-mounted clear Plexiglas. Illumination was provided by one 100 w. bulb

centered over the arm of the maze approximately 6 ft. above the apparatus. An air conditioner which was on continuously, provided a uniform masking noise.

Procedure

Two weeks before the beginning of the experiment Ss were placed on a 22 hr. water deprivation schedule and were given access to water for 2 hr. each day at approximately the same time as they were to be given water throughout the experiment. Each S received 1 min. of gentling each day for two weeks. The Ss were then assigned randomly to groups.

Thirty Ss were given reinforcement on .60 of the trials on one side and .40 on the other side of the maze (Group 60). Another group of thirty Ss were reinforced according to a 70:30 reinforcement schedule on one or the other side of the maze (Group 70). Half of the Ss in each group were given the larger proportion of reinforcement on the right side and the other half on the left side of the maze. Reinforcement for each S was assigned randomly by blocks of 20 trials with the restriction that each block have reinforcements in the ratio of 12:8 for Group 60 and 14:6 for Group 70 and that on each trial reinforcement was available on one or the other side of the maze. Reinforcement was 10 sec. of drinking. The Ss were run in a fixed

order at one trial per day under a correction procedure in which S was allowed to retrace the entire length of the incorrect arm in order to enter the correct arm. As a result S received reinforcement on every trial. Four reinforced trials were given each S, in either a RLLR or a LRRL order, followed by training with correction under the appropriate reinforcement schedule.

At the beginning of each trial S was placed in the start box facing the start box door. Two sec. later the start box door was raised. A response was defined as the first penetration of 10 in. into either arm of the maze. When S entered the side where reinforcement was present the sliding door separating the arm from the stem was closed. After completion of 10 sec. of drinking, S was returned to its home cage.

The SS were given access to water in their home cages for 90 min. approximately 30 min. after the last S was run. Deprivation was thus maintained at 20-22 hr.

It was planned to continue the experiment until the SS appeared to be responding at asymptote and then to give 20 additional trials to be used for asymptotic analysis regardless of the nature of the data collected. As a result SS were given 80 trials. These trials were then followed by

another block of 20 trials (trials 81-100) on which reinforcement was available on only one side of the maze. The side that reinforcement was placed on was the side of the maze to which S responded least frequently during the asymptotic block. Therefore, all Ss were switched to a 0:100 reinforcement schedule for the last 20 trials. One S died during the course of the study leaving 30 and 29 Ss in Groups 60 and 70, respectively.

RESULTS

Empirical Analyses

The side where the larger proportion of reinforcement was available for each S was defined to be the A_1 side.

The mean proportion of A_1 s in blocks of ten trials is plotted in Figure 1 for Groups 60 and 70, respectively. Inspection of the curve for Group 60 revealed a decrease in the mean A_1 proportion from block one to two, followed by a typical negatively accelerated curve. The Group 70 curve appeared to resemble the usual negatively accelerated function throughout.

A group by blocks of trials analysis of variance was performed on the frequency of A_1 s for the eight blocks of ten trials for the two groups. As shown in Table 1, no significant difference was found between groups although a significant groups by blocks interaction was found. The statistical tests used here for block effects and for the group by block interactions assume that the scores are independent. This is obviously not the case since we have

FIGURE 1.--Mean Proportion of A₁s Over Blocks of Ten Trials
for the Two Groups of Experiment 1
(Block 10 has 9 Trials)

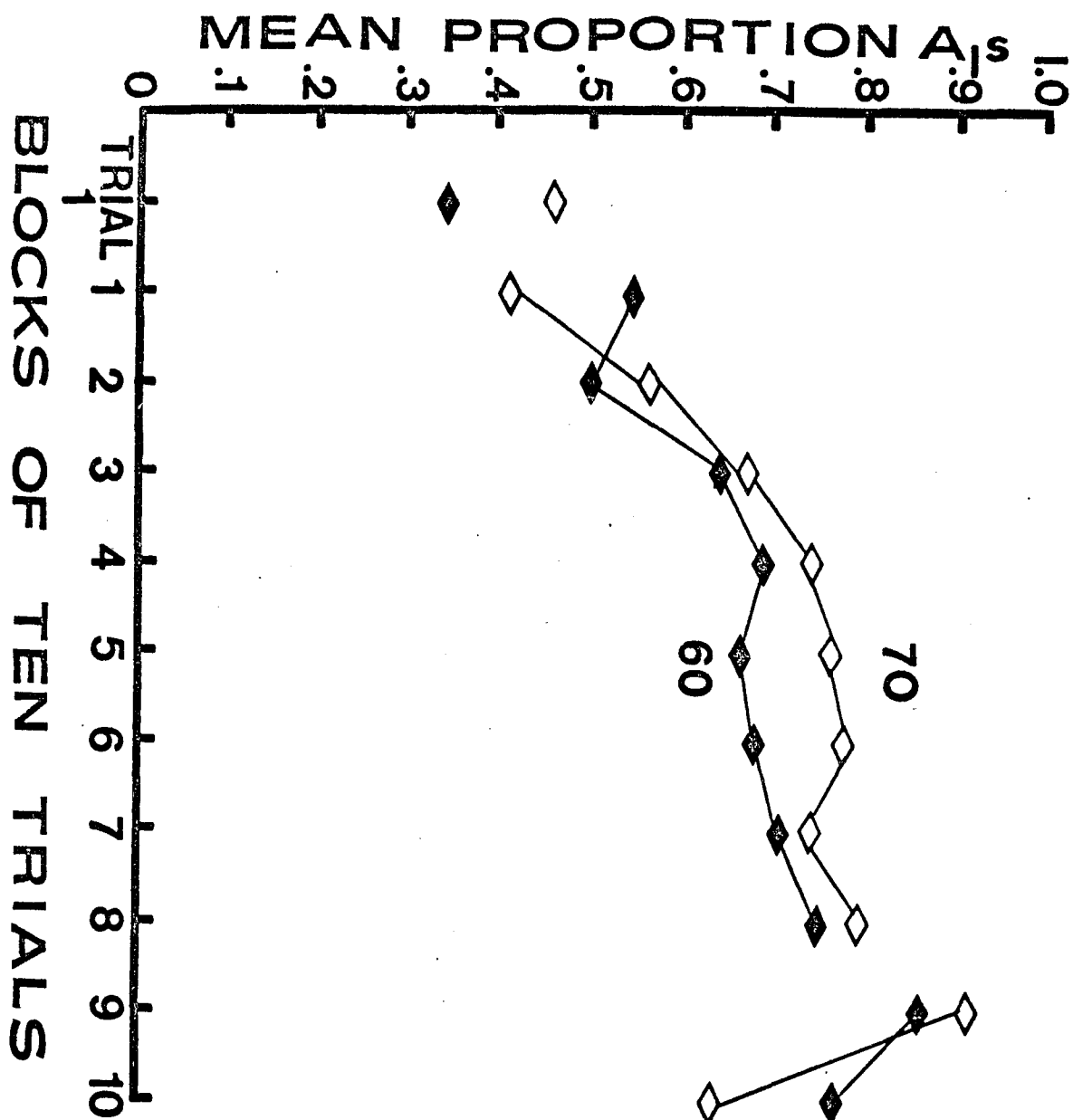


TABLE 1.--Analysis of Variance Based on Mean A_1 Frequency
For the Eight Blocks of Ten Trials for
Groups 60 and 70 of Experiment 1

Source	SS	df	MS	F
Groups (G)	7	1	7.00	.11
Error	3750	57	65.79	
Blocks (B)	445	7	63.57	111.53*
G X B	59	7	8.43	14.79* (1/57)*
Error	228	399	.57	
Total	4489	471		

* $p < .05$

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 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, the block effect simply demonstrated learning. Since the Greenhouse and Geisser procedure is the most conservative one and assumes maximum correlation between scores, the correction was applied only when the group by block interaction was significant under the original technique. Whenever this was done the corrected number of d.f.s. was put in parentheses in the analyses of variance table. If the F was still significant with the adjusted d.f. this was indicated by an asterisk, otherwise it was left blank. This procedure was followed for all group by block analyses of variance. Inspection of Figure 1 reveals little difference between the groups at the beginning and end of the experiment, although a relatively large difference appeared during the middle blocks of trials.

In accordance with the plan decided upon in advance of the experiment the mean A_1 proportion over trials 62-81

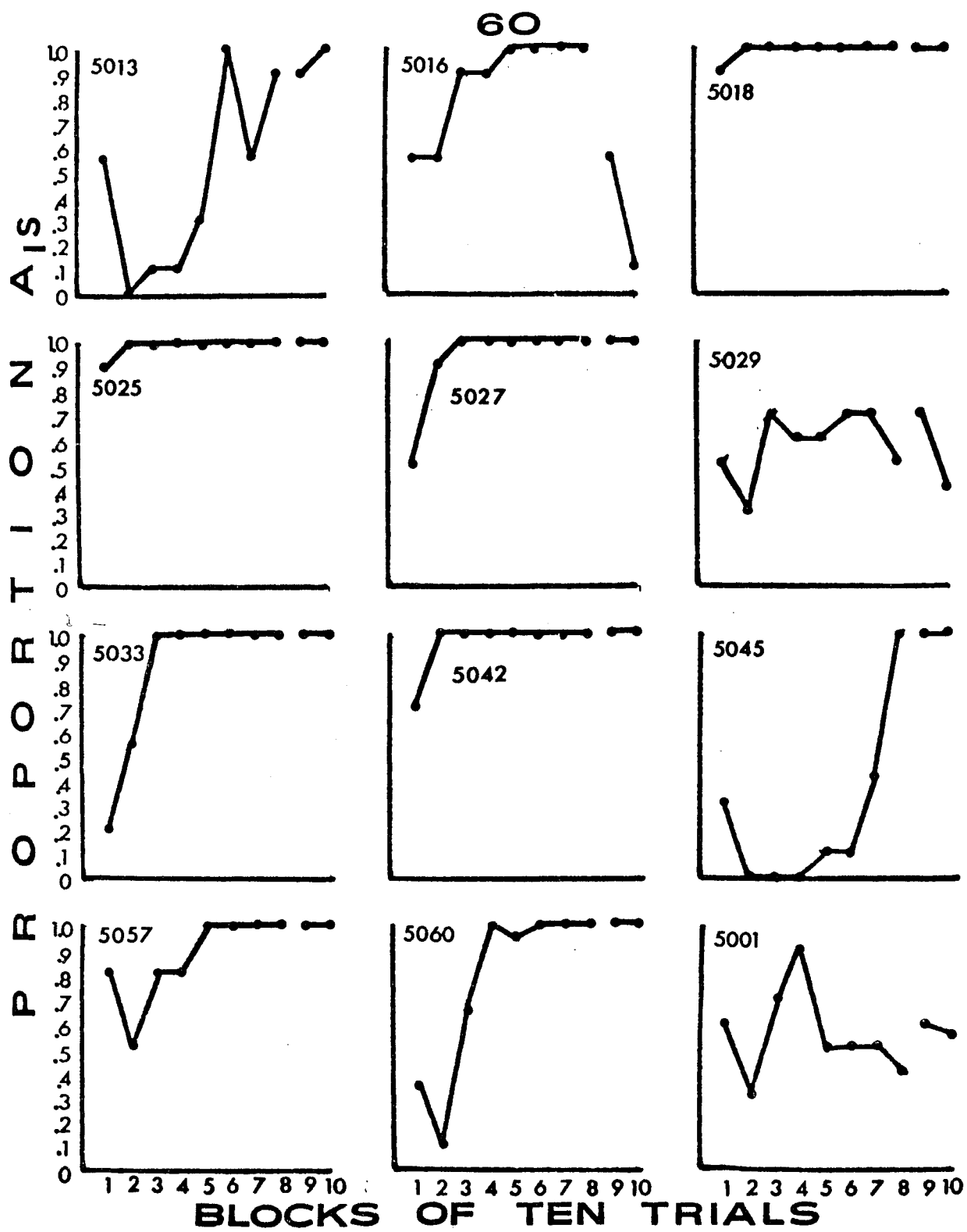
was taken as an estimate of the asymptotic response probability, and was .72 and .75 for Groups 60 and 70, respectively. A t -test performed on the frequency of A_1 s for the last 20 trials revealed no significant differences between groups ($t=.35$, $df=57$, $p > .05$).

Further inspection of Figure 1 reveals an apparent "overshooting" at asymptote for both groups. The Group 60 asymptote was 20% higher and that of Group 70 was 7% higher than its π value. However, t -tests performed on the frequency of A_1 s for the last 20 trials for each group revealed no significant differences from the π value for both Group 60 ($t=1.77$, $df=29$, $p > .05$) and Group 70 ($t=.81$, $df=28$, $p > .05$).

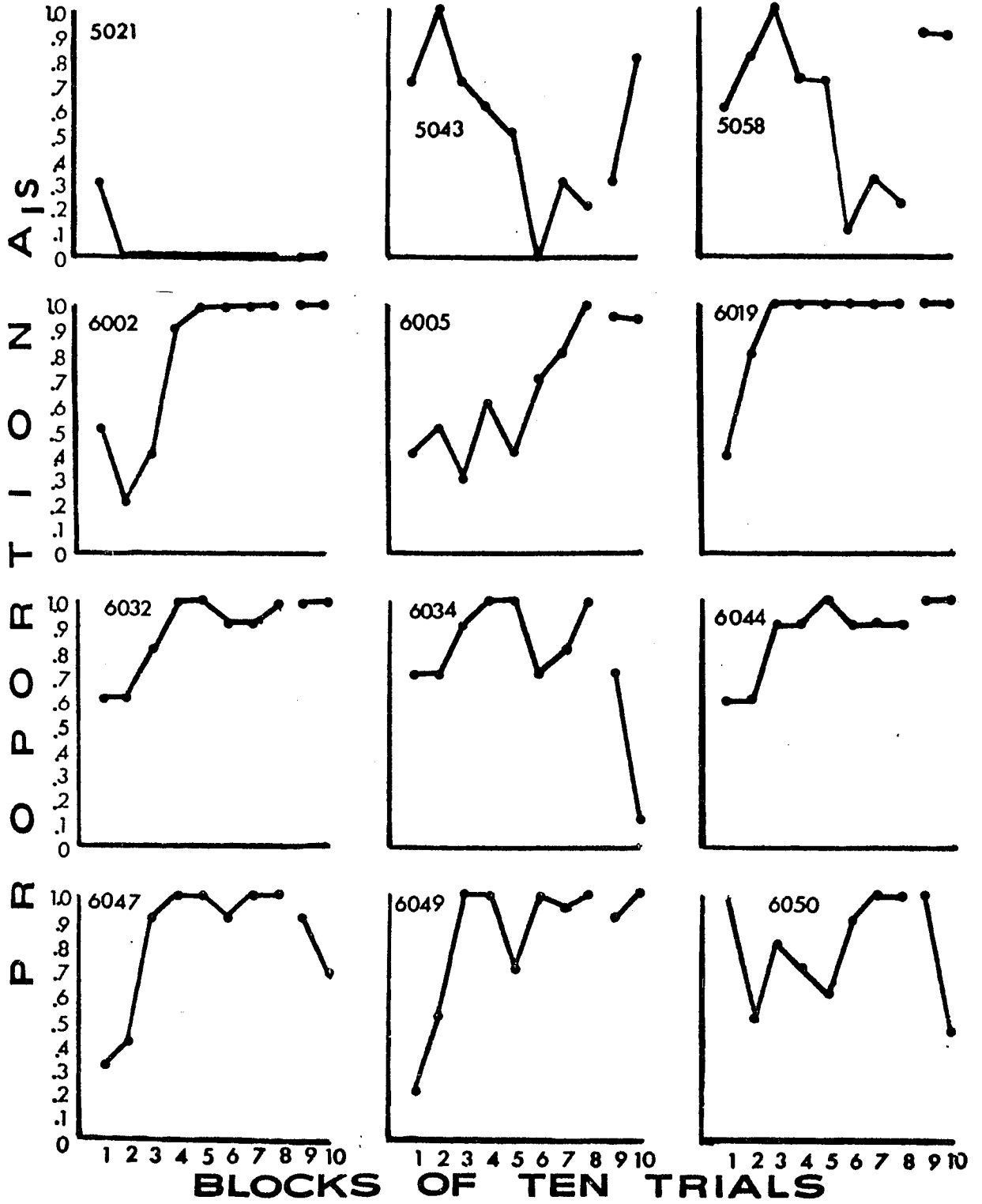
In Figures 2 and 3 are plotted the mean A_1 proportion over blocks of ten trials for individual S s in Groups 60 and 70, respectively. Inspection of these figures showed that the group curves in Figure 1 did not reflect individual organism behavior. The curves for individual organisms show that, at asymptote, most of the S s in both groups were close to or at 100% responding to either the A_1 or the A_2 side. Only the data from 3 S s in Group 60 and 5 in Group 70 appeared to be similar to their respective group curves.

The frequencies of A_1 responding in the last 20

FIGURE 2.--Mean Proportion of A_1 s Over Blocks of Ten Trials
for Individual Ss in Group 60 of Experiment 1
(Block 10 has 9 Trials)



60



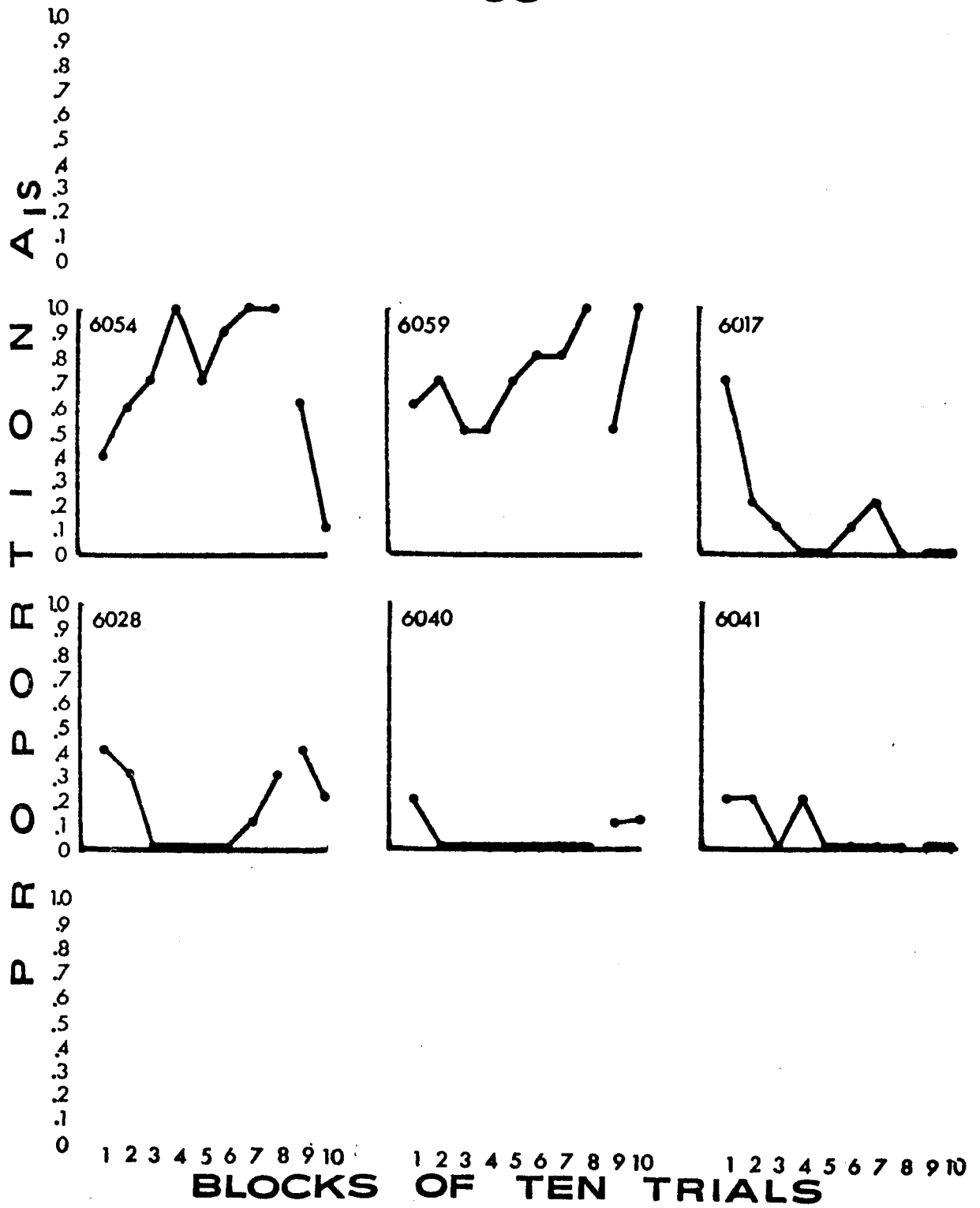
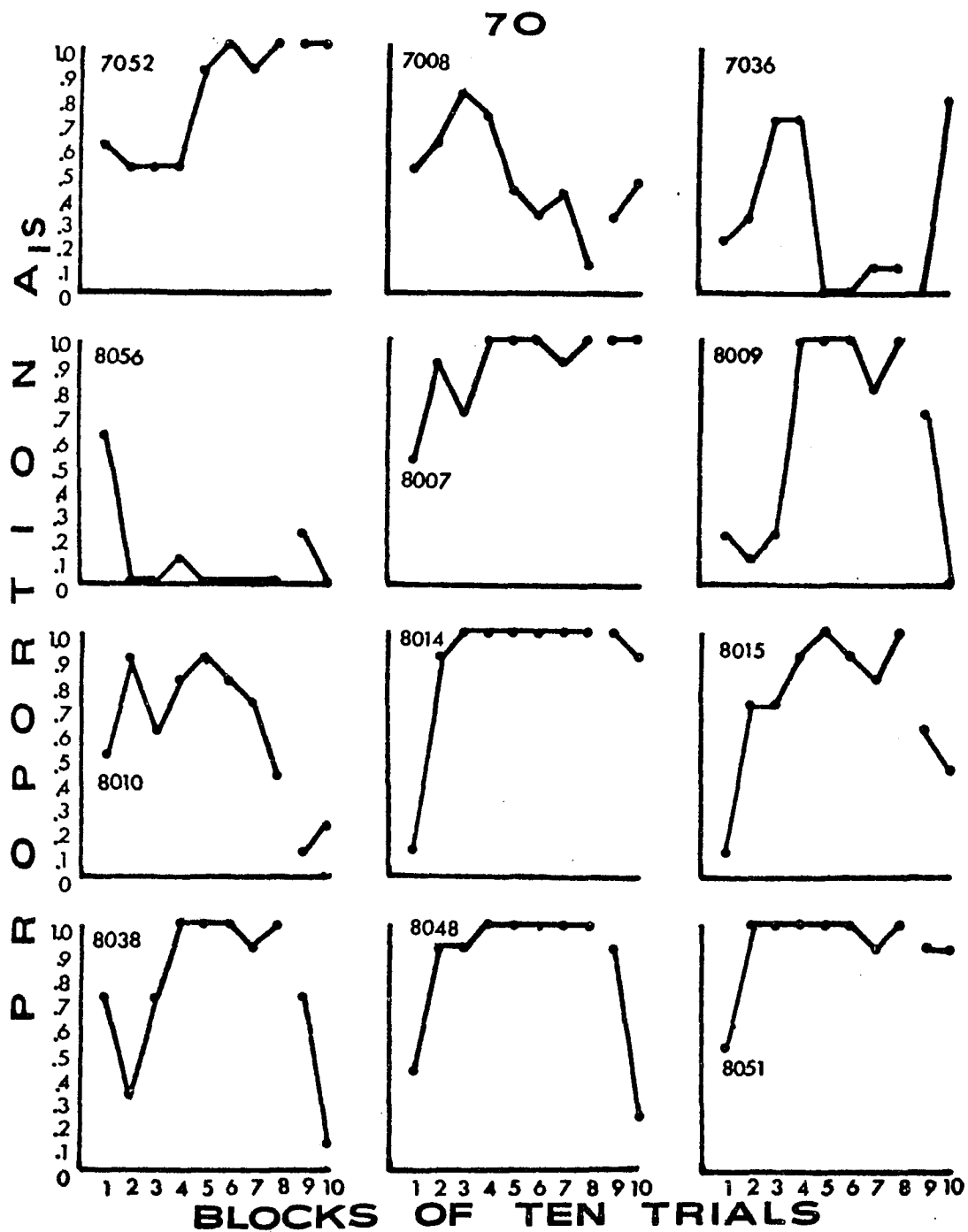
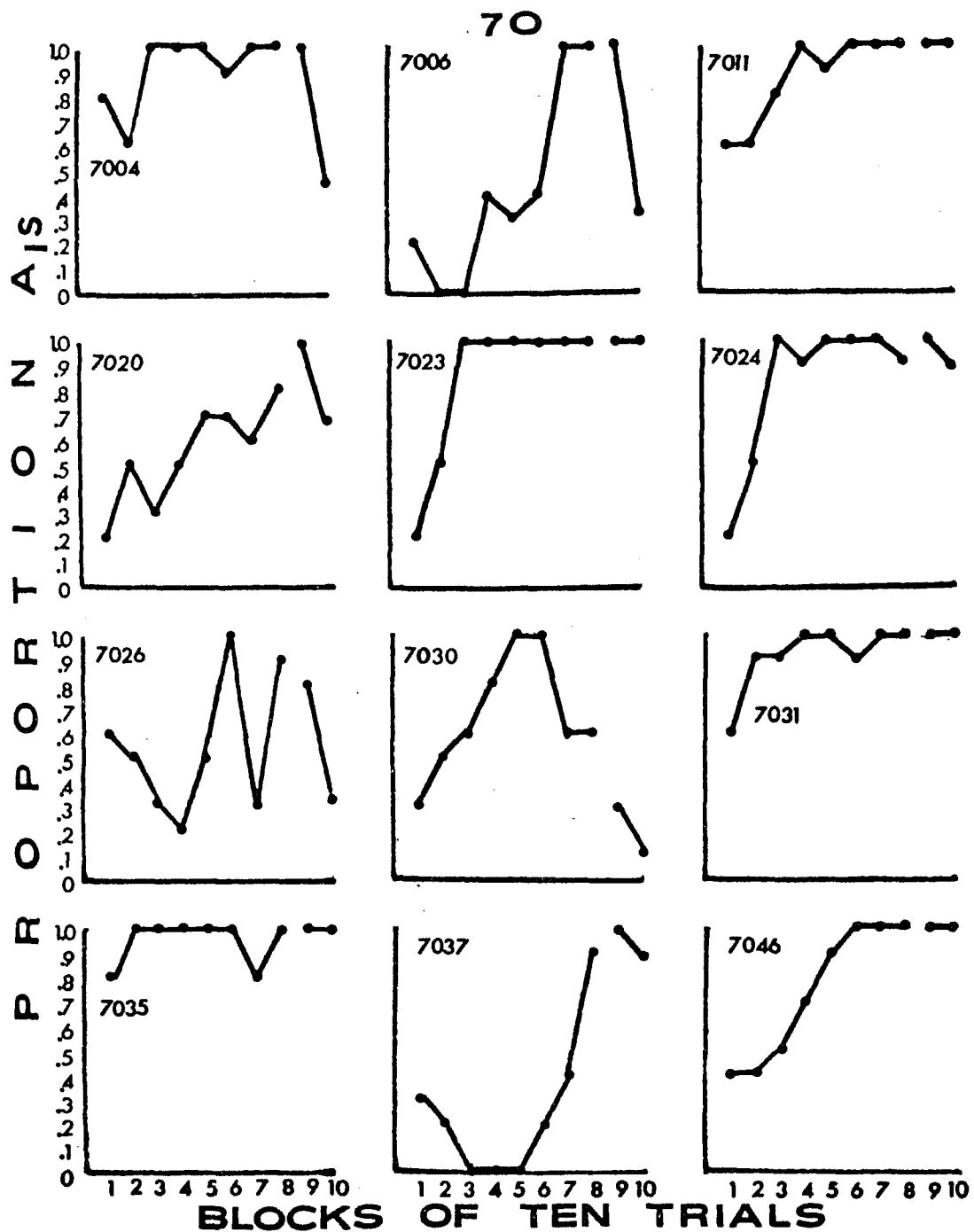
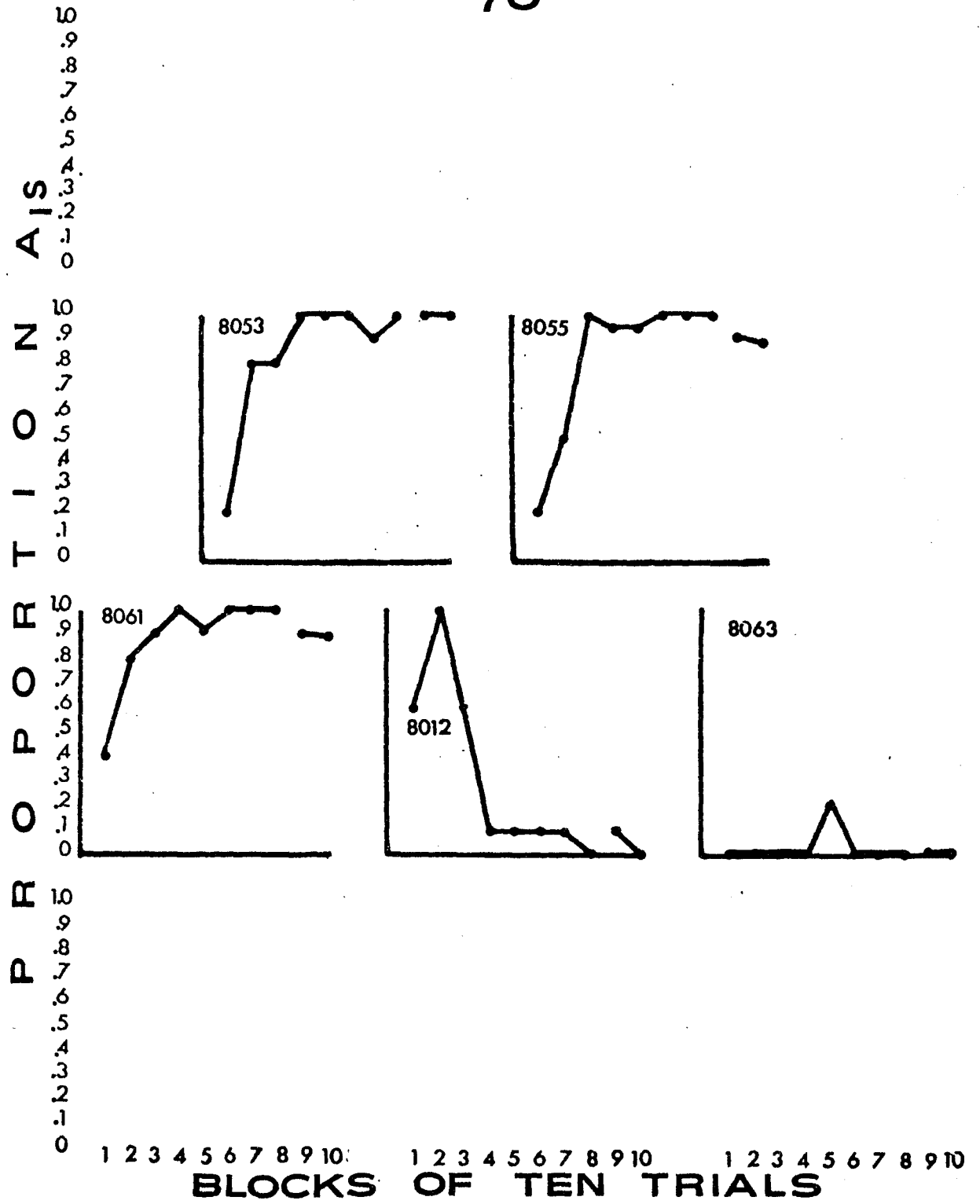


FIGURE 3.--Mean Proportion of A_1 s Over Blocks of Ten Trials
for Individual Ss in Group 70 of Experiment 1
(Block 10 has 9 Trials)







trials, or the "asymptotic block," for both groups are presented in Table 2. Inspection of Table 2 reveals that 19 Ss from each group went to the A_1 side 90-100% of the trials during the last block of 20 trials with 4 Ss from each group going 90-100% to the A_2 side. A χ^2 approximation, for unequal N s of less than 40 per group, to the Kolmogorov-Smirnov test (Siegel, 1956) was performed on the difference between the asymptotic frequency distributions for Groups 60 and 70, and revealed no significant difference ($\chi^2 = .59$, $df=2$, $p > .05$).

Inspection of Figure 1 reveals that when the Ss were switched to a 0:100 reinforcement schedule (i.e., when reinforcement was given only on the side opposite to the side on which S was "absorbed" at asymptote) a slight decline in the proportion of A_1 s occurred. This, taken along with the individual organism data in Figures 2 and 3, showed that, in general, the change in reinforcement schedule had little effect upon the Ss' behavior.

Table 3 presents the frequencies of responding to the side on which each S was absorbed at asymptote during the 19 trials when reinforcement was available only on the non-absorbed side. Inspection of Table 3 revealed that almost 60% of the Ss made 90% or more of their responses to the absorbed side.

TABLE 2.--Frequencies of A₁ Responses in the "Asymptotic Block" (Trials 62-81) for Real and Stat Rats in Experiment 1

Group 60	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Real	12	2	5	0	0	0	2	0	1	0	0	1	0	0	0	1	2	0	1	0	3
Equal θ	0	0	0	2	0	4	3	2	5	2	2	4	5	1	0	0	0	0	0	0	0
BW	16	1	2	1	0	0	0	0	1	0	0	0	0	0	1	0	1	0	1	0	6
PM	2	1	3	2	0	2	2	2	4	0	2	2	1	2	0	2	0	2	0	0	1
Group 70	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Real	9	7	3	0	0	0	0	2	3	0	0	0	0	0	0	1	0	0	0	2	2
Equal θ	0	1	2	6	3	5	4	2	1	3	2	0	0	0	0	0	0	0	0	0	0
BW	19	0	1	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	1	4
PM	6	1	1	0	4	2	2	2	4	0	0	2	1	2	1	0	1	0	0	0	0

Table 3.--Frequencies of Responding to the "Absorbed" Side
During the 19 Trials When Reinforcement Was
Available Only on the Non-Absorbed Side for
Real and Stat Rats in Experiment 1

	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Group 60																				
Real	14	4	2	0	0	1	1	0	1	0	0	4	1	0	0	0	1	1	0	0
BW	16	4	0	1	0	0	1	1	0	1	0	1	0	2	0	2	1	0	0	0
Group 70																				
Real	8	6	2	1	0	1	1	3	2	1	0	1	1	0	0	1	1	0	0	0
BW	12	4	4	0	2	0	0	1	1	2	1	0	0	1	0	1	0	0	0	0

Theoretical Analyses

Using trials 1-81, maximum likelihood parameter estimates (Bush and Mosteller, 1955; pages 129-131) were made for both Groups 60 and 70 for the Estes "matching" model (Equal θ), the Bush and Mosteller 20 model (2θ), the identity operator model (ID) and the Bush and Wilson secondary reinforcement model (BW).

Using an assumed value of .5 for the initial response probability and the individual reinforcement schedules one stat rat (Bush and Mosteller, 1955; pages 192-131) was "generated" corresponding to each real rat. An example of how stat rats were "generated" is presented in Table 4 for the BW model which uses equations (20) through (23). The other three models differed only in the operators applied.

Maximum likelihood parameter estimates for the four models are presented in Table 5 and reveals that the maximum likelihood value (L) was largest for the BW model, followed by ID and the 2θ models, and smallest for the Equal θ model for both groups.

In addition, the two parameters for Estes' Pattern model (PM), c , the conditioning parameter, and N , the number of patterns, were estimated using the method suggested by

TABLE 4.--Generation of Stat Rats

Example using BW model, assuming $\theta_1 = .2$, $\theta_2 = .1$, $\pi = .70$.

Trial Number	Equation Number	$P(A_1)_n$	Random Number	Response	Random Number	Side Reinforced
1.	-	.50	23	A_1	05	E_1
2.	20	$(.8) .5 + .2 = .6$	14	A_1	78	E_2
3.	21	$(.9) .6 + .1 = .64$	97	A_2	11	E_1
4.	22	$(.9).64 = .58$	44	A_1	85	E_2
5.	21	$(.9).58 + .1 = .62$	83	A_2	74	E_2
6.	23	$(.8).62 = .50$	06	A_1		

Example using Pattern Model, assuming $c = .17$, $N = 2$, $\pi = .70$.

Trial Number	Equation Number	$P(A_1)_n$	Random Number	Response	Random Number	Side Reinforced	Random Number (Compare to C)
1.	-	.50	60	A_2	69	E_1	01
2.	26	$.5 + .5 = 1.$	28	A_1	20	E_1	-
3.	24	1.0	13	A_1	72	E_2	20
4.	25*	1.0	96	A_1	52	E_1	-
5.	24	1.0	37	A_1	80	E_2	12
6.	25	$1.0 - .5 = .5$	68	A_2			

*Since $20 > 17$

TABLE 5.--Maximum Likelihood Parameter Estimates Based
on Trials 1-81 for the Four Linear Models
for Experiment 1

	Equal θ	2 θ		ID	BW	
	θ	θ_1	θ_2	θ	θ_1	θ_2
Group 60	.057	.160	.005	.190	.200	.090
L	$.27 \times 10^{-696}$	$.75 \times 10^{-418}$		$.22 \times 10^{-414}$	$.11 \times 10^{-399}$	
Group 70	.076	.200	.008	.150	.150	.080
L	$.170 \times 10^{-624}$	$.37 \times 10^{-428}$		$.33 \times 10^{-427}$	$.41 \times 10^{-406}$	

Estes (1959). Since explicit asymptotic expressions are available for the Pattern model, the observed proportion for two of these values, $P_{\infty}(A_1/E_1A_1)$ and $P_{\infty}(A_1/E_1A_2)$, were used to estimate the two parameters.

These values were $c = .17$ and $.14$ and $N = 1.25$ and 1.40 for Groups 60 and 70, respectively.

In order to avoid confusion in presenting the theoretical analyses the following procedure was adopted. Each model was evaluated separately, first on the basis of the group learning curves. A group by blocks analysis of variance was performed on the mean A_1 frequency for the 8 blocks of 10 trials comparing the group of real rats with the group of stat rats generated according to the model. If a significant group by blocks interaction was found, the correction suggested by Greenhouse and Geisser (1959) previously mentioned was applied. In addition, t -tests were performed on the mean A_1 frequency during the last 20 trials comparing real and stat rats.

If necessary, the models were then evaluated on the asymptotic A_1 frequency distribution, on which Kolmogorov-Smirnov tests were performed to compare real and stat rat "data." Finally, for those models surviving these tests, additional trials were computed for the stat rats for the

19 trials using the 0:100 reinforcement schedule. For these additional trials the real rat "asymptotic" A_1 proportions were used as an estimate of the initial probability of responding. The resulting distributions were compared to those of the real rats using a Kolmogorov-Smirnov test. The sequence of tests was thus used to determine which model best described the data.

The Estes Equal θ Model

In Figure 4 the mean proportion of A_1 s in blocks of ten trials is plotted for the Equal θ stat rats and the real rats for Groups 60 and 70. Inspection of Figure 4 reveals that the learning curve for the Equal θ appeared to be below that of the Group 60 real data almost throughout, but especially at asymptote. On the other hand, the Equal θ learning curve for Group 70 crossed that of the real rats at a few points.

The group by blocks analysis for the Equal θ model using the real and stat rat "data" is shown in Table 6 and revealed a significant group effect for Group 60 but not for Group 70. The t -tests revealed a significant between group difference at asymptote between real and Equal θ stat rats for Group 60 ($t=2.30$, $df=58$, $p<.05$) but not for Group 70 ($t=.23$, $df=46$, $p>.05$).

FIGURE 4.--Mean Proportion of A_1 s Over Blocks of Ten Trials
for the Equal θ Model Stat Rats for Groups 60 and 70
of Experiment 1

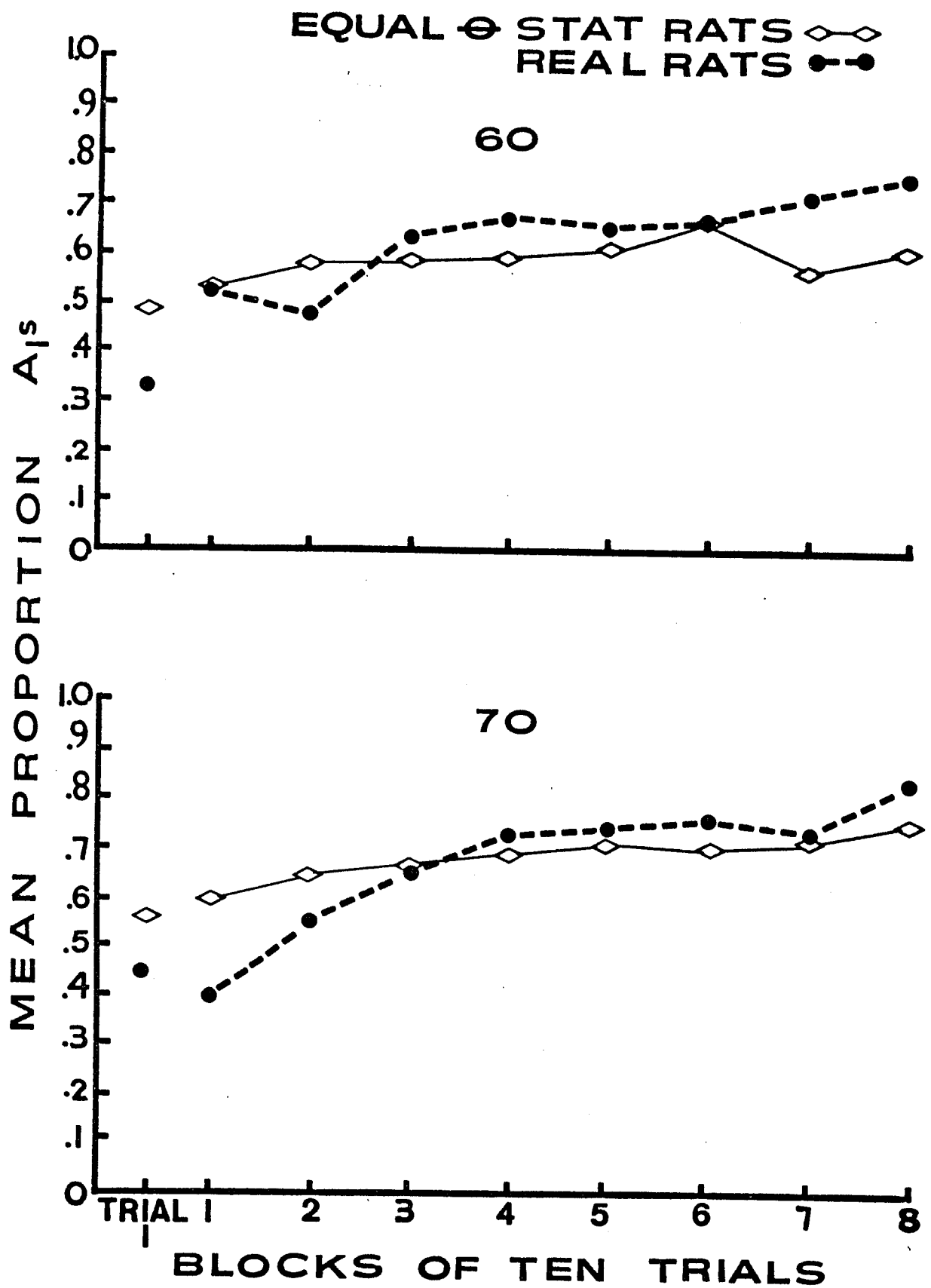


TABLE 6.--Analyses of Variance Based on Mean A_1 Frequency
For the Eight Blocks of Ten Trials for the
Equal Φ Model Comparisons for Experiment 1

Group 60				
Source	SS	df	MS	F
Group (G)	193	1	193.00	5.31*
Error	2109	58	36.36	
Blocks (B)	104	7	14.86	7.18*
G x B	66	7	9.43	4.56* (1/58)*
Error	841	406	2.07	
Total	3313	479		

Group 70				
Group (G)	1	1	1.00	.03
Error	1677	56	29.95	
Blocks (B)	345	7	49.29	13.01*
G x B	76	7	10.86	2.87* (1/57)
Error	1487	392	3.79	
Total	3586	463		

* $p < .05$

In Table 2 are presented the frequencies of A_1 responses in the last 20 trials for real and stat rats. Inspection of Table 2 revealed that most of the Equal θ stat rats clustered about the matching value of 12 and 14 for Groups 60 and 70, respectively, with few stat rats tending toward absorption. A Kolmogorov-Smirnov test was performed on the differences between the asymptotic A_1 frequency distributions for each stat rat versus real rat comparison for both groups, and revealed significant differences for both groups, $K_D=19$, $N=30$, $p < .05$ and $K_D=16$, $N=29$, $p < .05$ for Groups 60 and 70, respectively.

The Equal θ model, although it apparently described the learning curve for Group 70 adequately, was clearly inadequate in accounting for the amount of "absorption" demonstrated by real rats. As a result, the Equal θ model was rejected and was not subjected to any further tests.

Bush and Mostellers' 2θ Model

The learning curves for the 2θ model stat rats for Groups 60 and 70 is presented in Figure 5. Inspection of Figure 5 reveals that the 2θ model learning curves were well above those of the real rats throughout the course of the study. The group by blocks analysis of variance, as shown in Table 7, revealed significant group effects for both

FIGURE 5.--Mean Proportion of A_1 s Over Blocks of Ten Trials
for the 2 θ and ID Model Stat Rats for
Groups 60 and 70 of Experiment 1

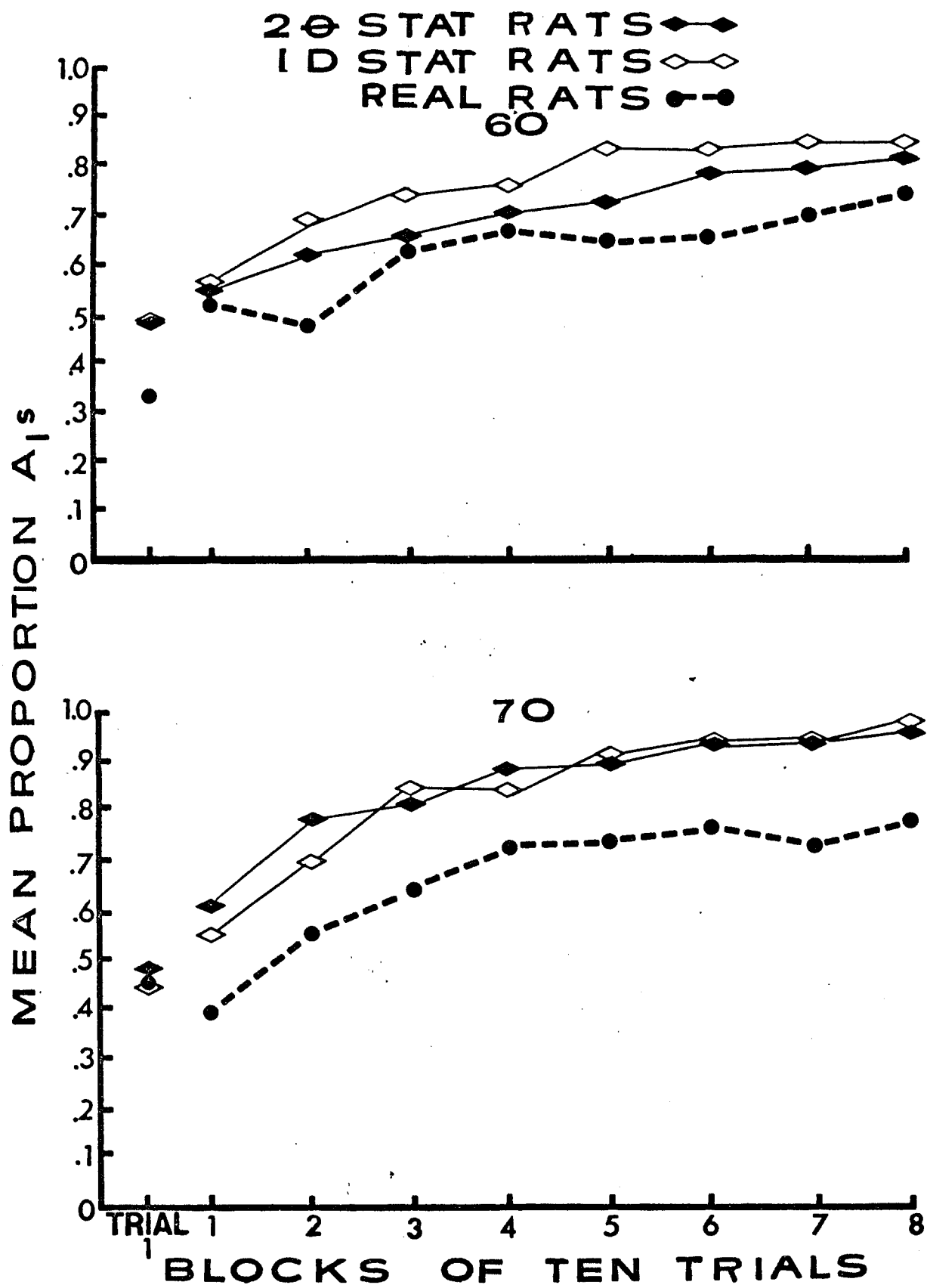


TABLE 7.--Analyses of Variance Based on Mean A_1 Frequency
For the Eight Blocks of Ten Trials for the
2 θ Model Comparisons for Experiment 1

Group 60				
Source	SS	df	MS	F
Group (G)	231	1	231.00	4.16*
Error	3223	58	55.57	
Blocks (B)	301	7	43.00	14.33*
G x B	40	7	5.71	1.90
Error	1217	406	3.00	
Total	5012	479		

Group 70				
Group (G)	129	1	129.00	4.26*
Error	1697	56	30.30	
Blocks (B)	445	7	63.57	17.56*
G x B	21	7	3.00	.83
Error	1419	392	3.62	
Total	3711	463		

* $p < .05$

Group 60 and 70. However, the t -tests performed on the mean A_1 frequency during the last 20 trials failed to yield a significant difference for Group 60 ($t = 1.27$, $df = 58$, $p > .05$) but did for Group 70 ($t = 3.04$, $df = 56$, $p < .05$). Since the 2θ model was clearly unable to account even for the group learning curve, it was dismissed without any further analyses.

Bush and Mostellers' Identity Operator Model

Here too, as shown in Figure 5, the ID model learning curves were well above those of the real rats. The group by blocks analyses of variance, as shown in Table 8, revealed significant group effects for both Groups 60 and 70. Again the t -tests failed to yield significance for Group 60 ($t = 1.70$, $df = 58$, $p > .05$) but did for Group 70 ($t = 2.78$, $df = 56$, $p < .05$). As a result the ID model, as the 2θ model, was dismissed because of the failure to describe adequately so gross an aspect of the data as the learning curve.

Bush and Wilsons' Secondary Reinforcement Model

In Figure 6 is presented the mean A_1 frequency in blocks of ten trials for the BW model for Groups 60 and 70. Inspection of Figure 6 reveals that the learning curves for

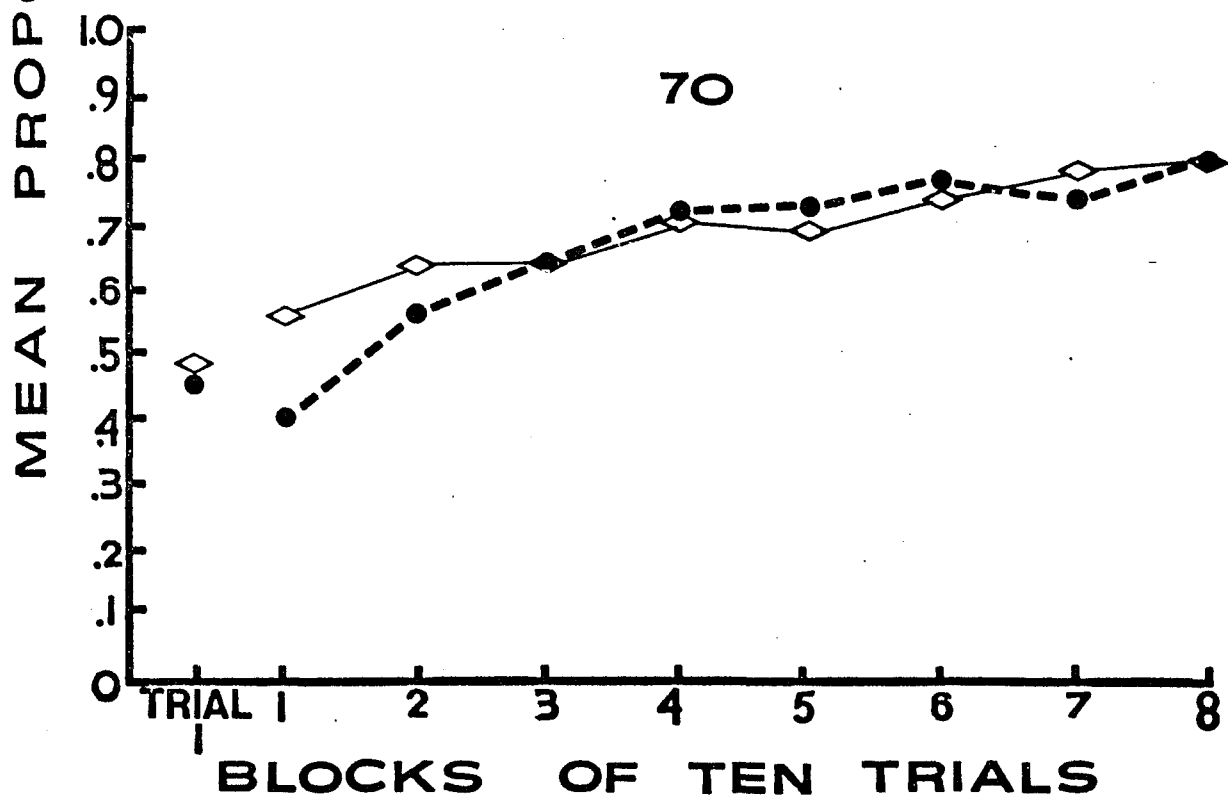
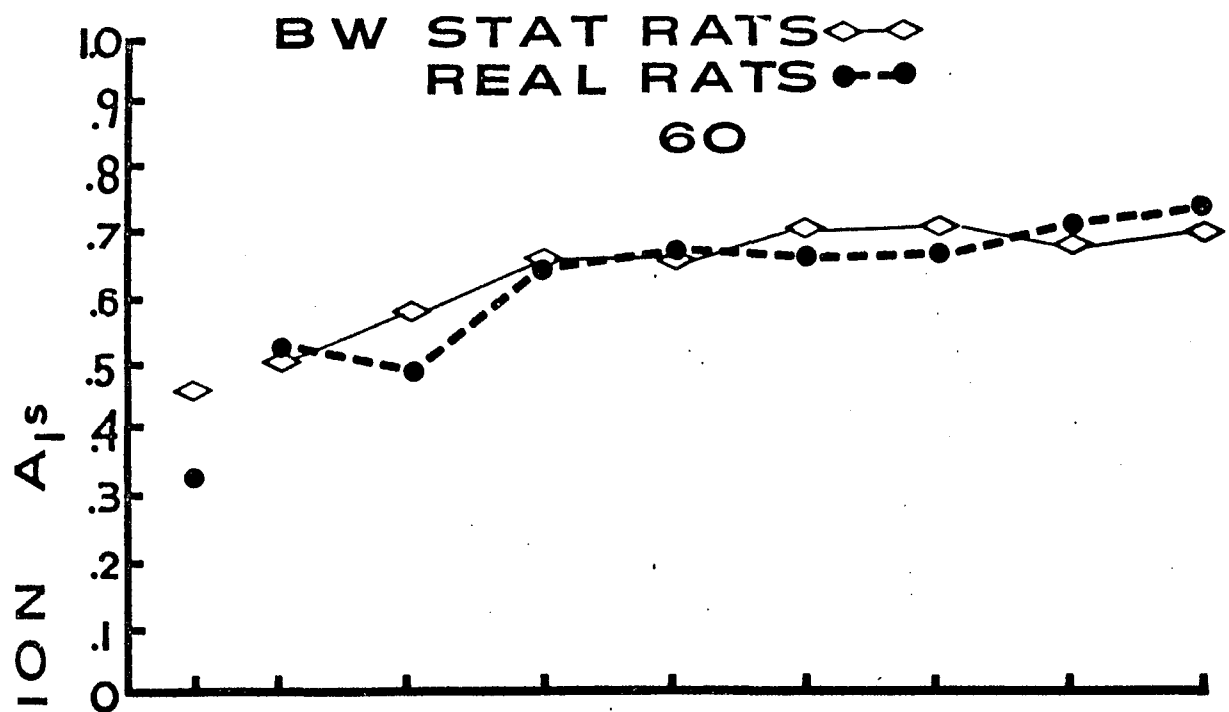
TABLE 8.--Analyses of Variance Based on Mean A_1 Frequency
For the Eight Blocks of Ten Trials for the
ID Model Comparisons of Experiment 1

Group 60				
Source	SS	df	MS	F
Group (G)	317	1	317.00	5.94*
Error	3094	58	53.34	
Blocks (B)	384	7	54.86	13.00*
G x B	36	7	5.14	1.22
Error	1712	406	4.22	
Total	5543	479		

Group 70				
Group (G)	131	1	131.00	4.22*
Error	1740	56	31.07	
Blocks (B)	416	7	59.29	15.28*
G x B	24	7	3.43	.88
Error	1522	392	3.88	
Total	3833	463		

* $p < .05$

FIGURE 6.--Mean Proportion of A_1 s Over Blocks of Ten Trials
for the BW Model Stat Rats for Groups 60 and 70
in Experiment 1



the BW model were extremely close to those of the real rats for both Groups 60 and 70. The group by blocks analyses of variance did not yield any significant group effects, as shown in Table 9, nor did the t -tests yield any between group differences for Group 60 ($t = .27$, $df = 58$, $p > .05$) or Group 70 ($t = .33$, $df = 56$, $p > .05$).

The frequencies of A_1 responses in the last 20 trials for real and stat rats are shown in Table 2. Inspection of Table 2 reveals that the BW stat rats responded in a manner similar to that of the real rats for both Groups 60 and 70. However, ten more stat rats went exactly 100% of the trials to the A_1 side than real rats for Group 70. Kolmogorov-Smirnov tests performed on the asymptotic A_1 frequency distribution failed to yield significant differences for either Group 60 ($K_D = 4$, $N = 30$, $p > .05$) or Group 70 ($K_D = 10$, $N = 29$, $p > .05$). Thus the BW model appears to account for the group learning curves as well as the absorption found on the A_1 and the A_2 side at asymptote for both groups.

During the last 19 trials of the experiment the reinforcement schedule was changed and reinforcement was given 100% of the trials only on the side opposite the one on which each S had been absorbed during the asymptotic block. The BW stat rats were also "run" for these additional

TABLE 9.--Analyses of Variance Based on Mean A_1 Frequency
For the Eight Blocks of Ten Trials for the
BW Model Comparisons for Experiment 1

Group 60				
Source	SS	df	MS	F
Group (G)	1	1	1.00	.02
Error	2635	58	45.43	
Blocks (B)	217	7	31.00	7.54*
G x B	21	7	3.00	.73
Error	1667	406	4.11	
Total	4541	479		

Group 70				
Group (G)	1	1	1.00	.03
Error	2074	56	37.04	
Blocks (B)	371	7	53.00	14.02*
G x B	48	7	6.86	1.81
Error	1483	392	3.78	
Total	3977	463		

*p < .05

19 trials, "reinforcement" being given only on the side opposite the stat rats "preferred" side during the last 20 trials. The real rats asymptotic $P_{\infty}(A_1)$ were used as the initial $P(A_1)$ for the stat rats for these trials. The distribution of the frequency of responses to the side absorbed during the last 19 trials were presented for real and stat rats for both groups in Table 3.

Kolmogorov-Smirnov tests were performed on the frequency distribution of responses during these 19 trials and revealed no significant differences for Group 60 ($K_D = 3$, $N = 30$, $p > .05$) or Group 70 ($K_D = 4$, $N = 29$, $p > .05$). Therefore, the general trend of a large amount of resistance to change displayed by real rats was also shown by the BW stat rats.

The number of rats making their first "switch" response (a response to the non-absorbed side) during the last 19 trials is presented in Table 13 for real and BW stat rats for both Groups 60 and 70. Inspection of Table 13 reveals a fairly close correspondence between real and stat organisms for both Groups 60 and 70, although as also shown in Table 3 stat rats appeared to be even more resistant to change than real rats.

TABLE 10.--Number of Rats Making Their First Response to the Non-Absorbed Side During the Last 19 Trials When Reinforcement Was Available Only On the Non-Absorbed Side for Real and BW Stat Rats for Experiment 1

Trial Number	Group 60		Group 70	
	Real	BW	Real	BW
1	1	3	1	2
2	4	2	0	3
3	3	2	1	1
4	1	1	1	2
5	0	0	1	3
6	2	1	1	2
7	0	0	0	1
8	2	2	4	0
9	1	1	0	1
10	0	0	2	1
11	0	0	1	0
12	0	0	1	0
13	2	1	1	1
14	0	0	1	0
15	0	0	2	0
16	0	0	0	0
17	0	0	1	0
18	0	1	2	0
19	0	0	1	0
Never Switched	14	16	8	12

Estes' Pattern Model

The estimated values of N , as indicated previously, were 1.25 and 1.40 for Groups 60 and 70, respectively. These values suggest that a 1 element model may be appropriate for the present data. However, from a logical point of view this appears to be clearly wrong, especially since in the 1 element model it is assumed that the organism's response probability changes in a single step from 0 to 1. Despite this logical objection, the values of c were recomputed using an assumed value of $N = 1$ and then some theoretical asymptotic conditional probabilities were computed. The results are shown in Table 11 and it is clear, from inspection, that the 1 element model is unable to handle first order conditional probabilities. The differences are of the order of magnitude of 50% or more.

Therefore, it was concluded that the values of N were an underestimate and a 2 element model was assumed. However when $N = 2$ was substituted in the asymptotic expressions used to estimate c , negative numbers were obtained. As a result, the original estimates of c (namely, .17 and .14 for Groups 60 and 70, respectively) were used as the best available estimate. Using the parameter estimates, an assumed value of .5 for the initial $P(A_1)$, and the individual

TABLE 11.--Comparison of 1-Element Model to Real Rats
for Groups 60 and 70 On Some Asymptotic
Conditional Response Probabilities
for Experiment 1

	Group 60		Group 70	
	Real	1-Element Model	Real	1-Element Model
$P_{\infty}(A_1/E_2A_2)$	.19	.00	.29	.00
$P_{\infty}(A_1/A_2)$	.23	.15	.30	.21
$P_{\infty}(A_1/E_2)$	.72	.45	.74	.49

reinforcement schedules, one stat rat was generated corresponding to each real rat.

In Figure 7 is presented the PM learning curves for Groups 60 and 70. Inspection of Figure 7 reveals that the PM learning curve was below that of Group 60 almost throughout, and especially at asymptote. However, as shown in Figure 7, the PM learning curve does cross the Group 70 curve a few times. The group by blocks analyses of variance, as shown in Table 12, revealed a significant group effect for Group 60 but not for Group 70. In addition, the t -tests failed to reveal any asymptotic differences for Group 60 ($t = 1.72$, $df = 58$, $p > .05$) or Group 70 ($t = .37$, $df = 56$, $p > .05$).

In Table 2 is presented the asymptotic frequencies of A_1 responses. Inspection of Table 2 reveals that the PM stat rats, similar to the Equal θ stat rats, tended to cluster around the matching values of 12 and 14 for Groups 60 and 70, respectively. However considerably more variability was demonstrated by PM stat rats than Equal θ stat rats. Despite this, the real rats showed even more absorption than PM stat rats. Kolmogorov-Smirnov tests performed on the asymptotic A_1 frequency distributions revealed significant differences for both Group 60 ($K_D = 13$, $N = 30$, $p < .05$)

FIGURE 7.--Mean Proportion of A_1 s Over Blocks of Ten Trials
for the PM Stat Rats for Groups 60 and 70
for Experiment 1

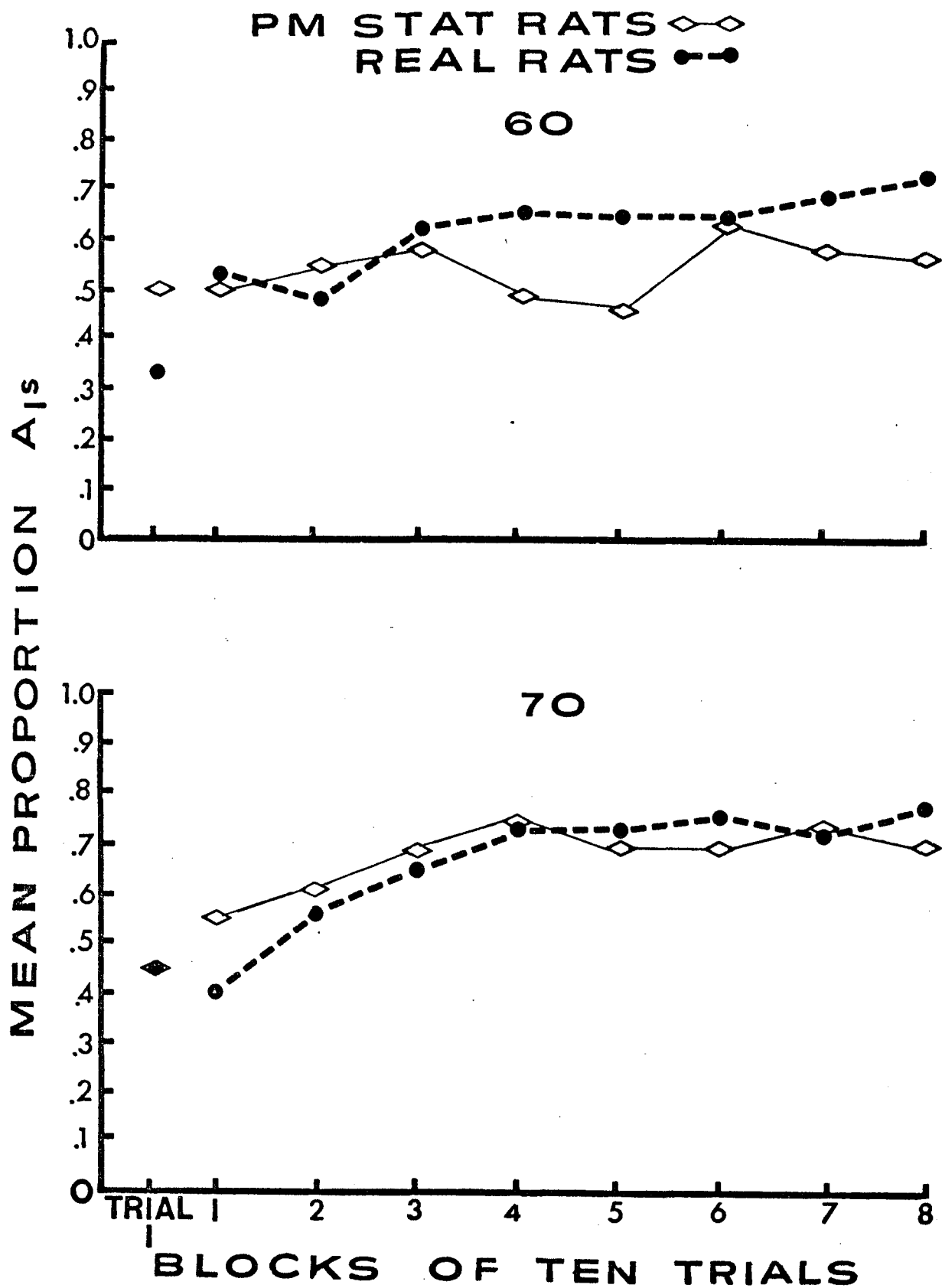


TABLE 12.--Analyses of Variance Based on the Mean A_1 Frequency
For the Eight Blocks of Ten Trials for the
PM Comparisons for Experiment 1

Group 60				
Source	SS	df	MS	F
Groups (G)	204	1	204.00	4.16*
Error	2845	58	49.05	
Blocks (B)	63	7	9.00	4.13*
G x B	41	7	5.86	2.72* (1/58)
Error	983	406	2.18	
Total	4136	479		

Group 70				
Groups (G)	1	1	1.00	.03
Error	1814	56	32.40	
Blocks (B)	219	7	31.29	7.28*
G x B	66	7	9.43	2.19* (1/57)
Error	1683	392	4.30	
Total	3783	463		

* $p < .05$

and Group 70 ($K_D = 11$, $N = 29$, $p < .05$), demonstrating that the PM model failed to account for the amount of absorption found in real rats.

At this point it may be well to summarize the results thus far presented.

Both the 2 θ and ID models failed to describe the group learning curves and on this basis were rejected. On the other hand the Equal θ and the PM model both, although unable to describe the group learning curves for Group 60, did describe that for Group 70. This is not surprising since both the Equal θ and PM models predict matching at asymptote, and Group 60 showed a 20% (although not significant) "overshoot," while Group 70 may have matched (a 7% "overshoot"). When the Equal θ and PM model were subjected to further test it was found that considerably more real rats were absorbed than predicted by either model. As a result both models were rejected due to the failure to account for the absorption found.

Thus, only the BW model appeared to account for the group learning curves, the absorption found at asymptote, as well as the resistance to change demonstrated by the real rats when switched to a 0:100 reinforcement schedule. As a result, 41 statistics, used by Weinstock et al (1965), were

computed to explore the fine detail of the data. The means and standard deviations (sd) for these statistics are presented for the BW model stat rats and real rats for both groups in Table 13. Of the 41 comparisons none of the differences were significant for Group 60 and only three for Group 70.

Some of the differences however appeared to be considerable and significant differences may have been masked by a large error variance. Specifically, for the Group 60 comparisons, three of the differences were 40% and four were 30%. On the other hand 24 differences were less than 10% and an additional 10 were less than 20%. Similarly, only 1 of the 38 non-significant differences for Group 70 was 40% and 2 were 30%. In addition, 27 differences were less than 10% and 8 were less than 20%. Furthermore, for Group 70, BW stat rats made the last A_2 significantly earlier, had significantly less A_2 s in block 1 and significantly less A_2 runs of 5 or more than real rats.

The significant differences found for Group 70 are not surprising when we consider that 10 more stat rats made 20 A_1 s during the last 20 trials than real rats. Since these stat rats would obviously make their last A_2 earlier than those Ss not completely absorbed, and since the

TABLE 13.--Means and Standard Deviations (sd) for Real and BW Stat Rats for Experiment 1

Group 60					
Statistic	Real		Stat		t
	Mean	sd	Mean	sd	
Trial no. 1st A_1	2.20	1.68	3.50	4.09	1.59
2nd A_1	4.13	2.08	5.33	5.40	1.11
3rd A_1	5.37	2.40	7.50	7.00	1.56
1st A_2	1.87	2.23	1.80	1.17	.15
2nd A_2	3.83	2.37	4.30	2.97	.67
3rd A_2	5.57	3.15	6.47	9.30	.49
Last A_2	55.17	26.93	48.70	29.69	.87
Number of A_2 s	29.30	23.92	28.20	27.26	.16
Mean A_2 Run Length	5.74	9.57	9.10	19.99	.81
Longest A_2 Run Length	14.97	20.30	13.90	21.00	.20
No. A_1 Runs Length 1	3.60	3.16	3.33	3.78	.29
2	1.73	1.98	1.23	1.23	1.14
3	.97	.98	.60	.71	1.68
4	.37	.66	.30	.53	.41
5 or more	2.03	1.52	1.83	1.29	.54
No. A_2 Runs Length 1	4.97	3.65	3.57	3.25	1.54
2	1.60	1.67	1.27	1.46	.80
3	.57	.80	.57	.72	.00
4	.30	.53	.50	.81	1.12
5 or more	1.13	1.26	1.23	1.69	.26

TABLE 13--Continued

Group 60					
Statistic	Real		Stat		t
	Mean	sd	Mean	sd	
Sequences:					
A ₁ A ₁ A ₁	37.90	24.86	41.53	28.79	.52
A ₂ A ₁ A ₁	4.97	3.48	3.67	2.53	1.59
A ₁ A ₂ A ₁	4.53	3.77	3.37	3.08	1.27
A ₂ A ₂ A ₁	3.40	2.39	3.27	2.97	.18
A ₁ A ₁ A ₂	4.30	3.44	3.30	2.40	1.30
A ₂ A ₁ A ₂	3.40	3.13	3.13	3.72	.30
A ₁ A ₂ A ₂	3.37	2.47	3.23	3.08	.19
A ₂ A ₂ A ₂	17.13	23.68	17.50	24.82	.06
A ₁ A ₁	43.00	24.79	45.50	28.89	.36
A ₁ A ₂	8.37	5.41	6.83	5.44	1.08
A ₂ A ₁	7.90	5.49	6.60	5.36	.91
A ₂ A ₂	20.73	24.05	21.07	26.04	.05
Alternations	16.27	10.90	13.43	10.80	1.03
No. A ₂ s Block 1	4.63	2.30	4.80	2.97	.24
2	5.07	3.17	4.20	3.82	.96
3	3.63	3.75	3.30	3.34	.35
4	3.20	3.82	3.40	3.71	.20
5	3.43	3.79	2.93	3.88	.50

TABLE 13--Continued

Group 60					
Statistic	Real		Stat		t
	Mean	sd	Mean	sd	
No. A ₂ s Block 6	3.27	4.02	2.90	3.96	.35
7	2.93	3.59	3.17	4.20	.23
8	2.47	3.78	2.97	4.25	.23
Group 70					
Trial no. 1st A ₁	3.70	7.54	1.86	1.36	1.47
2nd A ₁	6.52	8.32	4.10	2.50	1.50
3rd A ₁	7.83	5.09	5.97	3.22	1.72
1st A ₂	2.00	1.53	2.28	2.68	.49
2nd A ₂	3.97	1.94	4.07	3.46	.15
3rd A ₂	5.59	2.30	6.38	4.94	.79
Last A ₂	62.28	20.28	46.41	27.71	2.54*
Number of A ₂ s	26.90	20.81	25.28	25.37	.24
Mean A ₂ Run Length	4.91	7.80	3.71	5.80	.67
Longest A ₂ Run Length	11.31	11.95	13.48	22.41	.47
No. A ₁ Runs Length 1	3.55	3.20	3.28	2.81	.34
2	1.48	1.57	1.45	1.65	.08
3	.76	.97	.93	1.26	.57
4	.45	.56	.41	.81	.22
5 or more	2.34	1.37	2.07	1.55	.95

*p < .05

TABLE 13--Continued

Group 70					
Statistic	Real		Stat		t
	Mean	sd	Mean	sd	
No. A ₂ Runs Length 1	4.45	3.33	4.93	3.83	.56
2	1.66	1.60	1.45	2.06	.44
3	.55	.85	.48	.72	.35
4	.52	.86	.38	.61	.75
5 or more	1.17	1.05	.62	.96	2.12*
Sequences					
A ₁ A ₁ A ₁	40.48	22.45	42.72	26.82	.20
A ₂ A ₁ A ₁	4.79	2.78	4.66	3.27	.17
A ₁ A ₂ A ₁	4.17	3.37	4.62	3.68	.57
A ₂ A ₂ A ₁	3.72	2.68	2.76	2.81	1.43
A ₁ A ₁ A ₂	4.31	2.74	4.07	3.27	.36
A ₂ A ₁ A ₂	3.28	3.08	3.00	2.78	.42
A ₁ A ₂ A ₂	3.59	2.91	2.69	2.73	1.34
A ₂ A ₂ A ₂	14.66	19.63	14.48	24.56	.03
A ₁ A ₁	45.52	22.24	47.59	26.42	.33
A ₁ A ₂	8.14	4.93	7.66	5.62	.36
A ₂ A ₁	7.79	5.16	7.34	5.69	.34
A ₂ A ₂	18.55	20.28	17.41	25.10	.19
Alternations	15.93	10.19	15.00	11.31	.33

*p < .05

TABLE 13--Continued

		Group 70				
Statistic		Real		Stat		t
		Mean	sd	Mean	sd	
No. A ₂ s	Block 1	6.03	2.17	4.52	2.51	2.44*
	2	4.41	3.02	3.62	3.03	1.00
	3	3.45	3.32	3.55	3.30	.13
	4	2.72	3.42	3.00	3.71	.30
	5	2.55	3.63	3.14	3.92	.68
	6	2.31	3.67	2.59	3.85	.33
	7	2.72	3.35	2.21	3.70	.60
	8	2.14	3.61	2.14	3.60	.00

*p < .05

statistics represent group means, the behavior of these stat rats would tend to lower the overall group mean and result in an average earlier trial number of the last A_2 . Similarly, the smaller number of A_2 runs of five or more may merely reflect the fact that more stat rats were absorbed on the A_1 side and as a result made less long A_2 runs. In addition, the difference between mean number of A_2 s in the first block of trials probably reflects a slight position bias to the A_2 side for real rats.

DISCUSSION

The major finding of the present study was that when Ss were allowed to retrace the entire length of the incorrect arm, independent of reinforcement schedule, Ss tend to become "absorbed" on one or the other side of the maze. In fact, approximately 20% of the animals in the present study became absorbed on the low π side. i.e. where π was .3 or .4.

In addition when Ss were switched to a 0:100 reinforcement schedule, i.e. when reinforcement was given opposite the side S was absorbed on at asymptote on the original schedule, a large amount of resistance to change was found.

The theoretical analysis revealed that for Group 60 the group learning curve was adequately accounted for only by the Bush-Wilson model. The BW, Equal θ and Pattern model all described the Group 70 learning curve. The asymptotic frequencies of A_1 responding revealed that the Equal θ and Pattern models failed to account for the large amount of absorption found, although the Pattern model predicted more absorption than the Equal θ model. Only the BW model had large numbers of rats behaving like real rats at asymptote in that both real and stat rats were absorbed

on the A_1 and the A_2 side.

The analysis of the fine detail of the data revealed a considerable amount of success for the BW model in accounting for the detailed structure of the data. Furthermore, the resistance to change displayed by Groups 60 and 70 was mirrored by the BW stat rats. In fact somewhat more stat rats failed to switch to the reinforced side.

These results appear to contradict those of Parducci and Polt. Their individual organism data were not published and it is not clear if the matching they found was an individual organism result or simply an artifact, as found here, due to the averaging of individual organism data. The group learning curves are apparently in agreement with the previous findings of Weinstock (unpublished) and Wright (1967). Wright published individual organism curves and found matching and absorption for his rats, although he did not report much absorption on the low proportion side.

The present result lends strong support for the BW model. In the BW model it is assumed that if S makes an A_1 response and is then reinforced for an A_2 , there is an increment in $P(A_1)$, although less than the increment due to an A_1 that is directly reinforced. The model can be justified, as pointed out in the introduction, in terms of delay

of reinforcement and stimulus termination or trace considerations. This discussion will be deferred to include the results of Experiment 2.

Since Group 60 showed a considerable (20%) but non-significant "overshoot" and Group 70 a slight (7%) and also non-significant overshoot, it is not clear if the group learning curve data is in conflict with those results showing probability matching (Brunswik, 1939, Estes, 1957a). These two studies that showed matching both used a choice point correction procedure. Thus the type of correction procedure employed may be a significant variable. However, if absorption is the typical outcome for an individual S, questions concerning the group mean learning curve may become relatively trivial. Again we shall return to this matter after considering the results of Experiment 2.

EXPERIMENT 2

The results of Experiment 1 were unequivocal in that, at asymptote, 50 of the 59 Ss were responding almost 100% or 100% of the time to one or the other side of the T-maze with 12 Ss going almost 100% or 100% of the time to the low probability side. Furthermore, during the last 19 trials, when Ss were switched to a 0:100 reinforcement schedule, the Ss showed a large resistance to change. These results strongly suggest that "absorption" rather than "matching" is the typical outcome for probability learning in the correction T-maze.

Since the arm length in Experiment 1 was longer than that used in the unpublished Weinstock study, which showed group overshooting, arm length may be a major variable. Examination of the literature lends support to this belief. Some Es have given correction at the choice point through the use of valve doors which allow access to reinforcement only when a "correct" response is made. Both Brunswik (1939), using massed trials, and Estes (1957a), using one trial per

day, apparently obtained matching with correction at the choice point. However, close inspection of Brunswik's data suggests that the group curves may not have been asymptotic. Similarly, examination of Estes' data by Bitterman, Wodinsky and Candland (1958) led them to conclude that the result is an artifact due to averaging of the results of individual Ss. They noted that over the last 16 trials 7 Ss were going almost 100% or 100% of the time to the high π side (exactly 5 responded at 100%), while 6, appeared to be matching and the remaining 3 were tending towards 0% of the time to the high π side.

The present experiment was designed to resolve the apparent contradictions in results by systematically varying the length of the arms of the T-maze and, thus, the depth of penetration allowed on correction trials. To this end, two groups of rats were given correction at the choice point, one under a 67:33 reinforcement schedule and the other a 80:20 reinforcement schedule. Two other groups were given a 67:33 reinforcement schedule, with one group correcting after a partial entry, 11 in., and the other after a complete entry into the incorrect arm, 22 in. Another goal of the present study, as in Experiment 1, was to determine which of the linear models, the Equal θ , 2θ , Identity

Operator or Bush-Wilson model, or the N-Pattern model best describes the data. The results of Experiment 1 indicated that the Bush-Wilson model gave an excellent approximation to behavior in the correction T-maze when S is allowed to retrace the entire length of the incorrect arm and that the other models failed even to account for the gross features of the data.

METHOD

Subjects

One hundred and two female albino rats, 100-120 days old at the start of the experiment were obtained from Albino Farms, Little Silver, New Jersey.

Apparatus

Three enclosed T-mazes painted flat gray, measuring 5 in. high and 5 in. wide throughout were used. The start box was 10 in. long and the stem was 18 in. long. The cross piece, including the choice area was 59 in. long for the choice point groups (Group C), 79 in. long for the group receiving correction 11 in. up the arm (Group I), and 101 in. long for the group allowed to retrace the entire length of the incorrect arm (Group L). Guillotine doors separated the start box, stem and each of the arms. The doors of the arms were mounted 26 in. from the end wall of each goal box so that the distance from the door in the arms to the choice area was 1, 11, and 22 in. for Groups C, I and L, respectively. The doors to the arms were mounted in a V-shaped groove which was approximately $\frac{3}{8}$ in. at the top. This permitted the door to be placed in an upright position at the beginning of the trial. The choice response required of the Ss was to

push the door $\frac{1}{4}$ in. or more in a horizontal direction as measured at the top of the groove. A drinking tube, similar to those used in the home cages was mounted on the end wall of the goal box. The apparatus was covered with hinge-mounted clear Plexiglas. Illumination was provided by two 100-W. bulbs, one centered above the start box and the other centered over the arm of the maze approximately 6 ft. above the apparatus. An air conditioner was run continuously to provide a uniform masking noise.

Procedure

Two weeks before the beginning of the experiment Ss were given access to water for 2 hr. each day at approximately the same time as they were given water throughout the course of the experiment. Each S received 1 min. of gentling each day for two weeks. Ss were then given 10 preliminary training trials at one trial per day in an alley painted flat gray throughout, to train the Ss to push a door similar to the ones in the arms of the T-maze. The alley measured 5 x 5 x 48 in., and was covered with hinge-mounted clear Plexiglas. The last 18 in. of the alley served as a goal box and was separated from the alley by a guillotine door. The Ss were required to push the guillotine door,

which was mounted in a V-shaped groove similar to those in the T-maze, separating the alley and the goal box approximately $\frac{1}{4}$ in. in order to gain access to the goal box.

Those Ss failing to meet this criterion for two successive days were discarded. Reinforcement consisted of 10 sec. of drinking for these trials.

After preliminary training Ss were randomly assigned to groups. One group of 36 Ss was run in the T-maze and was given reinforcement on .67 of the trials on one side and .33 on the other side of the maze (Group C67) while the second group ($n = 36$) received an 80:20 reinforcement schedule (Group C80). The Ss in Group I and L ($n = 15$ each) were given reinforcement on a 67:33 reinforcement schedule. Half of the Ss in each group were given the larger proportion of reinforcement on the right side and the other half on the left side of the maze. Reinforcement for each S was assigned randomly by blocks of 15 trials with the restriction that exactly 10 reinforcements were available on one side of the maze for the .67 groups and exactly 12 reinforcements were available on one side of the maze for the .80 group and that on each trial reinforcement was available on one or the other side of the maze. Reinforcement was 10 sec. of drinking. Each group was further subdivided into squads and Ss

within squads were run in a different random order each day. A correction procedure was used, correction being affected at the location of each group's respective "choice point." The Ss were given one trial per day. The first four trials were reinforced forced trials given in either a RLLR or LRRL order followed by training under the appropriate reinforcement schedule.

At the beginning of each trial S was placed in the start box facing the start box door. Two sec. later the start box door was raised. A response was defined as being the first door in the arm of the maze which was pushed approximately $\frac{1}{4}$ in. When S pushed the door leading to the reinforced side, the door was raised allowing S access to the reinforcement. The door was then closed behind S to prevent retracing. After completing 10 sec. of drinking S was returned to its home cage. When S responded to the non-reinforced side both doors were left in place until S corrected and responded to the other door.

The Ss were given access to water in their home cages for 90 min., approximately 30 min. after the last S was run. Deprivation time was 20-22 hr. The criterion for discarding an S in the maze was failure to leave the start

box within 20 min. on two consecutive trials.

The Ss were run to "asymptote" followed by an additional 20 trials, using the same procedure as in Experiment 1. As a result the choice point Ss were given 111 trials while the I and L Group Ss were given 122 trials. An additional 12 trials were given to the choice point groups involving a change in the reinforcement schedule. Specifically, reinforcement was available on one side of the maze in accordance with the straight line function $\pi(n) = .20 + .03n$, where n ran from 1 to 12 representing trials 112-123. The function for reinforcement on the other side of the maze was given by $1 - \pi(n)$. The function was applied on each trial and a table of random numbers was consulted to determine whether reinforcement was available on one or the other side of the maze. As a result $\pi(n)$ took on values from .23 to .56.

In the last month of the study, an epidemic of unknown origin swept the colony and resulted in the loss of 24 Ss. In addition, three Ss were discarded for failing to run on the early trials in the alley or the maze and two died during the early part of the study leaving 30, 25, 8 and 10 Ss in Groups C67, C80, I and L, respectively.

RESULTS

Empirical Analyses

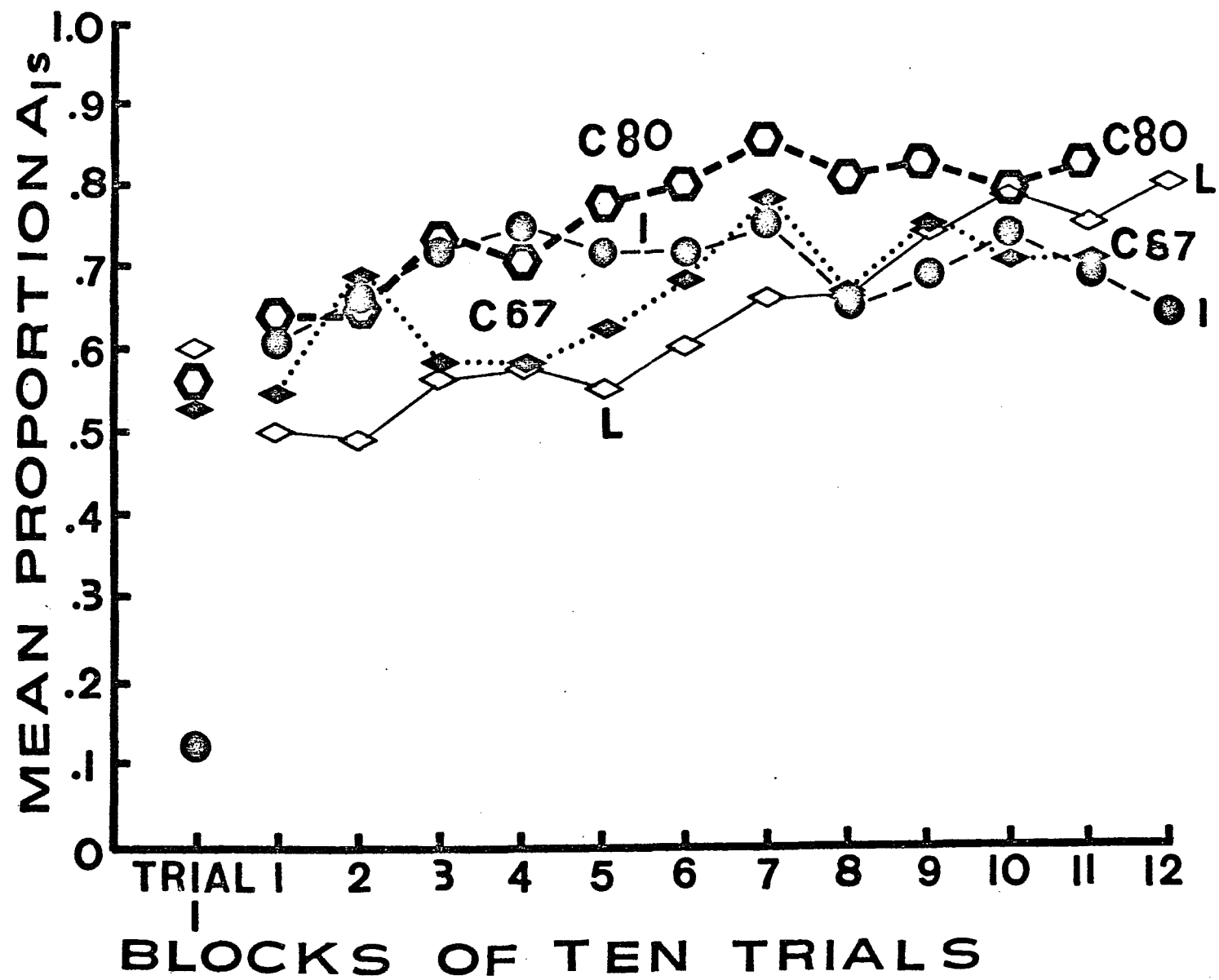
The side where the larger proportion of reinforcement was available for each S was defined to be the A_1 side.

The mean proportion of A_1 responses in blocks of ten trials is plotted in Figure 8 for all four groups.

Inspection of the Group C67 curve revealed a decrease in the proportion of A_1 s from block 2 to 3 followed by a relatively flat portion for 30 trials. The subsequent positive acceleration resulted in a somewhat S-shaped acquisition function. Group L also showed a relatively flat curve for the first 50 trials again resulting in an S-shaped acquisition function. However, the curves for Groups I and C80 appeared to be, typically, negatively accelerated throughout.

In accordance with the plan decided upon in advance of the study the mean A_1 proportion, over trials 92-111 for Groups C67 and C80 and over trials 102-122 for Groups I and L, was taken as an estimate of the asymptotic response probability. The mean proportion of A_1 responses for the

FIGURE 8.--Mean Proportion of A₁s Over Blocks of Ten Trials
for Groups C67, C80, I and L in Experiment 2
(The Last Block for Groups I and L Contains
11 Trials)



asymptotic block was .71, .85, .68 and .79 for Groups C67, C80, I and L, respectively.

A group by blocks (11 blocks of 10 trials each) analysis of variance was performed on the mean A_1 frequency for Groups C67 and C80. The result, shown in Table 14, revealed a significant Group effect, demonstrating that Group C80 had a higher level of responding to the A_1 side than C67. In addition, a t -test performed on the frequency of A_1 s during the asymptotic block also revealed a higher level of responding by Group C80 as compared to Group C67 ($t = 2.44$, $df = 53$, $p < .05$).

An analysis of variance based on the mean A_1 frequency for the last 20 trials for Groups C67, I and L failed to yield significance, as shown in Table 15. These analyses suggest that π has an effect with a choice-point correction procedure but that, for a given π value, arm length has no apparent effect on the group asymptotic mean. In view of the previous results, it is not surprising that t -tests comparing each group's asymptotic A_1 frequency to the group π value failed to yield a significant differences for Group C67 ($t = .95$, $df = 29$, $p > .05$), Group C80 ($t = 1.37$, $df = 24$, $p > .05$), Group I ($t = .11$, $df = 7$, $p > .05$) or Group L ($t = 1.62$, $df = 9$, $p > .05$).

TABLE 14.--Analysis of Variance Based on Mean A_1 Frequency
for the Eleven Blocks of Ten Trials for
Groups C67 and C80 in Experiment 2

Source	SS	df	MS	F
Groups (G)	166	1	166.00	6.46*
Error	1363	53	25.72	
Blocks (B)	253	10	25.30	7.86*
G x B	36	10	3.60	1.12
Error	1705	530	3.22	
Total	3523	584		

* $p < .05$

TABLE 15.--Analysis of Variance Based on the Mean A_1 Frequency
During the Last 20 Trials for Groups C67, I and L
in Experiment 2

Source	SS	df	MS	F
Between	43	2	21.50	.80
Within	1204	45	26.76	
Total	1247	47		

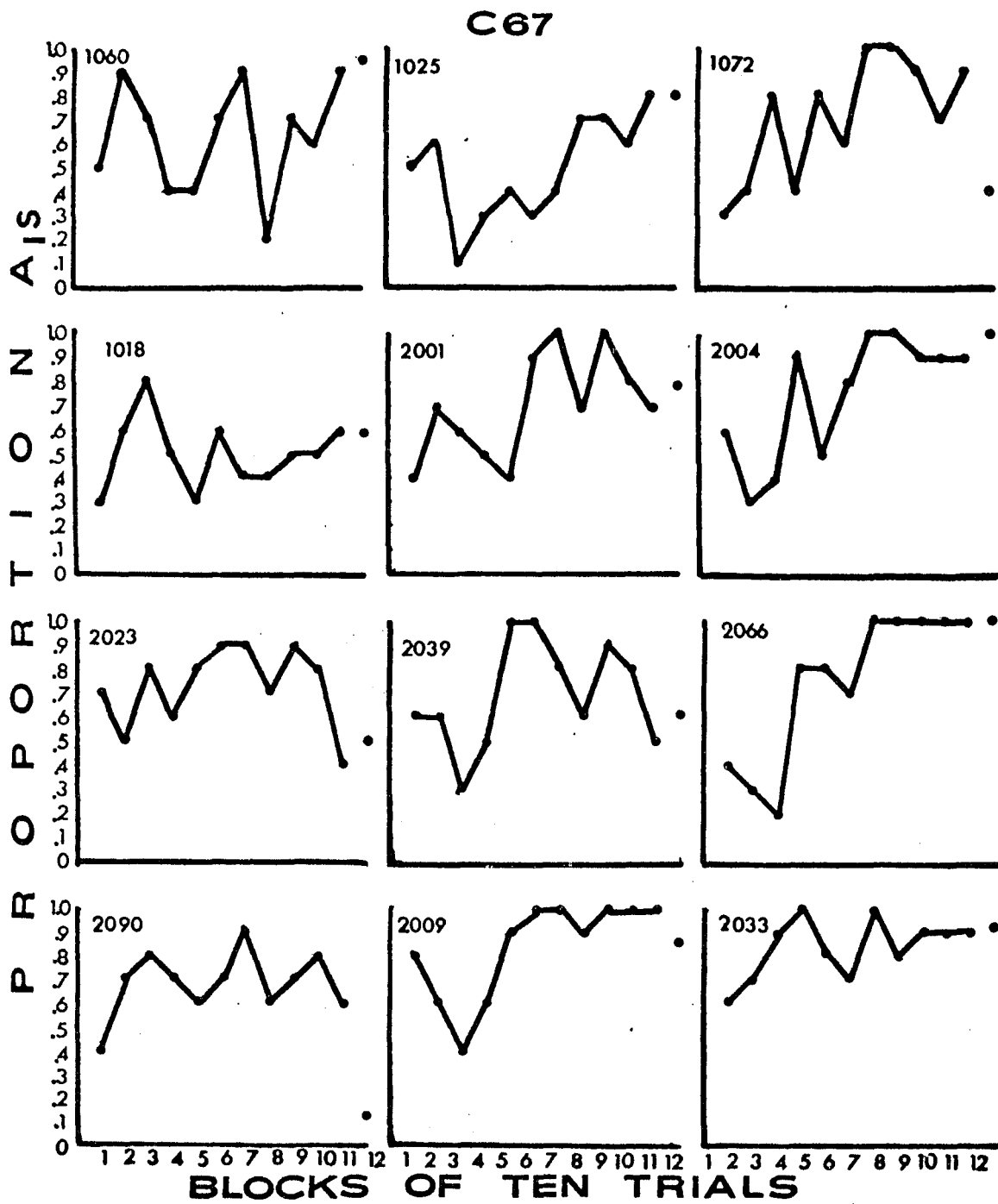
In Figures 9,10,11, and 12 are plotted the mean A_1 proportion as a function of blocks of ten trials for individual Ss in Groups C67, C80, I and L, respectively. Inspection of these figures suggests that the group learning curves do not reflect individual organism behavior.

The individual organism curves show that, at asymptote, 13 of the 30 Ss in Group C67, 17 of the 29 in C80, and more than half of the Ss in Groups I and L, were going 100% or almost 100% of the time to one or the other side of the maze. In fact, only the data from 13 of the 73 Ss from all of the groups appeared to be similar to their corresponding group curves.

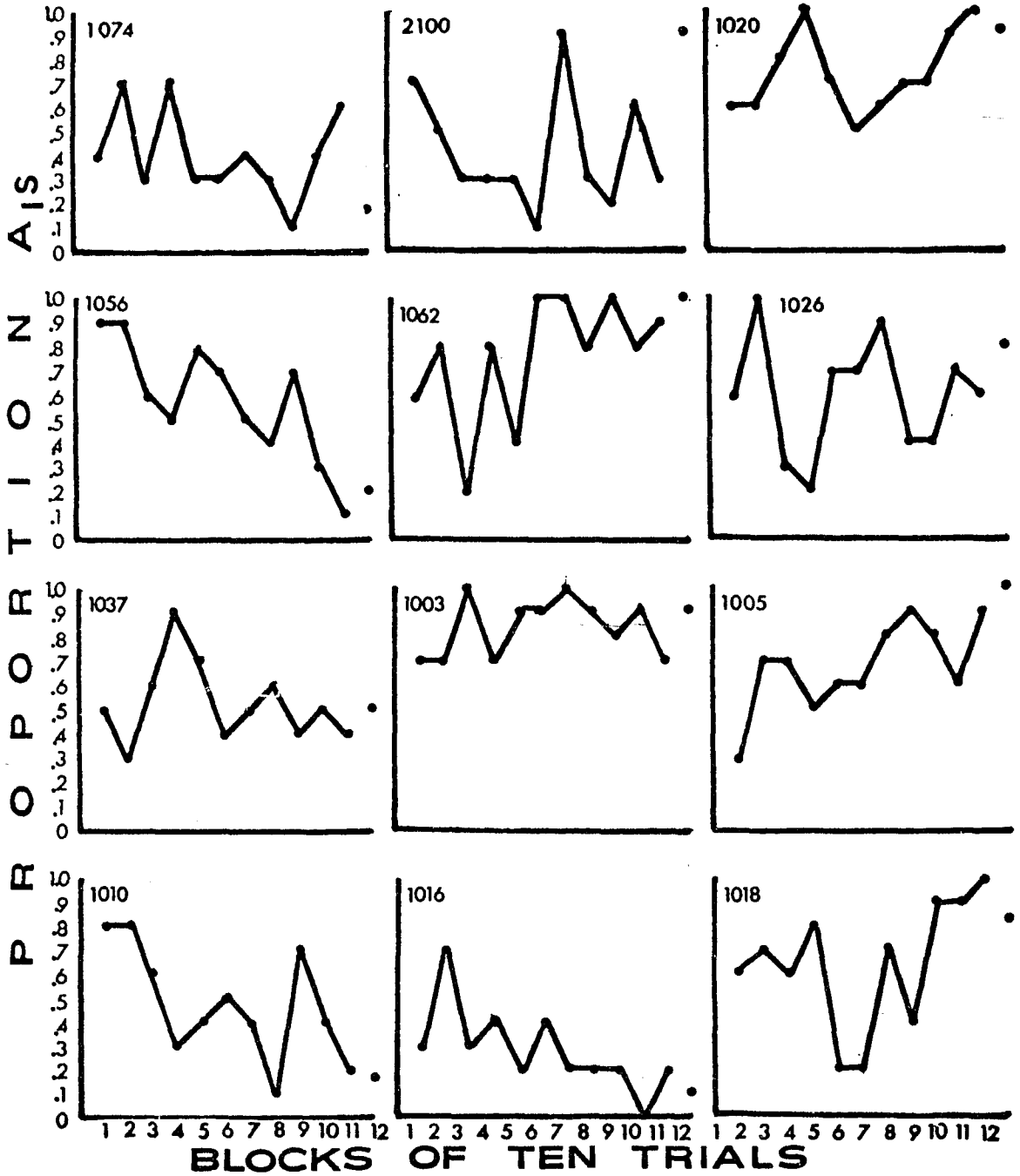
The frequency of A_1 responses during the asymptotic trials for the four groups are presented in Table 16 and reflects the absorption seen in the individual organism curves. The χ^2 approximation to the Kolmogorov-Smirnov test was performed on the difference between the C67 and C80 asymptotic A_1 frequency distribution and yielded a significant difference ($\chi^2 = 8.30$, df = 2, $p < .05$) showing that more rats were absorbed in Group C80 than Group C67.

In Figure 13 is plotted the proportion of A_1 s for Groups C67 and C80 as a function of trials for trials 102-123. Trials 112-123 involved a change in reinforcement

FIGURE 9.--Mean Proportion of A_1 s Over Blocks of Ten Trials
for Individual Ss in Group C67 in Experiment 2
(Block 12 has 12 Trials)



C67



C67

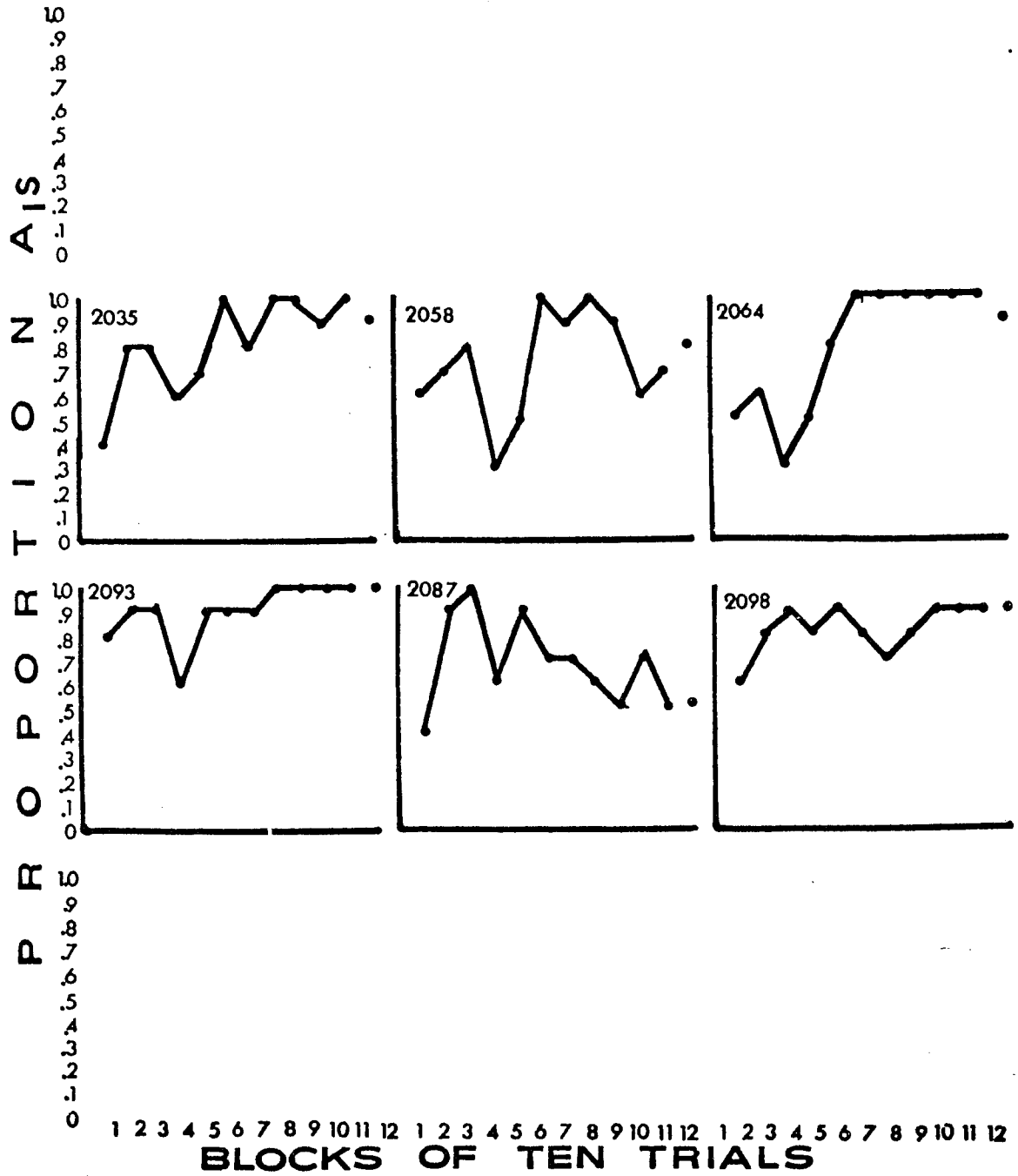
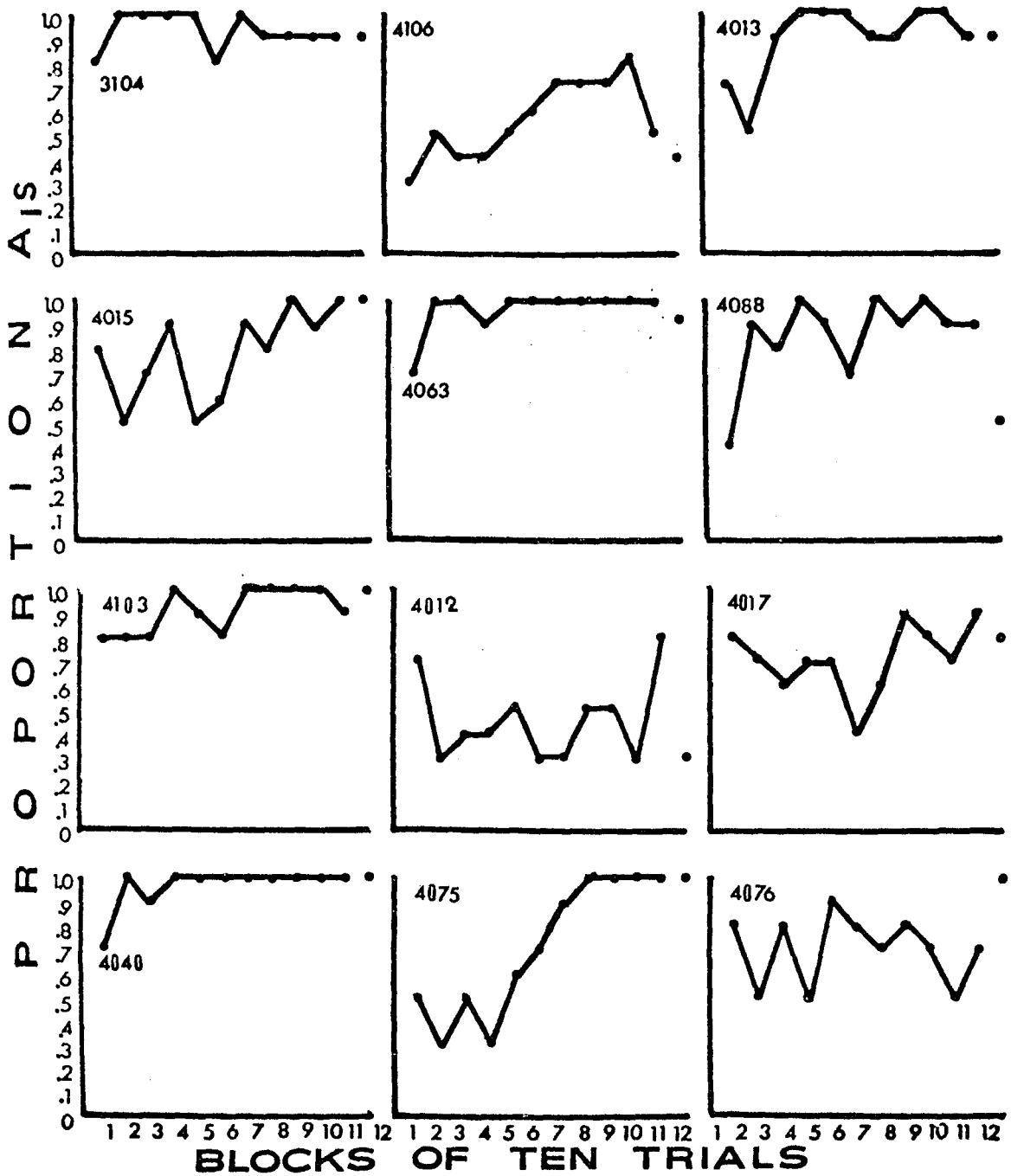
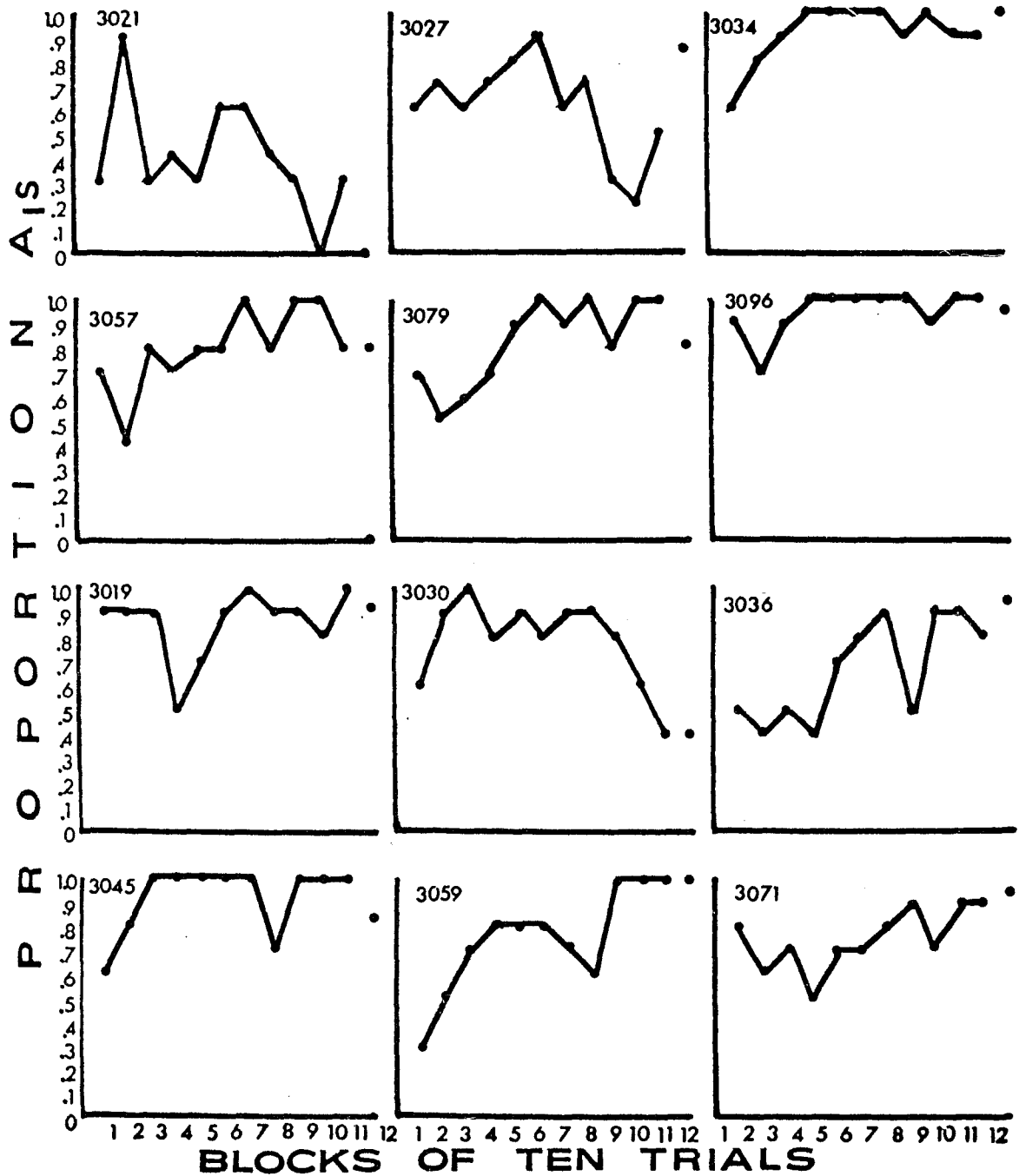


FIGURE 10.--Mean Proportion of A_1 s Over Blocks of Ten Trials
for Individual Ss in Group C80 in Experiment 2
(Block 12 has 12 Trials)

C80

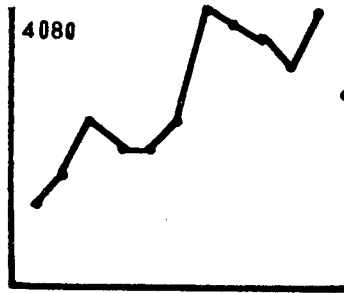


C80



C80

P R O P O R T I O N A I S
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
E



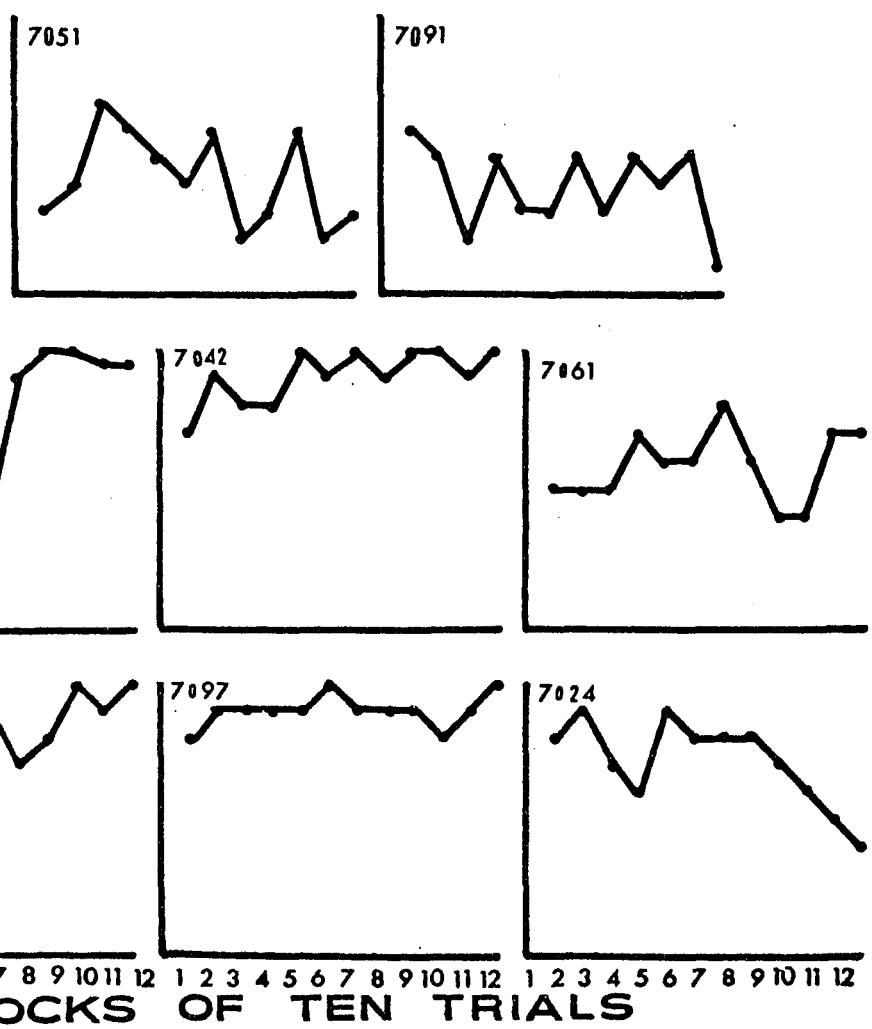
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
BLOCKS OF TEN TRIALS

FIGURE 11.--Mean Proportion of A_1 s Over Blocks of Ten Trials
for Individual Ss in Group I in Experiment 2
(Block 12 has 11 Trials)

P
R
O
P
O
R
T
I
O
N
A
I
S

I

0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0



BLOCKS OF TEN TRIALS

FIGURE 12.--Mean Proportion of A_1 s Over Blocks of Ten Trials
for Individual Ss in Group L in Experiment 2
(Block 12 has 11 Trials)

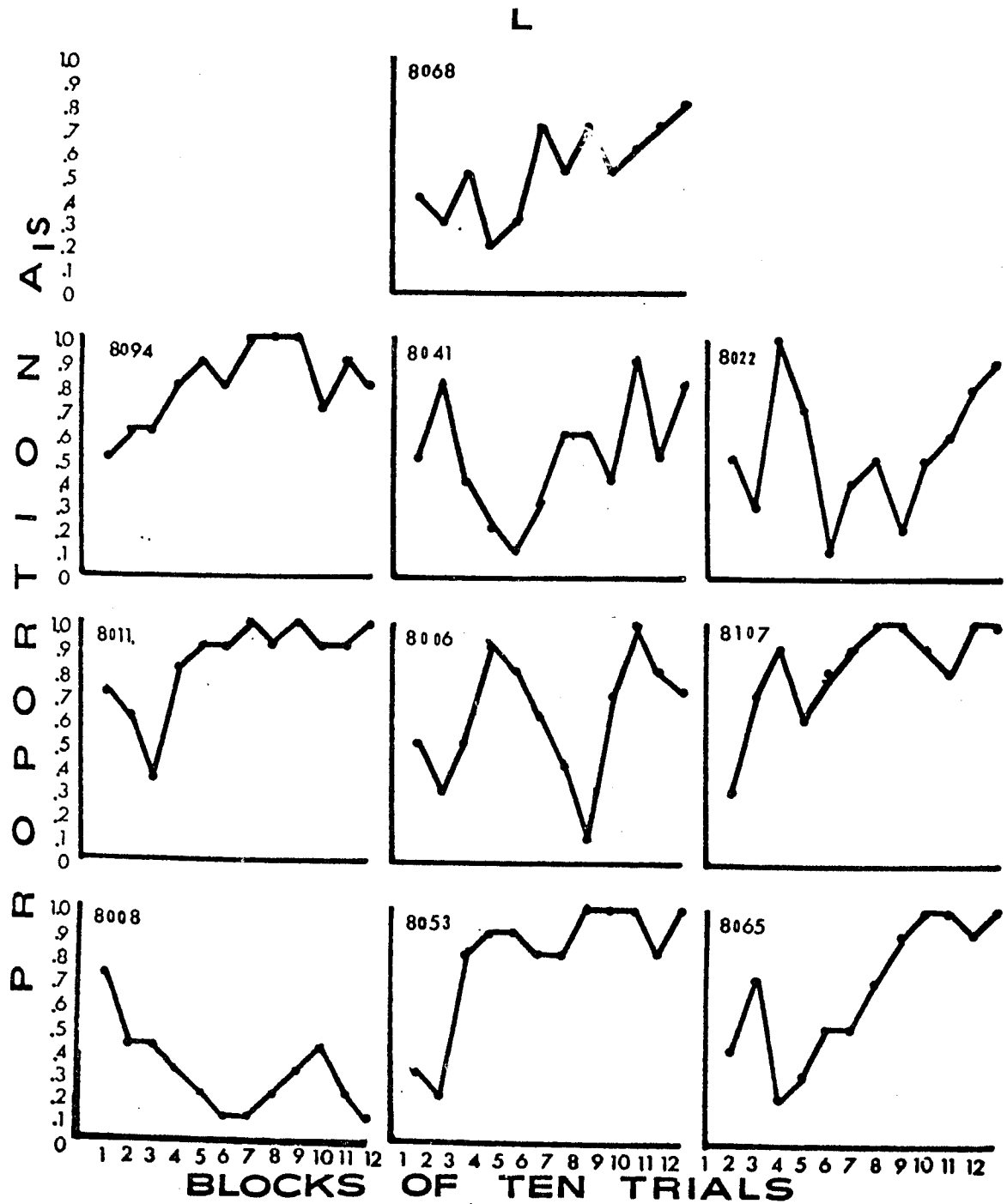
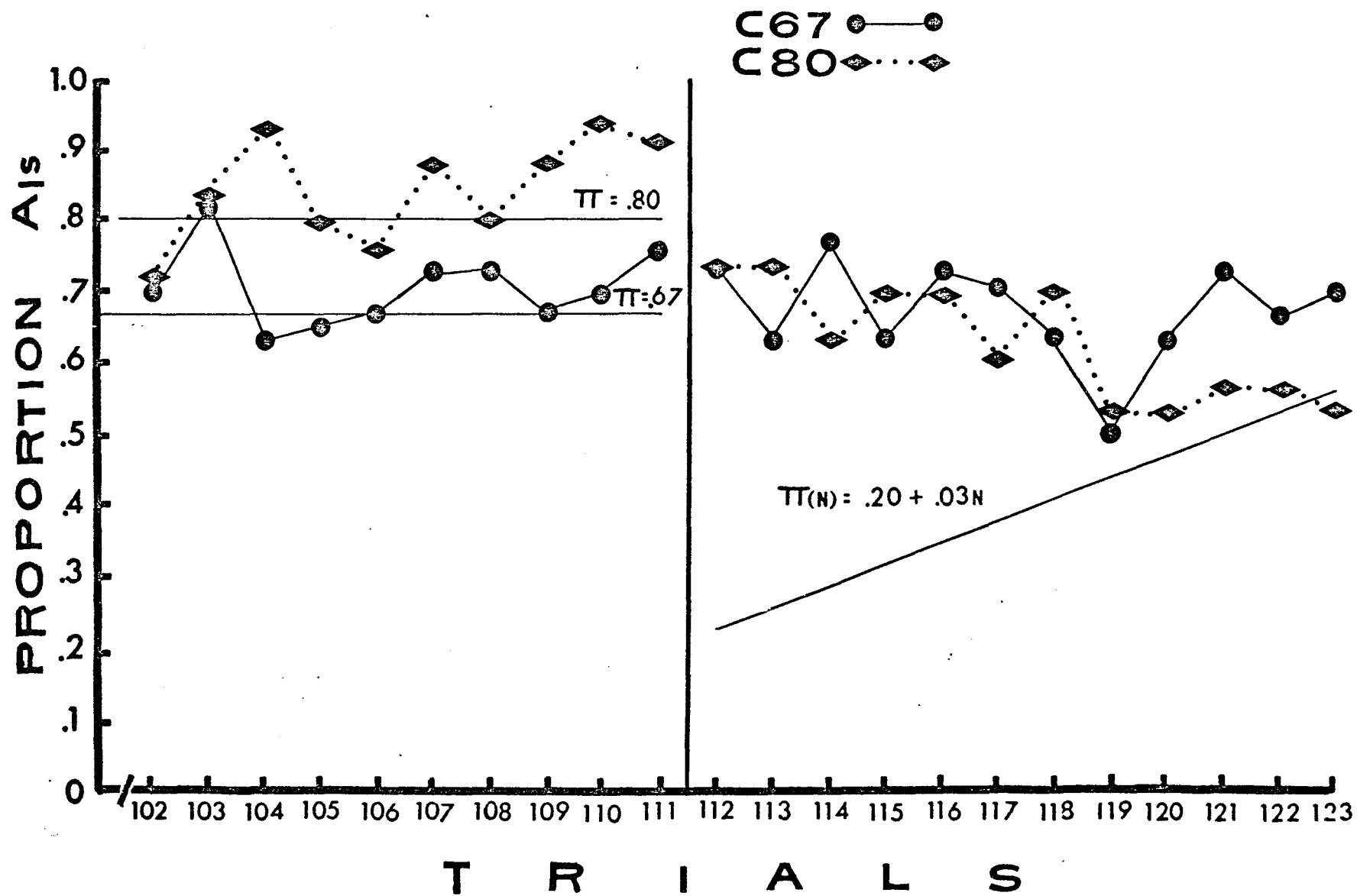


TABLE 16.--Frequencies of A_1 Responses During the "Asymptotic Block" for Real and Stat Rats in Experiment 2

Group C67	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Real	4	3	3	1	2	2	3	3	1	2	1	2	0	0	1	0	1	0	1	0	0
Equal θ	0	1	0	1	4	3	4	4	6	4	2	0	0	0	1	0	0	0	0	0	0
BW	3	4	2	2	2	1	4	2	2	2	1	0	0	2	0	1	1	1	0	0	0
PM	1	2	3	1	1	3	4	3	3	1	4	1	0	1	0	1	1	0	0	0	0
Group C80																					
Real	7	3	7	2	1	0	0	1	1	1	1	0	0	1	0	0	0	0	0	0	0
Equal θ	0	4	2	4	4	7	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0
BW	5	4	6	1	1	2	2	2	1	0	0	0	0	1	0	0	0	0	0	0	0
PM	6	1	2	1	1	1	2	4	0	3	0	1	1	1	0	0	1	0	0	0	0
Group I																					
Real	0	3	1	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	0	0	0
Equal θ	0	0	0	1	0	0	0	1	2	1	0	0	3	0	0	0	0	0	0	0	0
BW	1	0	1	0	1	0	0	1	1	0	0	0	0	1	0	1	0	0	0	0	1
Group L																					
Real	1	2	1	1	1	2	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Equal θ	0	0	0	0	0	2	3	1	1	2	1	0	0	0	0	0	0	0	0	0	0
BW	3	1	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	1	0	1	0

FIGURE 13.--Proportion of A_1 s as a Function of Trials for Trials 102-123 for Groups C67 and C80. During Trials 102-111, $\pi = .67$ and $.80$ for Groups C67 and C80, respectively. During Trials 112-123, π Ranged from $.23$ to $.56$ as Determined by the Function

$$\pi(n) = .20 + .03n, n = 1, \dots, 12$$



schedule for these groups. The probability of reinforcement was determined by the function, $\pi(n) = .20 + .03n$, where n ran from 1 to 12 representing trials 112-123. Trials 102-111 are included for comparative purposes. During these trials $\pi(n)$ varied from .23 to .56 which was a decrease from .67 and .80 for Groups C67 and C80, respectively. Inspection of Figure 13 reveals a slight tendency toward a decrease in the proportion of A_1 s. During the last 12 trials the mean A_1 proportions were .68 and .76 as contrasted with values of .71 and .85 for the asymptotic block, for Groups C67 and C80, respectively. Furthermore, the individual organism learning curves in Figures 9 and 10 revealed that most S s were relatively unaffected by the change in π . Specifically, only 4 S s from Group C67 and 3 from C80 made a "switch" from their "preferred" side. When the data from the 13 S s in Group C67 that were absorbed during the asymptotic block are inspected an even stronger picture of resistance to change emerges. For these S s an average of 10.4 (out of a possible 12) responses were made to the absorbed side, despite the fact that for 10 of these S s π was reduced from .67 to .23-.56. The 17 S s from Group C80 that were absorbed at asymptote made an average of 10.9 (out of a possible 12) responses to the absorbed side, despite the

fact that for all but one of these Ss π was reduced to .23-.56 from .80.

Theoretical Analyses

Using trials 1-111 (original π) for Groups C67 and C80 and trials 1-122 for Groups I and L maximum likelihood parameter estimates were obtained for the four groups for the Equal θ , 2θ , ID and BW models. It should be noted that Groups I and L had only 8 and 10 rats, respectively by the end of the study because of the unusually high mortality rate. As a result stable estimates for these groups could not be obtained and these groups are not emphasized in the theoretical analysis. Using an assumed value of .5 for the initial $p(A_1)$, the parameter estimates, and the individual reinforcement schedules, one stat rat was generated corresponding to each real rat.

Maximum likelihood parameter estimates for the four models for the four groups are presented in Table 17. Inspection of Table 17 suggests no apparent relationship between θ and π nor θ and arm length.

The parameters c and N for the PM were estimated from the asymptotic data, as in Experiment 1, for Groups C67 and C80 only. Because of the small number of ss in Groups I and L it was felt that stable parameter estimates based on the asymptotic data could not be obtained. As a result the PM was evaluated for Groups C67 and C80, but

TABLE 17.--Maximum Likelihood Parameter Estimates for the
Four Linear Models for Experiment 2

	Equal θ	2 θ		ID	BW	
	θ	θ_1	θ_2	θ	θ_1	θ_2
Group C67	.060	.075	.010	.050	.078	.052
L	$.20 \times 10^{-913}$	$.48 \times 10^{-856}$		$.26 \times 10^{-857}$	$.37 \times 10^{-832}$	
Group C80	.065	.051	.005	.043	.067	.040
L	$.12 \times 10^{-631}$	$.22 \times 10^{-586}$		$.45 \times 10^{-586}$	$.71 \times 10^{-557}$	
Group I	.086	.080	.009	.078	.068	.043
L	$.88 \times 10^{-259}$	$.11 \times 10^{-231}$		$.14 \times 10^{-228}$	$.47 \times 10^{-226}$	
Group L	.033	.073	.002	.066	.082	.042
L	$.13 \times 10^{-262}$	$.57 \times 10^{-298}$		$.71 \times 10^{-298}$	$.25 \times 10^{-291}$	

not for Groups I and L.

The procedure adapted for presenting the theoretical analysis in Experiment 1 was used here. Each model was evaluated separately on the basis of the group learning curves. A group by blocks analysis of variance was performed on the mean A_1 frequency for the 11 blocks of 10 trials for Groups C67 and C80 and the 12 blocks of 10 trials (block 12 had 11 trials) for Groups I and L for each model versus real rat comparison. In addition, t -tests were performed comparing real and stat rats on the mean A_1 frequency during the asymptotic block. Where necessary, the models were then evaluated on the asymptotic frequencies of A_1 s by Kolmogorov-Smirnov tests performed on the cumulative distribution. Stat rat data were also obtained for the remaining models on the reinforcement schedule $\pi(n) = .20 + .03n$, $n = 1, \dots, 12$, using the real rats' asymptotic A_1 proportion as an estimate of the initial $P(A_1)$ for these trials. The cumulative distributions were compared with those of the real rats and evaluated with a Kolmogorov-Smirnov test. Using these measures it was possible to determine which model best described the data.

Estes' Equal θ Model

The mean proportion of A_1 s in blocks of ten trials is plotted for the Equal θ model in Figure 14 for the four groups. Inspection of Figure 14 revealed that the Equal θ learning curves for all four groups were close to or somewhat above those of the real rats, during the early blocks, although the real rats surpassed the stat rats in the later blocks, especially at asymptote.

The group by blocks analysis of variance, as shown in Table 18, failed to yield a significant group effect for any of the four groups. In addition the t -tests comparing the mean asymptotic A_1 frequency revealed no significant differences for Group C67 ($t = 1.18$, $df = 58$, $p > .05$), Group C80 ($t = 1.17$, $df = 48$, $p > .05$), Group I ($t = .69$, $df = 14$, $p > .05$) or Group L ($t = 1.59$, $df = 18$, $p > .05$).

Table 16 presents the frequencies of A_1 responses during the asymptotic trials for the real and stat rats of the four groups. Inspection of Table 16 revealed that the Equal θ stat rats tended to cluster about the matching value of 13-14 for Groups C67, I and L and 16 for Group 80 and therefore did not reflect the amount of absorption shown by the real rats.

The Kolmogorov-Smirnov tests performed on the

FIGURE 14.--Mean Proportion of A_1 s Over Blocks of Ten Trials
for the Equal Φ Model Stat Rats for Groups C67,
C80, I and L of Experiment 2

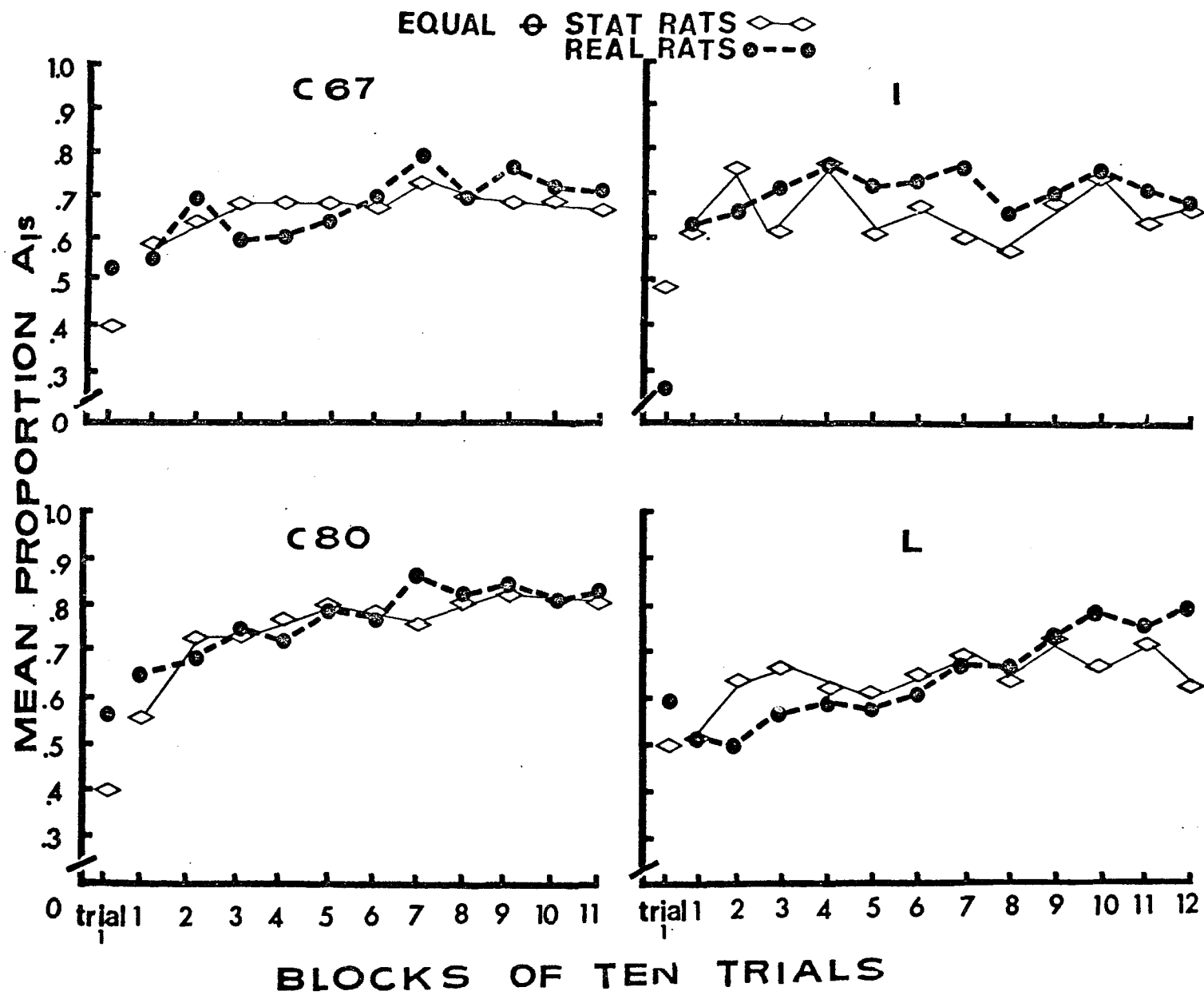


TABLE 18.--Group by Blocks Analyses of Variance Based on
Mean A_1 Frequency for the Equal ϕ Model
Comparisons for Experiment 2

Group C67					Group C80			
Source	SS	df	MS	F	SS	df	MS	F
Group (G)	13	1	13.00	.90	3	1	3.00	.19
Error	836	58	14.41		762	48	15.88	
Blocks (B)	153	10	15.30	4.67*	244	10	24.40	13.56*
G x B	37	10	3.70	1.13	24	10	2.40	1.33
Error	1903	580	3.28		863	480	1.80	
Total	2942	659			1896	549		

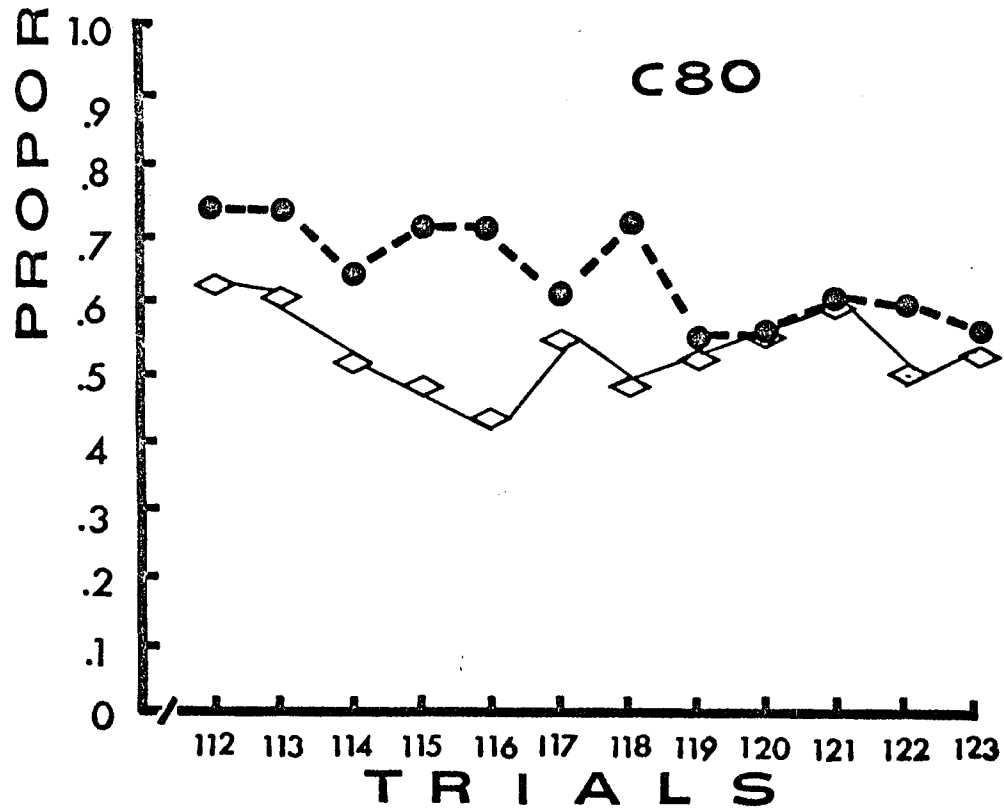
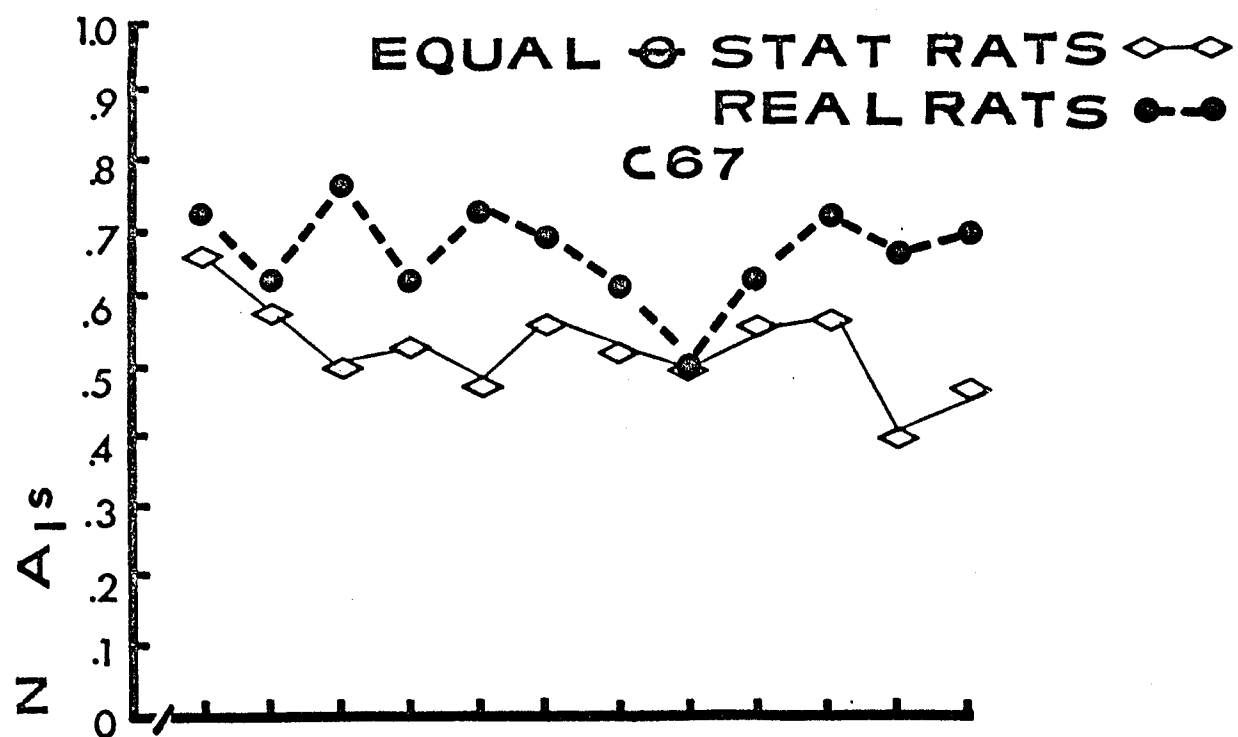
Group I					Group L			
Source	SS	df	MS	F	SS	df	MS	F
Group (G)	12	1	12.00	.43	1	1	1.00	.25
Error	397	14	28.36		72	18	4.00	
Blocks (B)	36	11	2.36	.70	165	11	15.00	2.85*
G x B	37	11	3.36	.97	50	11	4.55	.87
Error	536	154	3.48		1041	198	5.26	
Total	1008	191			1329	239		

* $p < .05$

cumulative distributions of the frequencies of A_1 s during the asymptotic block revealed a significant difference for Groups 80 ($K_D = 11$, $N = 25$, $p < .05$), while just missing significance for Groups C67 ($K_D = 9$, $N = 30$, $p > .05$), I ($K_D = 4$, $N = 8$, $p > .05$) and L ($K_D = 6$, $N = 10$, $p > .05$).

In summary then the Equal θ model appeared fairly accurately to describe the group learning curves. However there appeared to be large discrepancies between the asymptotic A_1 frequency distribution of real and Equal θ stat rats, although 3 of the 4 comparisons were not statistically significant. This may reflect a lack of sensitivity of the test since 35 real S s were tending towards absorption on the A_1 side and 3 towards the A_2 side (across all groups), while only 7 stat rats were tending toward absorption on the A_1 side and none on the A_2 side. Despite this, the Equal θ stat rats for Groups C67 and C80 were given another 12 trials where $\pi(n)$ varied from .23 to .56, and the initial $P(A_1)$ for these trials determined by the real rat asymptotic mean A_1 proportion. In Figure 15 is presented the mean proportion of A_1 s during trials 112-123 for the Equal θ model for Groups C67 and C80. Inspection of Figure 15 reveals that Equal θ stat rats were considerably below the real rats during these trials and that it appeared that Equal θ rats were

FIGURE 15.--Proportion of A_1 s Over Trials 112-123 for the
Equal Φ Model Stat Rats for Groups C67 and C80
in Experiment 2



considerably more effected by the change in π than real rats.

An analysis comparable to that in Experiment 1 was then performed. Specifically, the "preferred" side was defined for each real $\underline{S}$ as the side on which $\underline{S}$ made the majority of its responses during the asymptotic block. For the 2 $\underline{S}$ s not showing a preference, i.e. $P(A_1) = .5$, the preferred side was determined randomly. A distribution of the frequencies of responses to the "preferred" or "absorbed" side made during these 12 trials is presented in Table 19. Inspection of Table 19 reveals that almost 70% of the real rats made at least 10 responses to the preferred side (out of a total of 12), while less 25% of the Equal θ stat rats did. The Kolmogorov-Smirnov test comparing the cumulative frequency distributions was significant for Group C67 ($\underline{K}_D = 10$, $\underline{N} = 30$, $\underline{p} < .05$) and Group 80 ($\underline{K}_D = 12$, $\underline{N} = 25$, $\underline{p} < .05$).

Despite the fact that the Equal θ model did an adequate job on the group learning curve, the failure to account for the amount of absorption found must be assessed as a failure for the model. In addition, the marked failure to follow the behavior of real rats during the change in reinforcement schedule, behavior that showed some resistance to

TABLE 19.--Frequencies of "Preferred" or "Absorbed" Responses
 During the Last 12 Trials (112-123) for Groups
 C67 and C80 and Stat Rats When π Changed
 From .67 and .80 to $\pi(n) = .20 + .03n$,
 $n = 1, \dots, 12$ for Groups C67 and C80,
 Respectively in Experiment 2

Group C67	12	11	10	9	8	7	6	5	4	3	2	1	0
Real	4	7	9	2	1	1	3	1	1	0	0	1	0
Equal θ	0	0	7	5	2	6	3	2	3	2	0	0	0
BW	7	2	6	4	1	2	3	3	0	1	1	0	0
PM	2	1	2	5	4	3	5	5	3	0	0	0	0
Group C80													
Real	8	2	7	4	1	0	0	2	1	0	0	0	0
Equal θ	0	0	5	6	3	4	3	2	1	1	0	0	0
BW	7	3	7	1	1	2	4	0	0	0	0	0	0
PM	1	0	1	3	4	5	4	3	4	0	0	0	0

change, is further evidence for the inadequacy of the Equal θ model.

Bush and Mostellers' 2θ Model

In Figure 16 is presented the 2θ learning curves for the four groups. Inspection of Figure 16 reveals large discrepancies, especially at asymptote, between real and stat rats, for all four groups. The group by blocks analyses of variance, shown in Table 20, just failed to show a significant group effect for Group C67 but did for the other 3 groups. Furthermore, the t -tests comparing the mean asymptotic A_1 frequency yielded significant differences for Groups C67 ($t = 2.92$, $df = 58$, $p < .05$), C80 ($t = 2.65$, $df = 48$, $p < .05$) and I ($t = 2.17$, $df = 14$, $p < .05$) but not for Group L ($t = .85$, $df = 18$, $p > .05$). Therefore, as was found in Experiment 1, the 2θ model failed to account for even the group learning curve and is therefore not considered further.

Bush and Mostellers' Identity Operator Model

In Figure 16 is presented the learning curves for the ID model. Inspection of Figure 16 reveals large discrepancies between real and stat rats, especially at asymptote. The group by blocks analyses of variance, shown in

FIGURE 16.--Mean Proportion of A_1 s Over Blocks of Ten Trials
for the 2 θ and ID Model Stat Rats for
Groups C67, C80, I and L for
Experiment 2

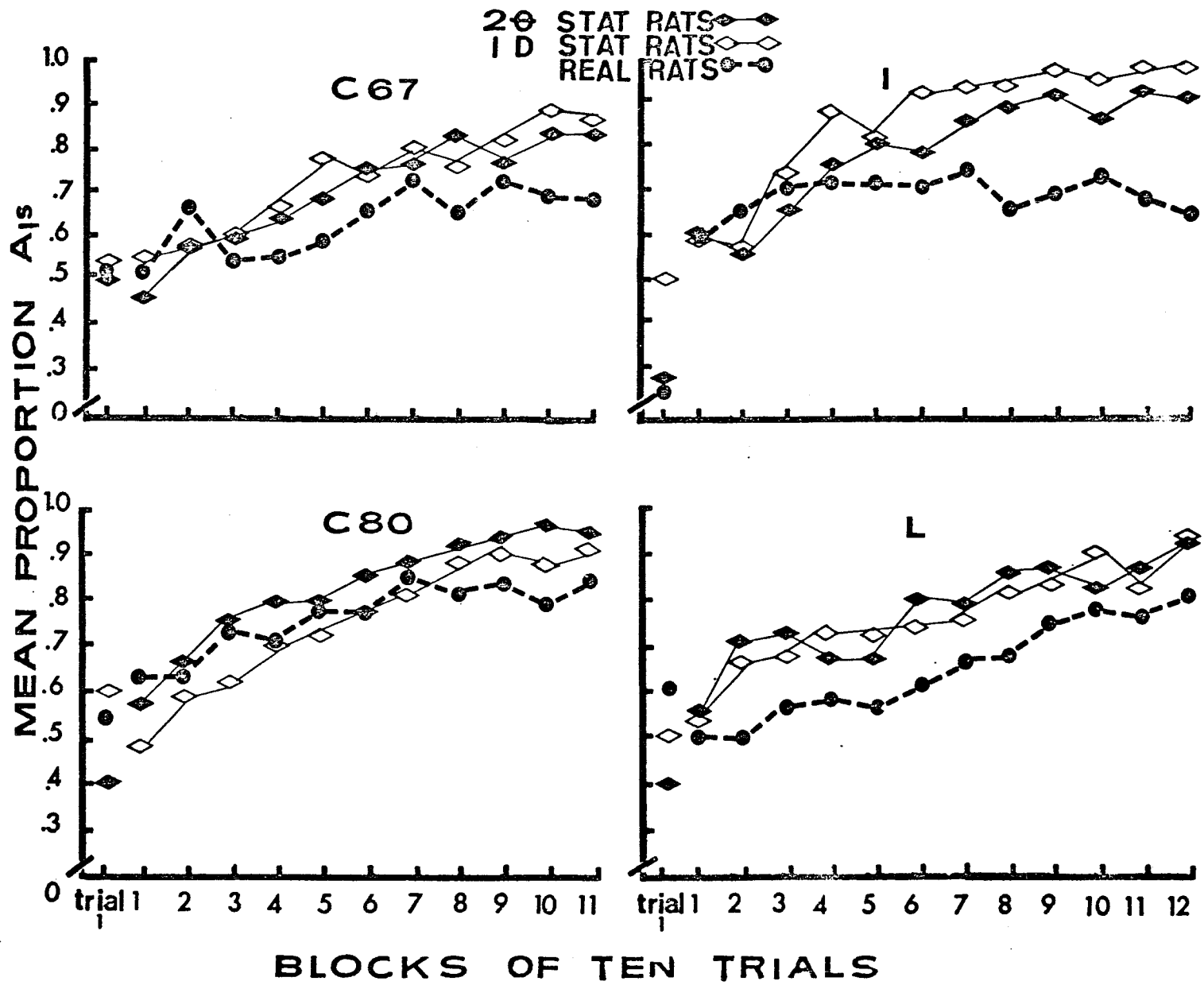


TABLE 20.--Group by Blocks Analyses of Variance Based on
Mean A_1 Frequency for the 20 Model Comparisons
for Experiment 2

Group C67					Group C80			
Source	SS	df	MS	F	SS	df	MS	F
Group (G)	61	1	61.00	3.66	85	1	85.00	5.75*
Error	968	58	16.69		710	48	14.79	
Blocks (B)	445	10	44.50	12.68*	~~483~~	10	48.30	25.69*
G x B	83	10	8.30	2.36*(1/58)	41	10	4.10	2.18*(1/48)
Error	2036	580	3.51		901	480	1.88	
Total	3593	659			2220	549		

Group I					Group L			
Source	SS	df	MS	F	SS	df	MS	F
Group (G)	154	1	154.00	7.75*	108	1	108.00	14.50*
Error	278	14	19.86		134	18	7.45	
Blocks (B)	108	11	9.82	3.30*	280	11	25.45	4.85*
G x B	68	11	6.18	2.03*(1/14)	22	11	2.00	.38
Error	466	154	3.04		1040	198	5.25	
Total	1074	191			1584	239		

*p < .05

Table 21, all revealed significant group effects. Furthermore the t -tests on the differences between real and stat rats asymptotic A_1 responses yielded significant differences for Groups C67 ($t = 2.42$, $df = 58$, $p < .05$) and I ($t = 2.92$, $df = 14$, $p < .05$) but not for Groups C80 ($t = 1.67$, $df = 48$, $p > .05$) or L ($t = 1.16$, $df = 18$, $p > .05$). Therefore the ID model failed to account for the group learning curve and was not subjected to any further tests.

Bush and Wilson's Secondary Reinforcement Model

In Figure 17 is presented the BW learning curves for the four groups and inspection revealed close correspondence between real and stat rats for Group C67 but somewhat less for Group C80. The real rats tended to be consistently above the stat rats, especially for Group C80. The BW learning curve for Group I was well below that of the real rats throughout while the BW stat rats followed the course of the real rats for Group L for most of the study but fell well below during the last four blocks of trials.

The group by blocks analyses of variance, shown in Table 22, failed to reveal any significant group effects nor did any of the t -tests reveal any between group differences for Groups C67 ($t = .21$, $df = 58$, $p > .05$), C80

TABLE 21.--Group by Blocks Analyses of Variance Based on
Mean A_1 Frequency for the ID Model Comparisons
for Experiment 2

Source	Group C67				Group C80			
	SS	df	MS	F	SS	df	MS	F
Group (G)	72	1	72.00	4.41*	64	1	64.00	4.49*
Error	948	58	16.35		684	48	14.25	
Blocks (B)	511	10	51.10	15.72*	415	10	41.50	19.86*
G x B	72	10	7.20	2.22*(1/8)	40	10	4.00	1.91*(1/48)
Error	1885	580	3.25		1091	480	2.09	
Total	3488	659			2204	549		

Source	Group I				Group L			
	SS	df	MS	F	SS	df	MS	F
Group (G)	139	1	139.00	9.74*	104	1	104.00	13.00*
Error	214	14	15.29		144	18	8.00	
Blocks (B)	116	11	10.55	3.95*	260	11	23.64	4.84*
G x B	82	11	7.45	2.79*(1/14)	16	11	1.45	.31
Error	411	154	2.67		943	198	4.76	
Total	962	191			1467	239		

* $p < .05$

FIGURE 17.--Mean Proportion of A_1 s Over Blocks of Ten Trials
for the BW Model Stat Rats for Groups C67, C80,
I and L in Experiment 2

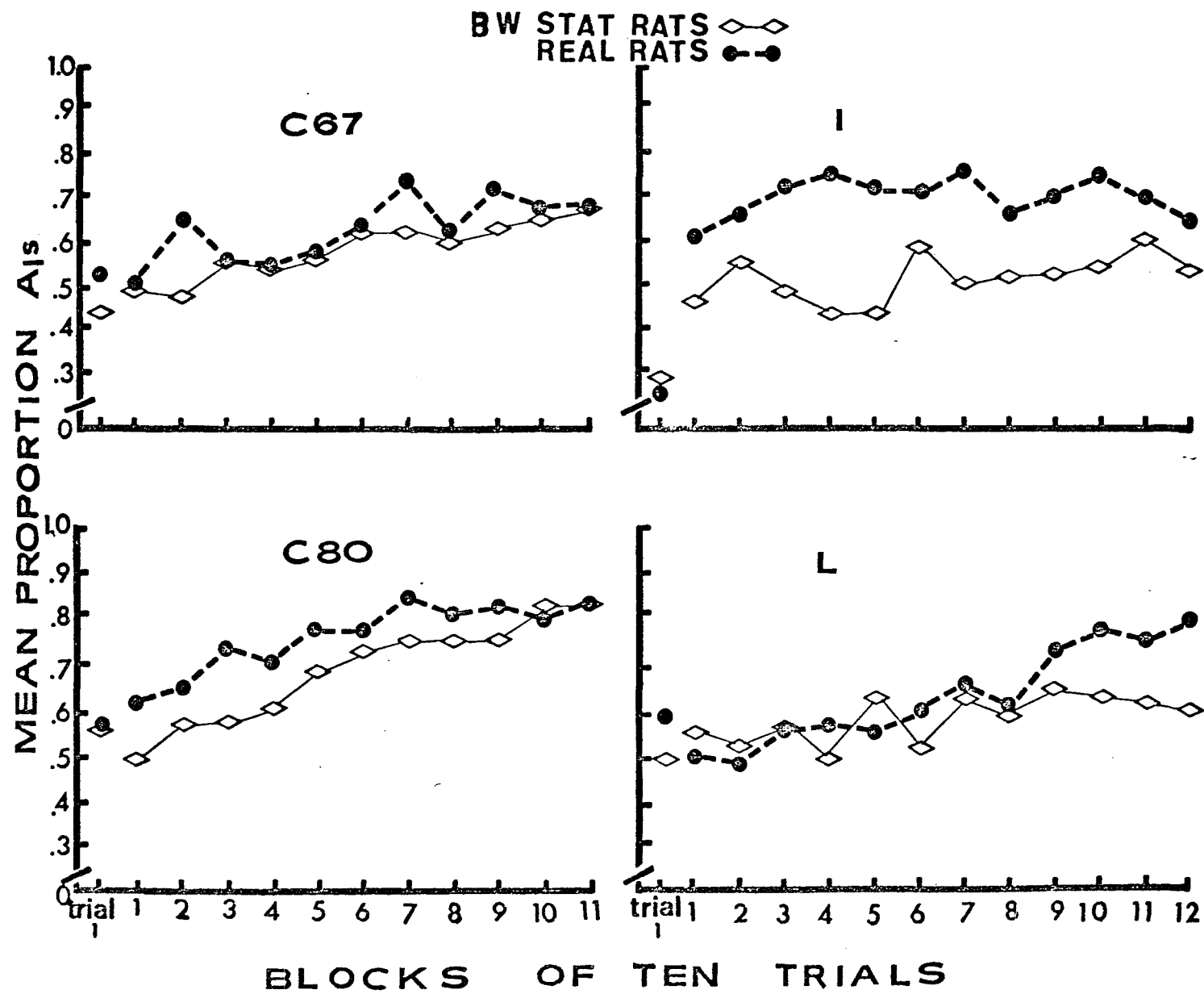


TABLE 22.--Group by Blocks Analyses of Variance Based on
Mean A₁ Frequency for the BW Model Comparisons
for Experiment 2

Group C67					Group C80			
Source	SS	df	MS	F	SS	df	MS	F
Group (G)	33	1	33.00	1.07	67	1	67.00	2.61
Error	1798	58	31.00		1230	48	25.63	
Blocks (B)	218	10	21.80	6.69*	423	10	42.30	18.08*
G x B	43	10	4.30	1.32	36	10	3.60	1.54
Error	1888	580	3.26		1124	480	2.34	
Total	3980	659			2880	549		

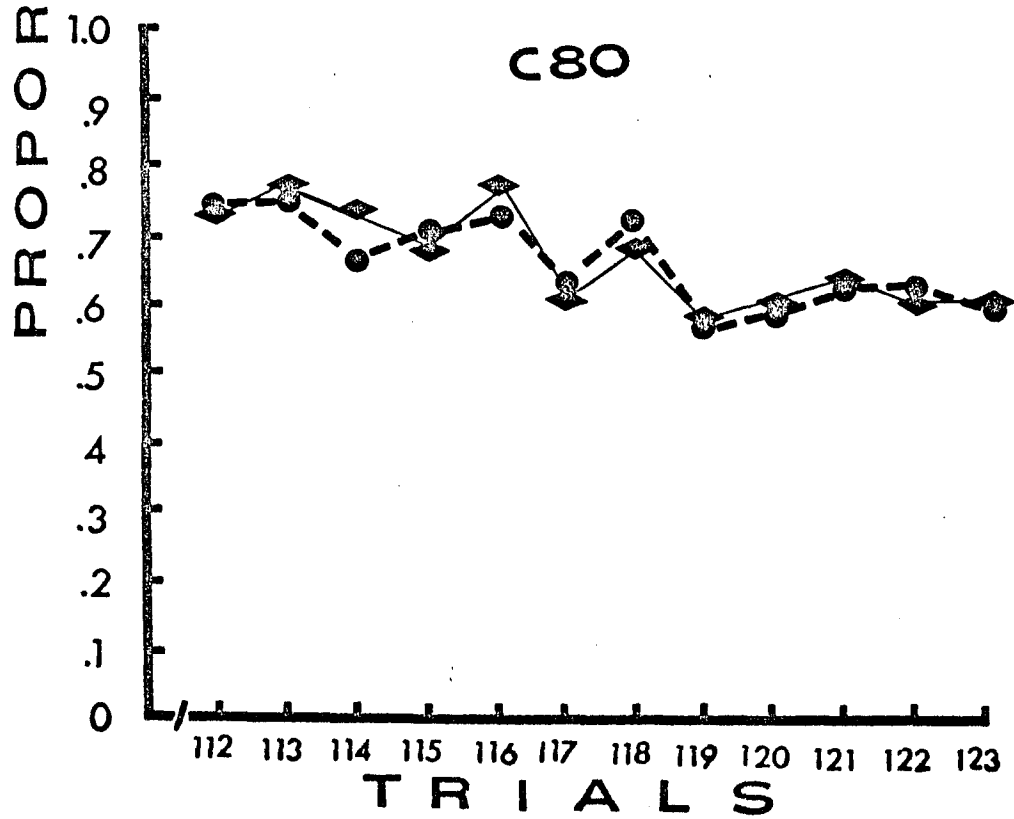
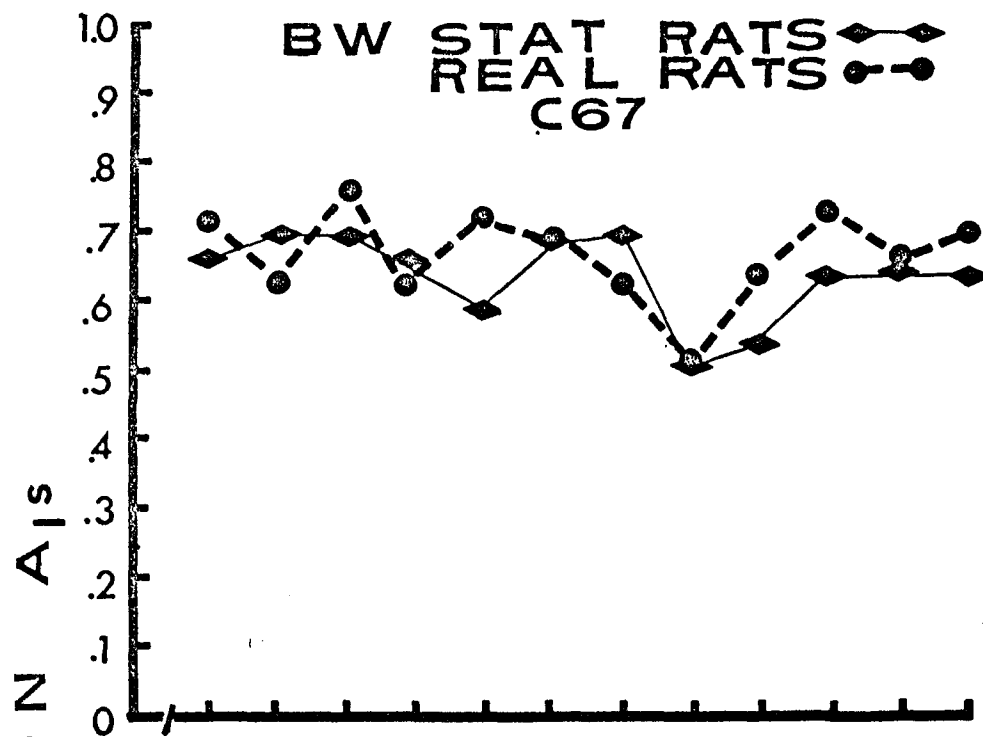
Group I					Group L			
Source	SS	df	MS	F	SS	df	MS	F
Group (G)	153	1	153.00	2.37	16	1	16.00	.26
Error	845	14	60.36		1128	18	62.67	
Blocks (B)	25	11	2.27	.53	159	11	14.45	2.82*
G x B	23	11	2.04	.48	53	11	4.82	.94
Error	663	154	4.31		1014	198	5.12	
Total	1709	191			2370	239		

*p < .05

($t = .26$, $df = 48$, $p > .05$), I ($t = .68$, $df = 14$, $p > .05$) or L ($t = 1.11$, $df = 18$, $p > .05$).

In Table 16 is presented the frequencies of A_1 s during the asymptotic block for real and stat rats and inspection reveals an extremely close correspondence between real and BW stat rats for Groups C67 and C80, and a fairly good one for Groups I and L, despite the small number of S_s in those groups. The Kolmogorov-Smirnov tests comparing the cumulative distributions failed to reveal any significant differences for any of the four groups ($K_D = 2$ or 3 for Groups C67, I, C80 and L, where $N = 30, 8, 25$, and 10 respectively, $p > .05$). On this encouraging note BW stat rat "data" were computed for the 12 trials when π was changed. Figure 18 presents the mean proportion of A_1 s over trials 112-123 for the BW stat rats. An extremely close correspondence between real and stat rats can be observed. In addition, as shown in Table 19, the distribution of the frequencies of "absorbed" responses during these 12 trials for real and stat rats were very similar. Here too Kolmogorov-Smirnov tests performed of the cumulative distributions failed to detect any significant differences ($K_D = 3, 5$, $N = 30, 25$, $p > .05$ for Groups C67 and C80, respectively). At this point the BW appears to be most effective in

FIGURE 18.--Proportion of A_1 s Over Trials 112-123 for the
BW Model Stat Rats for Groups C67 and C80
in Experiment 2



describing the behavior of real rats, at least of the four linear models.

It may be well to summarize the results of the analyses of the linear models. The 2 θ and ID models were dismissed, as in Experiment 1, for failure to account for the crudest feature of the data, the group learning curves. The Equal θ model, on the other hand, did quite well with the group learning curves but did poorly on the asymptotic A_1 frequencies. The failure to detect differences in 3 of the 4 comparisons was attributed to a lack of power, since the differences in the number of ss absorbed were more 100%. Furthermore, the Equal θ model failed to describe the behavior during the 12 trials involving a change in the reinforcement schedule.

The BW model remains as the best linear model despite some discrepancies in the descriptions of the group learning curves. However the correspondence between real and stat rats for both the asymptotic A_1 frequency distribution and the changed reinforcement schedule was excellent.

Estes' Pattern Model

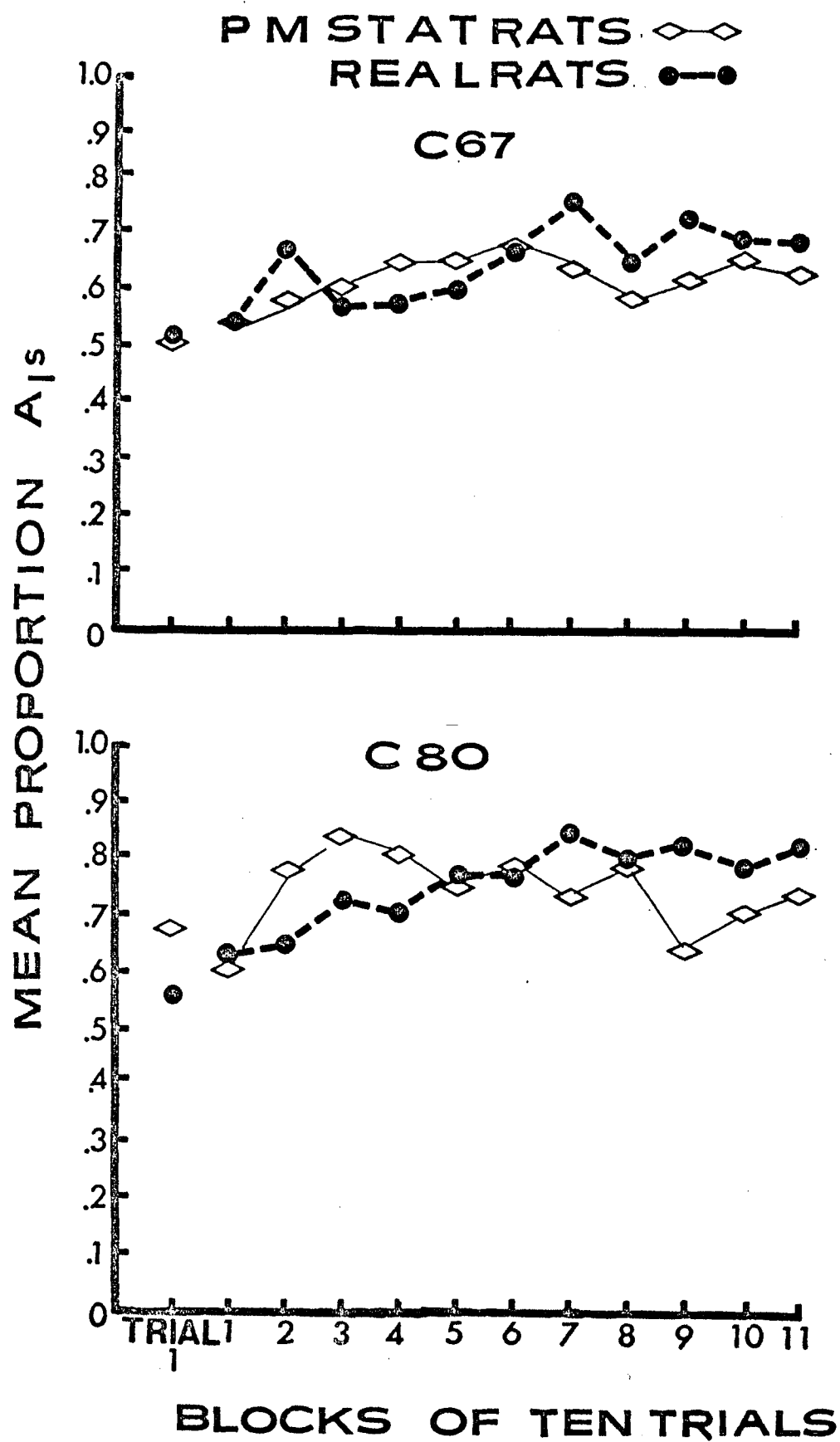
The PM was evaluated with the data from Groups C67 and C80 only. The parameter estimates yielded $N = 2.62$ and

1.97 for Groups C67 and C80, respectively. These values were taken to be slight underestimates of $N = 3$ and 2 for Groups C67 and C80, respectively. These values were then substituted into the asymptotic expressions and solved for c . The resulting estimates were $c = .12$ and $.20$ for Groups C67 and C80, respectively.

Using the estimated value of c , the individual reinforcement schedule, and $N = 2$ for Group 80 and assuming that initially, one of the two patterns were conditioned to an A_1 , one stat rat was generated corresponding to each $\underline{S}$. Stat rats were generated in the same manner for Group C67 except that $N = 3$ and the initial response probability differed. Since there were 3 patterns, it was assumed that one was conditioned to an A_1 while a second to an A_2 , initially. The conditioned status of the third pattern was determined randomly. As a result, approximately half of the stat rats had an initial response probability of $1/3$ while the others had one of $2/3$.

In Figure 19 is presented the learning curves for the PM for both groups and inspection reveals a fairly close correspondence between real and stat rats although the stat rats were somewhat below real rats during the last five blocks of trials. The group by blocks analyses of variance

FIGURE 19.--Mean Proportion of A_1 s Over Blocks of Ten Trials
for the PM Stat Rats for Groups C67 and C80
for Experiment 2



shown in Table 23, failed to detect any significant group effects. The t -test also failed to reveal any significant between groups differences ($t < .43$, $df = 58$ or 48 for Groups C67 and C80, respectively; $p > .05$).

Inspection of the frequencies of A_1 responses, shown in Table 16, revealed fewer PM stat rats than real rats were absorbed or tended toward absorption at asymptote. Specifically, 17 and 12 real rats were absorbed or tended toward absorption on the A_1 or A_2 side for Groups C67 and C80, respectively, while some 7 and 10 PM stat rats were. These differences were of the order of magnitude of 40%. The Kolmogorov-Smirnov tests failed to yield significance ($K_D = 5$, $N = 30$, $p > .05$) for Group C67, and the Group C80 comparison just missed significance ($K_D = 10$, $N = 25$, $p > .05$).

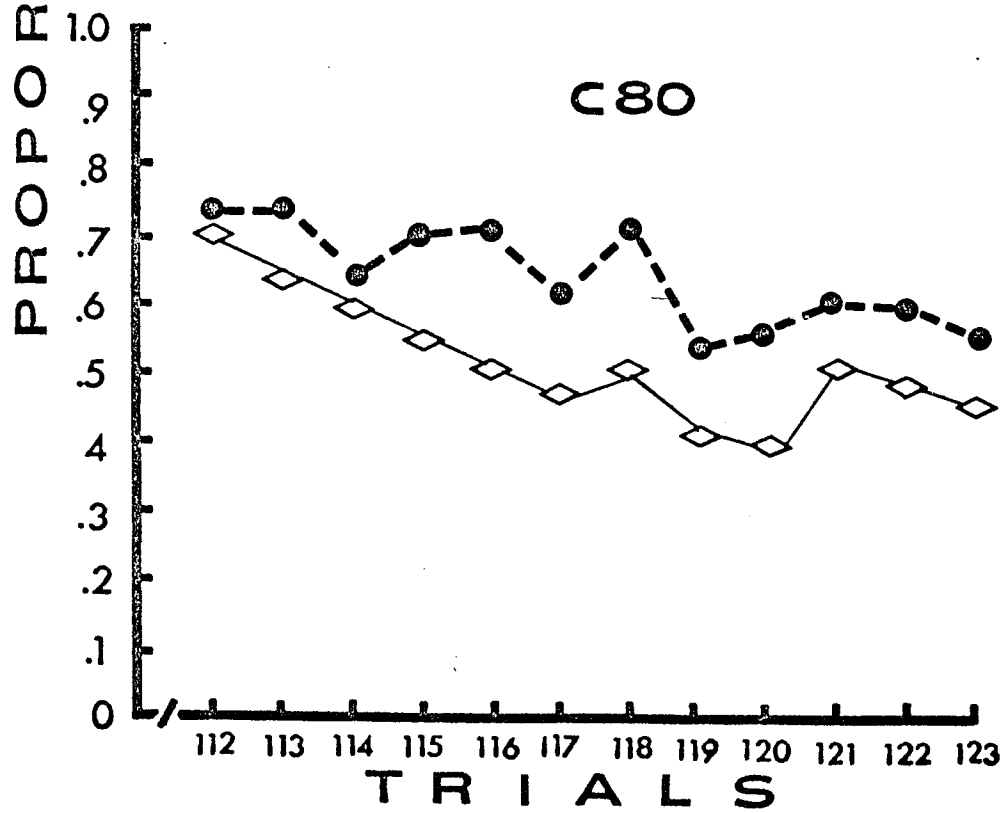
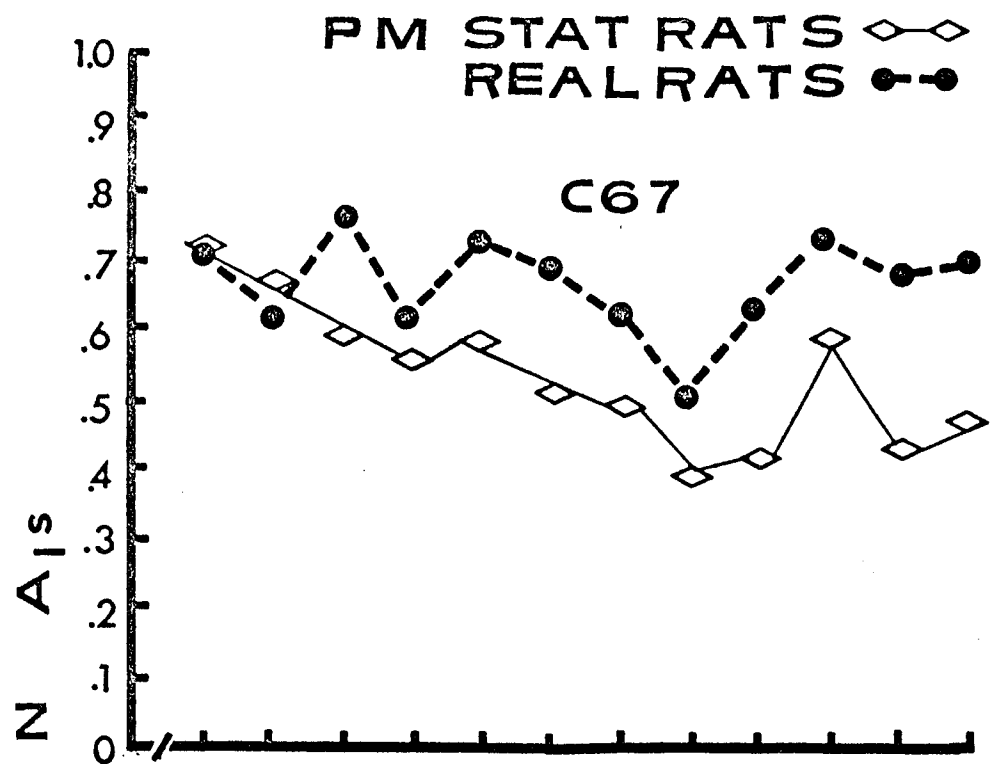
The PM stat rats, similar to the BW and Equal θ stat rats, were tested using the 12 trials of the changing π schedule. The mean A_1 proportion during these trials is presented in Figure 20. Inspection of Figure 20 reveals a marked decrease in the PM curve, although the real rat data remained fairly stable. In general, the PM curve was well below that of real rats. Furthermore, inspection of Table 19 revealed that the PM stat rats made considerably less

TABLE 23.--Group by Blocks Analyses of Variance Based on
Mean A₁ Frequency for the PM Comparisons for
Experiment 2

Source	Group C67				Group C80			
	SS	df	MS	F	SS	df	MS	F
Group (G)	11	1	11.00	.75	2	1	2.00	.13
Error	845	58	14.57		745	48	15.52	
Blocks (B)	143	10	14.30	4.18*	198	10	19.80	8.29*
G x B	32	10	3.20	.94	21	10	2.10	.88
Error	1986	580	3.42		1147	480	2.39	
Total	3017	659			2113	549		

*p < .05

FIGURE 20.--Proportion of A_1 s Over Trials 112-123 for the
PM Stat Rats for Groups C67 and C80
for Experiment 2



"preferred" responses than real rats during these trials. A Kolmogorov-Smirnov test revealed a significant difference for Group C67 ($K_D = 15$, $N = 30$, $p < .05$) and Group C80 ($K_D = 16$, $N = 25$, $p < .05$).

To review then, the PM adequately described the group learning curve. However, it failed to account for the amount of absorption found, although the differences were not statistically significant. These differences were reasonably large (40%) and may indicate a lack of power of the Kolmogorov-Smirnov test.

With regard to the choice point groups the BW model appeared to describe the more detailed aspects of the data best, although the PM model also did an adequate job. The differences in the number of Ss absorbed for the Equal θ stat rat versus real rat comparisons were very large, although statistically significant only for Group C80. The Equal θ model was rejected on this basis and its inability to predict the resistance to change found when the reinforcement schedule was changed. The PM also failed to account for the behavior under the change in π . However, it might be argued that the PM was able to account for the behavior under the original reinforcement schedule, and that the differences in the amount of absorption reflected sampling

fluctuations. As a result, the BW and Pattern models were subjected to further analysis by examining the "fine structure" of the data using the statistics of Experiment 1.

Groups I and L were not subjected to any further analysis because of the small number of Ss that completed the study.

To eliminate any confusion in presenting the results each model was evaluated separately. In Table 24 is presented the means and standard deviations (sd) for these statistics for the real and stat rats for Groups C67 and C80.

Bush and Wilson "secondary reinforcement" model

Inspection of Table 24 reveals that 6 of the 44 comparisons for Group C67 and 10 of the 44 comparisons for Group C80 were significant. The BW stat rats made significantly more A_2 s in block 2 than C67 real rats. This is reflected in the apparent flatness of the BW learning curve for the first 2 blocks while the real rats' learning curve showed the usual large increase generally found in the early part of a learning curve. In addition, stat rats made more $A_2A_1A_2$ s, A_1A_2 s, A_2A_1 s and alternations than C67 real rats. All of these measures are related, since the $A_2A_1A_2$ sequence includes alternations, and of course the sequences A_1A_2 and A_2A_1 comprise the alternation measure. These

TABLE 24.--Means and Standard Deviations (sd) of Real and Stat Rats for BW and PM for Experiment 2

Group C67									
Statistic	Real			BW			PM		
	Mean	sd		Mean	sd	t	Mean	sd	t
Trial no. 1st A ₁	2.17	1.65		2.07	1.36	.24	2.00	1.48	.41
2nd A ₁	4.00	1.81		4.10	2.39	.18	5.03	4.25	1.27
3rd A ₁	5.40	1.94		6.27	3.22	1.30	6.83	4.88	1.45
1st A ₂	2.10	1.57		2.00	1.51	.26	2.13	1.52	.06
2nd A ₂	4.54	3.24		4.67	3.07	.18	5.87	5.19	1.08
3rd A ₂	6.60	3.61		6.77	3.20	.19	8.63	6.53	1.47
Last A ₂	101.03	16.27		105.30	9.25	1.23	107.07	6.53	1.91
Number of A ₂ s	37.07	16.07		42.30	19.57	.89	40.53	14.33	.88
Mean A ₂ Run Length	1.95	.60		1.92	.81	.17	2.16	.66	1.26
Longest A ₂ Run Length	5.97	2.77		5.30	2.53	1.01	7.80	4.60	1.87
No. A ₁ Runs Length 1	7.17	3.88		9.57	5.50	2.02*	8.27	3.33	1.29
2	3.70	2.27		4.43	2.42	1.26	3.70	2.00	.00
3	2.90	2.09		2.37	1.45	1.15	2.50	1.23	.89
4	1.37	1.38		1.83	1.42	1.24	1.27	1.15	.30
5 or more	4.10	2.13		3.87	2.28	.43	3.67	1.49	.91

*p < .05

TABLE 24.--Continued

		Group C67							
Statistic		Real		BW		t	PM		t
		Mean	sd	Mean	sd		Mean	sd	
No. A ₂ Runs	Length								
	1	10.87	4.27	12.83	4.17	1.87	10.90	3.71	.02
	2	4.17	2.07	4.57	2.77	.60	3.80	2.12	.72
	3	1.50	1.28	2.00	1.65	1.28	2.20	1.42	1.97
	4	.90	.98	1.20	1.35	.94	.67	.75	1.01
	5 or more	1.53	1.82	1.40	1.87	.15	1.57	1.52	.09
Sequences:									
A ₁ A ₁ A ₁		42.63	20.92	34.13	21.38	1.58	39.93	18.58	.54
A ₂ A ₁ A ₁		11.87	3.15	12.23	3.90	.39	10.90	2.87	1.22
A ₁ A ₂ A ₁		10.60	4.26	12.33	3.94	1.65	10.43	3.63	.16
A ₂ A ₂ A ₁		7.97	3.94	9.00	4.89	.87	8.17	2.98	.23
A ₁ A ₁ A ₂		11.50	3.31	11.97	3.81	.51	10.63	3.02	1.10
A ₂ A ₁ A ₂		6.67	3.68	9.30	5.31	2.19*	7.73	3.43	1.14
A ₁ A ₂ A ₂		7.77	4.11	8.90	5.15	.95	8.03	3.06	.28
A ₂ A ₂ A ₂		10.00	9.40	11.13	12.93	.38	13.17	11.01	1.20
A ₁ A ₁		54.70	19.95	46.63	22.72	1.48	51.07	17.26	.76
A ₁ A ₂		18.70	4.95	21.63	4.74	2.24*	18.87	4.54	.14
A ₂ A ₁		18.50	5.22	21.43	4.96	2.12*	18.67	4.68	.13
A ₂ A ₂		18.10	12.97	20.30	17.05	.55	21.40	12.56	1.01

*p < .05

TABLE 24.--Continued

Group C67									
Statistic	Real			BW			PM		
	Mean	sd		Mean	sd	t	Mean	sd	t
Alternations	37.20	10.17		43.06	9.70	2.22*	37.44	9.22	.14
No. A ₂ s Block	1	4.50	1.63	4.70	2.15	.41	4.53	2.67	.05
	2	3.10	1.72	4.80	2.02	3.47*	4.03	2.85	1.53
	3	4.07	2.63	4.03	1.97	.07	3.77	2.55	.52
	4	4.10	2.15	4.23	2.14	.26	3.33	3.00	1.09
	5	3.80	2.37	4.03	2.18	.84	3.33	2.59	.75
	6	3.17	2.54	3.43	2.51	.47	3.07	2.42	.15
	7	2.20	2.27	3.40	2.46	1.94	3.43	2.32	2.05*
	8	3.30	2.72	3.60	2.79	.48	4.13	2.69	1.17
	9	2.53	2.58	3.40	2.37	1.39	3.67	2.56	1.68
	10	2.90	2.33	3.17	2.54	.43	3.30	2.38	.63
	11	2.93	2.73	2.93	2.56	.00	3.47	2.23	.84
Group C80									
Trial no.	1st A ₁	1.76	1.18	2.24	1.82	1.09	1.60	1.13	.11
	2nd A ₁	3.60	1.85	5.00	3.85	1.59	3.56	1.98	.07
	3rd A ₁	5.12	1.97	7.08	4.29	2.13*	5.56	2.87	.68
	1st A ₂	2.44	1.96	2.68	3.18	.33	2.72	2.05	.53
	2nd A ₂	6.08	4.18	4.88	3.75	1.04	8.56	12.17	1.06
	3rd A ₂	10.08	9.66	6.88	4.65	1.41	14.12	14.28	1.27
	Last A ₂	93.88	21.94	98.60	17.58	.82	98.64	15.47	.97

*p < .05

TABLE 24.--Continued

Group C80									
Statistic	Real		BW		t	PM		t	
	Mean	sd	Mean	sd		Mean	sd		
Number of A ₂ s	25.56	16.76	33.40	16.43	1.65	27.76	10.94	.64	
Mean A ₂ Run Length	1.60	.41	1.69	.49	.41	2.30	.74	4.12*	
Longest A ₂ Run Length	4.20	2.30	4.72	2.60	.74	7.84	4.54	3.53*	
No. A ₁ Runs Length 1	5.36	4.43	6.72	4.17	1.19	5.40	2.71	.04	
2	3.00	2.65	3.80	2.10	.40	2.32	1.93	1.02	
3	1.56	1.36	2.64	2.28	2.01*	1.16	1.16	1.12	
4	1.20	1.17	1.40	1.30	.56	.64	.84	1.87	
5 or more	4.44	1.70	4.80	2.33	.62	3.76	1.14	1.66	
No. A ₂ Runs Length 1	9.68	4.61	11.64	4.03	1.38	7.12	3.05	2.05*	
2	2.68	1.93	4.04	2.46	2.13*	3.16	1.67	.93	
3	1.52	1.68	1.60	1.98	.15	1.00	1.23	1.24	
4	.68	1.16	.80	.98	.41	.44	.57	.96	
5 or more	.52	.75	.88	1.27	1.21	1.20	.89	2.83*	✓

*p < .05

TABLE 24.--Continued

	Group C80								
Statistic	Real		BW		t	PM		t	
	Mean	sd	Mean	sd		Mean	sd		
Sequences:									
A ₁ A ₁ A ₁	59.68	26.54	45.60	23.89	1.95	62.08	16.88	.34	
A ₂ A ₁ A ₁	9.88	4.56	12.32	3.33	2.10*	7.44	2.74	2.28*	
A ₁ A ₂ A ₁	9.36	4.71	11.32	3.98	1.48	6.84	2.95	2.21*	
A ₂ A ₂ A ₁	5.36	4.33	7.32	4.70	1.71	5.60	2.32	.26	
A ₁ A ₁ A ₂	9.32	4.85	11.84	3.41	1.92	7.20	3.05	1.81	
A ₂ A ₁ A ₂	5.08	4.52	6.44	4.09	1.04	5.16	2.84	.08	
A ₁ A ₂ A ₂	5.24	4.27	7.04	4.60	1.57	5.64	2.45	.42	
A ₂ A ₂ A ₂	5.08	6.41	7.12	7.53	1.08	9.04	6.15	2.29*	
A ₁ A ₁	69.88	23.35	58.24	21.85	1.84	69.96	14.65	.02	
A ₁ A ₂	15.00	7.19	18.84	6.32	2.06	12.60	4.46	1.46	
A ₂ A ₁	14.64	7.28	18.48	6.22	2.03*	12.60	4.54	1.24	
A ₂ A ₂	10.48	10.62	14.44	11.57	1.31	14.84	7.89	1.62	
Alternations	29.64	14.47	37.32	12.54	1.96	25.20	9.00	1.34	

*p < .05

TABLE 24.--Continued

		Group C80								
Statistic		Real		BW			PM			
		Mean	sd	Mean	sd	t	Mean	sd	t	
No. A ₂ s	Block 1	3.68	1.87	4.96	2.51	2.02*	3.88	1.95	.37	
	2	3.40	2.24	4.16	2.22	1.21	2.24	2.92	1.59	
	3	2.64	2.00	4.16	2.24	2.49*	1.52	2.17	1.87	
	4	2.76	2.44	3.80	2.02	1.71	1.84	2.29	1.41	
	5	2.12	2.05	3.00	1.96	1.52	2.40	2.53	.43	
	6	2.16	1.89	2.56	2.10	.70	2.04	2.27	.21	
	7	1.44	1.81	2.36	1.87	2.28*	2.56	2.52	1.78	
	8	1.84	1.71	2.36	1.85	1.02	1.96	2.37	.20	
	9	1.56	2.06	2.36	2.02	2.08*	3.60	3.07	2.80*	
	10	1.96	2.72	1.64	1.92	.48	2.92	2.70	1.25	
	11	1.56	2.02	1.56	1.63	.00	2.48	3.09	1.26	

*p < .05

differences suggest that the real rats had a greater tendency to repeat responses than stat rats. Finally, stat rats made significantly more A_1 runs of length 1 than C67 real rats.

For Group C80 the picture is even less satisfactory since 10 of the differences were significant. Stat rats made more A_2 s in blocks 1, 3, 7 and 9 which probably reflects the fact that the learning curve for the stat rats was somewhat below that of the real rats throughout the course of the study. The stat rats also made significantly more $A_2A_1A_1$ s, A_1A_2 s and A_2A_1 s which suggest that real rats had a greater tendency to repeat responses than stat rats. The 3rd A_1 was made significantly later for stat rats than real rats which may reflect a slight position bias for the real rats. Finally, stat rats made significantly more A_1 runs of length 1 and A_2 runs of length 2.

Thus the BW model apparently failed to describe much of the fine detail of the data. This may not be as bad as it seems since, most of the non-significant differences were small. Specifically, almost 60 of the 72 non-significant differences for both groups combined were of the order of magnitude of 10% or less, while only 7 of the remaining were more than 30%.

Estes' Pattern Model

Inspection of Table 24 reveals that only 1 of the 44 comparisons for Group C67 and 8 of the 44 comparisons for Group C80 were significant. PM stat rats made significantly more A_2 s in block 7 than real rats which may simply reflect the fact that the PM learning curve was somewhat below the Group C67 real rat curve during the latter half of the study.

The picture for the Group C80 comparison is not as encouraging since 8 significant differences were found. Stat rats made more A_2 s in block 9 than real rats, which again may reflect the fact that the PM learning curve was below that of the real rats during the latter half of the study. In addition stat rats had a longer mean A_2 run length, a longer longest A_2 run length, more A_2 runs of 5 or more, as well as more sequences of $A_2A_2A_2$. These differences may be because almost twice as many real than stat rats were absorbed on the A_1 side and this may have resulted in more longer runs of A_2 s by stat rats. Finally stat rats also made less $A_2A_1A_1$ s, $A_1A_2A_1$ s and less A_2 s of length 1. Again this may be because more real rats were absorbed on the A_1 side and, thus, measures incorporating A_1 repetitions and short A_2 runs would reflect this difference.

Here too, as with the BW comparisons, most of the C67

non-significant differences were relatively small. In particular, 33 of the 43 non-significant differences were 10% or less while only 1 was 30% or more. In contrast however, 12 of the 36 non-significant differences for Group C80 were 30-50% in magnitude, while only 20 were 10% or less.

Thus for both the BW and PM comparisons, large discrepancies were found, especially for the Group C80 comparisons. Both models apparently fell short of an accurate description of the "fine grain" of the data.

The PM appeared to be somewhat more successful than the BW model in describing some of the fine detail although the BW model was extremely accurate in predicting the distribution of the asymptotic frequencies of A_1 responses. Both models fell short in describing much of the fine detail for Group C80 although, again, the BW model was very accurate in describing the distribution of the asymptotic frequencies of A_1 s. As a result, a post hoc decision was made to analyze asymptotic conditional response probabilities that might reflect differences between the models.

The BW model assumes that a correction trial, an $A_i E_j$ leads to an increase in $P(A_i)$, while for the PM these trials lead to an increase in $P(A_j)$ with probability C . As a result, the $P_\infty(A_i/E_j A_i)$, $i = 1, 2$, $j = 1, 2$ $i \neq j$,

as well as other asymptotic probabilities were computed and are presented in Table 25. Inspection of Table 25 reveals a close correspondence between BW stat rats and real rats, and marked departures by PM stat rats in the asymptotic probability of an A_1 , or an A_2 given that the previous trial was a correction trial reinforced on the A_2 or A_1 side, respectively. However, some of the departures of the Pattern Model from the real data disappear when theoretical conditional probabilities were computed. In all, these analyses lend minor additional evidence in favor of the BW model over the PM.

TABLE 25.--Comparison of Real and Stat Rats for BW and PM
on Some Asymptotic Conditional Response
Probabilities for Experiment 2

Group C67				
	Real	BW	PM	Theoretical PM
$P_{\infty}(A_1)$	.708	.702	.662	.667
$P_{\infty}(A_1/E_2A_1)$	.791	.809	.698	.737
$P_{\infty}(A_2)$	.292	.298	.338	.333
$P_{\infty}(A_2/E_1A_2)$	.519	.532	.475	.516

Group C80				
	Real	BW	PM	Theoretical PM
$P_{\infty}(A_1)$	.854	.855	.733	.800
$P_{\infty}(A_1/E_2A_1)$	.871	.875	.710	.800
$P_{\infty}(A_2)$	.146	.145	.267	.200
$P_{\infty}(A_2/E_1A_2)$	.500	.481	.552	.500

DISCUSSION

The major finding of Experiment 2 was that, using a choice point correction or a retrace arm correction procedure, many rats tended to become absorbed on one or the other side of the T-maze. Most of the Ss were absorbed on the high proportion side with very few tending towards absorption on the low proportion side. In addition, when π was systematically changed, Ss tended to show considerable resistance to change.

A finding in the present study that is somewhat ambiguous is the effect of reinforcement schedule on the amount of absorption. More absorption was found in Group C80 than in Group C67. Approximately 35% and 5% of the Ss in Group C67 were absorbed at asymptote on the high and low proportion side, respectively, while almost 70% of the Ss in Group C80 were absorbed on the high proportion side and none on the low proportion side. The larger amount of absorption found for Group C80 may merely reflect a "ceiling" effect. That is, since .80 is so close to 1.0, given a similar distribution around the mean, more Ss should get "trapped" at 1.0 than those in a group with $\pi = .67$.

The present study also failed to detect any significant differences in the degree of absorption as a function

of arm length. However, approximately 55% of the Ss in Groups I and L combined were absorbed at asymptote (45% and 10% on the high and low proportion side, respectively) in contrast to 40% for Group C67 which received the same proportion of reinforcement. These data suggest that arm length may have an effect on the degree of the absorption, but that because of the small number of Ss in Groups I and L these differences were not detected. In addition the large differences in the degree of absorption between Groups C67 and C80 further complicate matters.

The theoretical analysis revealed that the group learning curves were adequately described by the BW, Equal θ and Pattern models. Analysis of the asymptotic frequencies of A_1 responding revealed that almost four times as many real than Equal θ stat rats and two times as many real than PM stat rats were absorbed on the A_1 and A_2 side at asymptote. Despite the fact that only one of these differences were statistically significant, the Equal θ model was not considered further because of the extremely large size of the differences. The PM, on the other hand, although apparently unable to account for the amount of absorption found did describe the fine detail of the data for Group C67 excellently. Similar analysis for Group C80 revealed a number

of shortcomings for the PM. This is in contrast to the BW model which fell short of an adequate description of the fine detail for both groups, although it gave an excellent description of the asymptotic behavior found.

The use of a changing π value at the end of Experiment 2 provides strong support for the BW model as the BW stat rats mirrored the resistance to change exhibited by real rats. The PM and Equal θ stat rats, however, failed to reflect the resistance to change observed. This result can be taken as evidence against an Equal θ or Pattern model although, unfortunately, these trials were not carried far enough to be definitive. In addition, post hoc analyses of the asymptotic $P(A_i/E_j A_i)$ in Experiment 2 revealed increases over the $P(A_i)$ for real rats which was adequately described by the BW model. The Pattern Model on the other hand showed some discrepancies here although it did predict the direction of change. Thus, this analysis provided only minor additional evidence against a Pattern and in support of the BW model. Nevertheless, the data of Experiment 2 do not provide strong enough evidence to eliminate the PM. Therefore, the Pattern Model as well as the Bush-Wilson model must both be considered to be capable of describing choice behavior under a choice point correction procedure.

GENERAL DISCUSSION

The major finding of both studies was that most rats tended to become absorbed on one or the other side of the T-maze, with most of the Ss absorbed on the high proportion side. Specifically, approximately 65% and 20% of the Ss in Experiment 1 were absorbed on the high and low proportion side, respectively, for a total of 85% using a retrace arm correction procedure. In Experiment 2, approximately 49% and 4% of the choice point Ss were absorbed on the high or low proportion side, respectively, for a total of 53%. If we place less emphasis on the data of Groups I and L in Experiment 2, because of the small number of Ss completing the study, the remaining data suggests that arm length may be a major factor in determining the amount of absorption.

The suggestion that depth of penetration or arm length may have an important effect on the degree of absorption gains some support from the results of Estes (1957a) and that of Wright (1967). Estes found approximately 44% and 18% of his Ss absorbed on the high and low proportion side, respectively or a total of 62%, using a choice point correction procedure. Wright, using a retrace arm correction procedure, found 75% and only 5% of his Ss absorbed on the high and low proportion side respectively, or a

total of 80%. However, this result may be more apparent than real since the different correction procedures may result in different learning rates. As a result, data from groups of rats receiving approximately the same number of trials, with different correction procedures, may give the appearance of different amounts of absorption. In particular, the learning parameters for the BW model were considerably larger in Experiment 1, where a retrace arm correction procedure was used, than for the choice point groups in Experiment 2.

The group learning curves yielded a confusing picture. The results of both studies generally showed matching at asymptote, although non-significant overshoots of almost 20% were found for two of the groups. Unfortunately these data do not throw light on the contradictions regarding findings of "matching" (Brunswik, 1939; Estes, 1957a; Parducci and Polt, 1958), "overshooting" (Weinstock, unpublished; Wright, 1967) or 100% responding (Bitterman, 1965). Bitterman (1965) has criticized Estes' conclusion of having found probability matching since, as pointed out by Bitterman et al (1958), the group curve was not representative of individual behavior. A marked failure of the individual organism learning curves to reflect the group curve was one

of the results of the present studies. However, if the typical outcome in the correction T-maze is absorption, as suggested here, the value of the group mean at asymptote becomes a trivial issue. This is because the proportion of Ss absorbed on the high and low proportion side will determine the asymptotic $P(A_1)$. The controversy now becomes one about empirical contradictions of the amount of absorption observed on the high and on the low proportion side. Bitterman (1965) reports that usually all of his Ss become absorbed on the high proportion side. This result is in direct conflict with those of the present studies, as well as Estes (1957a) and Wright (1967), all of which have found absorption on both the high and low proportion side. The reasons for the contradictions are not clear although differences in trial spacing and procedural differences (Bitterman frequently used a simultaneous visual discrimination problem) may account for the differences in results. In particular, the procedural differences may have led to much slower learning in Bitterman's experiments and differences in parameter values may well have led to little or no absorption on the low proportion side. In any event the question of whether the group asymptote shows matching becomes a trivial issue for the present results since the variability between Ss at asymptote is quite large.

In order to gain a better understanding of choice behavior in the correction T-maze, a more detailed analysis, such as the asymptotic distribution of the frequencies of A_1 responses, becomes essential.

From a theoretical viewpoint, the group learning curve may also not be of much value since a number of different models may account for the learning curve but fail upon finer analysis. Despite this, it would appear that at a minimum, a model should be able to describe the group learning curve, which aside from the group asymptote, is the crudest feature of the data.

The theoretical analyses revealed that the assumption of a smaller increment in $P(A_1)$ on correction trials when the A_1 side is reinforced, than on directly reinforced A_1 trials is obviously wrong. This model, Bush and Mostellers' 2θ model, predicted large overshoots of the real rat learning curves in both Experiments 1 and 2. Bush and Mostellers' identity operator model, where it is assumed that correction trials have no effect on the $P(A_1)$, also predicted large overshoots of the real learning curves in both studies. Thus, on the basis of the group learning curves, both the 2θ and ID models were rejected for both types of correction procedures.

On the other hand the Equal θ model and the Pattern model both appeared to describe fairly accurately the group learning curves in most cases, although it is not clear whether the theoretical prediction of asymptotic probability matching, for both models, was found. Small overshoots of π were found at asymptote and it is not known whether these represent real differences or simply reflect sampling errors.

However, when both the Pattern and Equal θ models were put to a more stringent test, that of accounting for the asymptotic variance in the form of the distribution of frequencies of A_1 responses, both models failed. The failure in Experiment 1 of both models was more evident than that in Experiment 2 since the differences in Experiment 2 were not statistically significant in most cases. However, it was felt that the magnitude of these differences were so large that the failure to find significant differences probably indicated a lack of sensitivity in the Kolmogorov-Smirnov test in detecting real differences with the N s used.

The Equal θ rats tended to cluster about the matching value and the Equal θ Model was clearly unable to account for the amount of absorption found. In particular, only 3 Equal θ stat rats were absorbed in Experiment 1 in contrast to 50 real rats. In Experiment 2, 38 real rats in contrast

to 7 Equal θ stat rats were absorbed. The PM model, on the other hand, did predict absorption for some organisms, but not nearly as much as was found. Specifically, 18 PM stat rats were absorbed in Experiment 1 in contrast to 50 real rats, whereas 17 stat rats and 29 real rats in the choice point groups were absorbed in Experiment 2. The differences in Experiment 2, however, were not statistically significant. Only the BW model appeared to account for the amount of absorption found. In Experiment 1, 52, and Experiment 2, 37 BW stat rats were absorbed in contrast to 50 and 38 real rats, respectively. When put to a further test the BW model in Experiment 1 was very successful in describing the fine structure of the data. However similar analyses in Experiment 2 revealed a considerable number of failures. In fact the Pattern model did as well or better in describing the fine structure than did the BW model in Experiment 2.

A major theoretical problem with the Pattern model is the lack of empirical grounding. In particular, there are great difficulties in supplying a psychological underpinning for the model. The assumption that a directly reinforced A_1 trial has no effect on the $P(A_1)$ and that correction trials on which an A_1 is reinforced alone affect the $P(A_1)$ on a relatively small proportion of such trials (10-20% for

parameter estimates obtained here) appear to be intuitively weak for the T-maze.

The BW model apparently serves as a good first approximation in describing behavior in the correction T-maze, although it was not particularly superior to the PM for the choice point correction procedure.

In the BW model it is assumed that an A_1E_2 or an A_2E_1 leads to an increase in the probability of the side initially chosen, rather than the reinforced side. This increment is assumed to be less than that due to a directly reinforced trial, i.e. an A_1E_1 or an A_2E_2 . The task is to provide a psychological rationale for these assumptions.

Bush and Wilson (1956) investigated two choice behavior of paradise fish and concluded that a "secondary reinforcement" model (the BW model) adequately described the fine detail of the data. The procedure they used to insure "secondary reinforcement" of an initial response not given primary reinforcement (fish eggs) was to allow S to see E place the eggs in the correct goal box through a transparent divider. A secondary reinforcement mechanism may have been operating in the present experiments since Ss did get water reinforcement in both arms of the maze and may have associated the stimuli of the goal arms with previous reinforcement.

This argument, however, does not appear attractive for the retrace arm groups even if the stimuli of the goal arms do become associated with previous reinforcements. This is because secondary reinforcement should not be stronger than the primary reinforcement S receives when it eventually gets reinforced in the other arm. Furthermore, the choice point correction groups did not enter the goal arms.

The most attractive psychological interpretation for the applicability of the Bush-Wilson model for the current situation involves a delay of reinforcement argument. In particular, the Ss run under conditions that permitted entrance into the arms appeared to run as rapidly as possible to the other side of the T-maze when "correcting." This observation leads to the suggestion that correction trials differ from immediate reinforcement trials only in that they lengthen the chain of responses before reinforcement or add delay of reinforcement. Furthermore, on a correction trial there was only one turning response, except possibly on the very early trials, and the Ss typically viewed the choice point stimuli from the stem only at the time of initial choice. Under these conditions, since S makes only one turning response in the presence of choice point stimulation, the probability of that turning response is increased when S

eventually gets reinforced. The longer response chain and therefore the longer delay of reinforcement may also be used to account for the smaller increment resulting from correction trials as opposed to directly reinforced trials. For the choice point correction procedure S may make an alternative turning response in the presence of choice point stimulation. In addition, since "correcting" at the choice point involves a shorter delay than that with a retrace arm correction procedure, the learning rate for the choice point groups should be closer to one another than those for a retrace arm procedure. This suggestion is somewhat supported by the data, since the ratio of the learning parameters, θ_1/θ_2 was approximately 2:1 for the retrace arm groups of Experiment 1, and less than 1.7:1 for the choice point groups of Experiment 2.

Although assuming that a longer response chain or longer delay of reinforcement may lead to differences in learning rates appears to be intuitively appealing, serious theoretical problems arise upon finer analysis. Estes (1950) defines θ as the proportion of stimulus elements in the population present in the sample on any given trial. Why delay, or any other "parameter of reinforcement" for that matter, should effect the size of the sample at the beginning of the trial is a theoretical mystery. If θ is redefined as the

proportion sampled and conditioned this difficulty may be avoided. However, this redefinition of θ creates other problems and further theoretical analysis seems necessary.

Since the BW model predicts absorption at asymptote and since absorption was found for a relatively small number of Ss in the choice point groups, it may be that the choice point Ss had not reached asymptote. This suggestion is strengthened by the fact that many BW choice point stat rats were not absorbed. In the two Experiments reported here the learning parameters were approximately twice as large for the retrace arm procedure than for the choice point procedure. Thus the different correction procedures apparently resulted in different learning rates and different degrees of absorption. Experimental manipulation of choice point stimulation S comes in contact with when correcting seems needed to resolve this argument.

In conclusion, the Bush-Wilson "secondary reinforcement" model best describes the behavior in the correction T-maze when S is permitted to retrace the entire length of the incorrect arm. However, under the choice point correction procedure the BW model has a number of shortcomings. Furthermore the Pattern model did almost as well as the Bush-Wilson model in describing behavior with a choice point

correction procedure. Unfortunately, Experiment 2 fails to discriminate between the two models and additional evidence is needed.

SUMMARY

Two experiments were conducted to investigate probability learning in the T-maze under a correction procedure. In Experiment 1 two groups of rats, receiving proportions of reinforcement of 70:30 ($n = 29$) and 60:40 ($n = 30$) respectively, were permitted to retrace the entire length of the "incorrect" arm on correction trials. In Experiment 2 two groups of rats, given reinforcement in the proportions 80:20 ($n = 25$) and 67:33 ($n = 30$), were restricted to the area of the "choice point" until a "correct" response was made. In both studies trials were spaced at one per day and water reinforcement was given to Ss that were under 20-22 hr. of water deprivation. The apparatus used was an enclosed T-maze that was painted flat gray throughout and covered with hinge-mounted clear Plexiglas.

The major finding of both studies was that Ss tended to be "absorbed" at asymptote. Taking 18 or more of the S's last 20 responses as the criterion of absorption, 65% of the Ss were absorbed on the larger proportion of reinforcement side and 20% were absorbed on the smaller proportion side in Experiment 1. In Experiment 2, 50% and 5% were absorbed on the larger and on the smaller proportion of reinforcement sides, respectively.

In both studies the reinforcement schedule was shifted after asymptote had been reached. In Experiment 1 reinforcement was made available only on the side opposite the one on which S was absorbed at asymptote, while in Experiment 2 the reinforcement schedule was changed according to a straight line function starting at .23 and ending at .56. During these trials most Ss were relatively unaffected by the shift in reinforcement proportion and consequently, may be said to show a considerable amount of "resistance" to the change in schedule.

Four linear learning models, which differ in their theoretical treatment of a correction trial, and Estes' Pattern model were assessed using the data of both experiments. Theoretical analysis revealed that the Bush and Mosteller 2θ and "identity operator" models both failed to describe as crude an aspect of the data as the group learning curves. The Estes equal θ model described the group learning curves successfully but failed to account for the amount of absorption found or the resistance to change under the new reinforcement schedules. The Bush and Wilson "secondary reinforcement" model, which assumes an increase in the probability of the initial turning response regardless of the side on which reinforcement is given, appeared

to account for not only the group learning curves but also the absorption and resistance to change found in both studies.

Analysis of the "fine detail" or "fine grain" of the results showed excellent correspondence between the Bush-Wilson model and the data for Experiment 1. However, in Experiment 2 a number of discrepancies were found between the Bush-Wilson model and the data, particularly for the group receiving an 80:20 reinforcement schedule.

Theoretical analysis of Estes' Pattern Model revealed large and statistically significant differences between the amount of absorption found and the amount predicted by the Pattern Model in Experiment 1. In Experiment 2, although these differences were large, they were not statistically significant. Further analysis of "fine structure" for Experiment 2 indicated fairly good correspondence between the model and the data. In addition the Pattern Model failed to account for the obtained resistance to change.

It was concluded that the Bush-Wilson secondary reinforcement model served as a good first approximation in describing behavior in the T-maze with correction under probabilistic reinforcement schedules. The Bush-Wilson model provided an excellent fit to the data of Experiment 1, in which the Ss were obliged to retrace the length of the

"incorrect" arm, but there were some discrepancies between the model and the data of Experiment 2 in which the Ss were restricted to the choice area after an incorrect response. For the data of Experiment 2 the Bush-Wilson model was only slightly superior to the Pattern Model. It is concluded that further experimentation is needed to enable a rational choice between the two models when a choice point correction procedure is used.

REFERENCES

- Bitterman, M. E. Phyletic differences in learning. American Psychologist, 1965, 20, 396-410.
- Bitterman, M. E., Wodinsky, J., and Candland, D. K. Some comparative psychology. American Journal of Psychology, 1958, 71, 94-110.
- Brunswik, E. Probability as a determiner of cat behavior. Journal of Experimental Psychology, 1939, 25, 175-197.
- Bush, R. R. and Mosteller, F. Stochastic models for learning. New York: Wiley, 1955.
- Bush, R. R. and Wilson, T. R. Two-choice behavior of paradise fish. Journal of Experimental Psychology, 1956, 51, 315-322.
- Estes, W. K. Toward a statistical theory of learning. Psychological Review, 1950, 57, 94-107.
- Estes, W. K. Of models and men. American Psychologist, 1957a, 12, 609-617.
- Estes, W. K. Theory of learning with constant, variable or contingent probabilities of reinforcement. Psychometrika, 1957b, 22, 113-132.
- Estes, W. K. Component and pattern models with Markovian interpretations. In R. R. Bush and W. K. Estes (Eds.), Studies in mathematical learning theory. Stanford: Stanford University Press, 1959, pages 9-52.
- Greenhouse, S. W. and Geisser, S. On methods in the analysis of profile data. Psychometrika, 1959, 24, 95-112.

- Hull, C. L. Principles of behavior. New York: Appleton-Century-Crofts, 1943.
- Hull, C. L. A behavior system. New Haven: Yale University Press, 1952.
- Parducci, A. and Polt, J. Correction vs noncorrection with changing reinforcement schedules. Journal of Comparative and Physiological Psychology, 1958, 51, 492-495.
- Siegel, S. Nonparametric statistics for the behavioral sciences. New York: McGraw Hill, 1956.
- Tolman, E. C. The determiners of behavior at a choice point. Psychological Review, 1938, 45, 1-41.
- Weinstock, S. Unpublished study.
- Weinstock, S., North, A. J., Brody, A. L. and LoGuidice, J. Probability learning in the T-maze with noncorrection. Journal of Comparative and Physiological Psychology, 1965, 60, 76-81.
- Wright, R. L. D. Motivational effects in probability learning. Psychonomic Science, 1967, 7, 329-330.

APPENDIX

Data Obtained Under the Original Reinforcement Schedules in Experiments 1 and 2

An A_1 designates a response to the high π side while an A_2 designates a response to the low π side. Reinforcement presented on the high and low π sides are designated E_1 and E_2 , respectively.

Code: $A_1E_1 = 1$ $A_1E_2 = 2$ $A_2E_2 = 3$ $A_2E_1 = 4$

Experiment 1

Group 60 N = 30

Rat
No.

6002	23231413113214344434423444224414221112212121211112121122121112121221112111 1212122
6005	41443321332223144114442442443211331242411311443324224141122412311412122112 1111222
5016	44412321232244341211221412112113121221111221112211112221211112212111121111 2112222
6017	32224142412414424334423444443334343344444343433444443444233444414133333344 4433444
5018	32231112111122111212121121212121211211121121221121212211111212121211111 1222122
6019	41113324334143221211111121122221211221112112211121122112112122111221111112 2212112

APPENDIX.--Continued

Rat
No.

5021 32231443443443434344343443344443443343444443443433343344434444433434434343
3443444

5025 4141222122222111111221112112121122122111122121121122211111221211211212111
2121122

5027 322314434111242221112121211121121212112122111112121211212111211122121212211
1121212

6032 33221113413131344412124112211212122111211221211211121121121322122114112221
1112112

5033 44443334321313221441212121121111112122212112211121111221212111112212211112
1221122

6034 41142231224121341212422421211111112221121221111122221224411422411121123221
1121112

6040 4144333423344334444344434443334443443343344444333434433344434434434343443
3344444

6041 1444333133124344442343344334444443342431444343433444433344434444333434344
4334344

5042 411122212212112112121121121211211112221212121211222111111212112211212121
2211112

6044 44113234222311241242421241121214121121221222211111121111222422121421111112
1312212

6047 33321413444444311322341211212111211211222212111211121121121234112112111112
1221122

6049 23224443444143413212422111211222111121122121321441112221121111312212112111
2211212

APPENDIX.--Continued

Rat
No.

6050 22221112111134143321142112212421111224133441223141211132211112211121122111
1212122

6054 23221413444422244113131311212412121221111231234111112122124122111112212111
1221122

5057 32321112142111244343144112212221211122414111212122211121212111221112211221
2111212

6059 11412321331213142113213441241312244134421123314211112213124113221114211111
1222122

5060 11143324233424334444441223311121211212111124112122112111212211122211122112
1112122

5013 23324112114334434443344444324343444343423343444412211211212121241233412114
2112212

5043 41113221324112122121113413212123142431111123244214433344344441443422344444
3234134

5045 32324442443444334434333444443444433434343444423443444334443311343331142111
2221112

5058 14442321221122144212122211121122241111134211221314434432434434434422413434
3444121

5001 33231112413143134413433441121211131122122141341432214231131344142234242113
2442444

6028 11142331344441213343433444334444433433444433344434434334444343334444314334
3441211

5029 33221413414433444213121234412124141313122214142413121142431211222441312441
4321312

APPENDIX.--Continued

Group 70 N = 29

Rat
No.

7004	33221113112141341412121111121221111211211112112121211142111111212122111 1211122
7006	22234443443434344444434343444434111243443431441413334414113141221112111111 1221212
7011	41112231334442224111313112411111112211211121132111221121111112121121112121 1111212
7023	444423313334444412121211121211211121111212121121111112122111111211222111 2121112
7024	11442334334444424122111221211111122111132111111221112111221111122111212112 2111422
7031	23224112441412112121122411121112211111211122112111121241121111112221111122 1111212
7035	41442221221111212211211111121211111221211121121211112112112114111121232111 1111222
7046	33334442111244244421434344111213111112342112141211121112111211111222111121 1121122
7052	11143321224113221444442424411233411314411224111122211211111111214212112121 1121112
7036	44442331334344341214314421241112121214441434434344343444344441344434344441 3334444

APPENDIX.--Continued

Rat
No.

8056 22324112143444343444444443443343424444434444344433444434443334344444434443
3434444

8007 14112331331112114122244121112412112111121121111212111211211221112124111211
1211212

8009 414432343343443444431344421244421122111111212112121211112121112431111111
2121212

8014 4144333433441211122111122211111122112112121111211121211112112112112111221
1121112

8015 33334443413411311131241412421112311112111112211211211212111123111113111112
1211122

8038 14112231321241244434424442121121211111211112221111211111212111123121111112
1212112

8048 2233441241422341111112212111111121112122211112111122111121112111121112
2112112

8051 444432242211111221122111111212111121121121121121121111224121121111112
1121212

8053 4441333433111412123114112122411111221112122121111112212111111113211211212
1112112

8055 44113334334412313411422111121111131122111421112112112111211211221211112121
1111122

8061 32334412441111243211231111112211211121111231112112112111122111211112
2111212

8012 11112334321211121211141121413314144344334433441344443444244341433434444444
4443334

APPENDIX.--Continued

Rat
No.

8063 4444333433444334344444433434443434434444143431443444343444333444344444434
4443434
7026 14112224331224244114424441224413434134441311112344311221111123443144114122
1112113
8010 22221143444112111412324134112121421113111121211412121241241111211442132242
4414142
7030 1441323433143141242421434112114141243112112112111222121111114112234141244
4124122
7020 14443331324344122414244241134443241412414111124312412131111341432241411142
2211412
7037 4114333433241134444334443434444444433433344444434424444433144313413114111
1213212
7008 41143234224341342111244112211121124241411441142331343414142434141341423442
4444344

Experiment 2

Group C67 N = 30

1056 22421111111121221412132441412111132344141212111441111232241231234444111212
1444444421212224444331344114433334342
1016 24434421441121212413433414131444324312431144442344431441244311444332443341
4344341441334424334343444444143233343
1010 44212411112123221214413412441222341444441224444233124111244431441113411144
4344143412413211144421312434442434423

APPENDIX.--Continued

Rat
No.

1020	43214131311444211111421133121212111122122411124111412244331421314314211121 413412141312241111111211232211112122
1018	44314142121124241212414213421411111132422341424343344442144431141113214211 3434442311111122111422112121121121212
2009	3211412311111214414244324132441341312241114121121112111212212111112211221 1231211211121111111211121122211211112
2085	1412331314311141111321112342111431124241134132111121212211111112423112111 2121112211212111121223112111111211122
2064	3421112342444411141113334421431423144224144211122112112121112122211111211 121211121121211121211221111112111222
2093	3424111111112231111122111222134133214111121123112112421111111212212124111 12112121121121112111121212121121112
2066	34434411231111221411231344144341114121224131221211441114221341211122111111 2111112212112121121112211112211212211
1062	344341112112244112121433413414341211221143141444321121211211111111122213 1412211111112122111221411133211121221
1037	24111114334334434241221142411442142211112121114114432314422433242414241411 4414112423341442141242234243144424312
1026	22113431141112121112243434441124424344134211413112442311214111111212124334 1231143414231414331411212414244112114
1003	12112133411414211112321111112221143121311121411212111212211141211222111111 3211121221144112122121141112121232143
1005	24143343141114211113441213132124414114214234214114121322113441141142222111 21241113241221111111414131421232221221

APPENDIX.--Continued

Rat
No.

1060 12233442114111111141112112242332444241134143424421431112113412121122214441
1434444123131121332311141411113212122

1025 24123441411311241412414343334433432444214114431134324444142434334411214241
1221441112111342421443212142111421232

1072 23441224434144434111411411233224142414244112241211341214314212112112121121
122111112112241121123113241411112222

1081 14111333434341124111311112422414312134114422414434412422424134121444414322
1413443134341121431144123144132122324

1074 4411243331411121113434444131241114242213314413144343344131413412234134114
4444324413344434332141144331144442111

2100 23412111241142413412333114444413314411343444243144243424444331122111214114
3334414344434134114331112311443314143

2087 34344211342141121111111212121214212131314211411121131224112141224143121241
1241423413121441111422214311134311133

2058 41113341224211411313211114212424234414432141444212421211211111212241111112
2122221111111113114114321133124112422

2001 42344341124311121442243421111134123123144134434213141112211112211122121141
1242421121111121141113122411234112232

2023 12141411123331414212421312411123111113244114211132121121113112212211114424
1141121421221112142142321121114343332

2039 4113423224111141214432144143343344211413112111211121221211111111113322211
1124344122111211411141211312122444324

2090 23414113341212111113312141224121211124144241224114311224413111222111114422
1124144321214421124111411222112134342

APPENDIX.--Continued

Rat
No.

2033 14211212344412111342242111112111121112211112241214113431211221121211121124
1141111222111231112214212121411211211
2098 3412314121411122114411123211211322211214111113122111412421121113421113211
1441121111212123122421111112121411122
2004 2111234313144444144212122344444112422111212412431444123121111112121211211
2111211112112242121421211113121112212

Group C80 N = 25

3021 34134414144112111112431413414444411234341144442424441414412112214144311441
4132441114443444144343444443412414433
3027 1444114112211342114111112143441411123114411214112111211421111144222414111
1111433444114434241444314441434411411
3034 144111124244142111121111221411111212121111111111122111121121111111121
212214111211111112111121241114111111
3057 1122441114211444141434111241211114121241411421412112241141111111211121124
121411112112111112112111111121141132
3079 1411141312112144414314341111241324124211111141211111112112111121124111121
121111112114124121211111111112111123
3096 424141414131124431112241111111211111221111121111111212121111211121111
111111111122113111122111112111121122
3019 114112111122111111123141111122444124421114411112244121111112111111121111
231111111213111131111241111121211122

APPENDIX.--Continued

Rat
No.

3030 131211414244111111121111121122411211124141111111122131141111112211131411
1112111211121441214111114434434414112
3036 11341414411124344241414443142111144344142311142114241214111121111311112414
1342141141111121124111112111112432111
3045 114424141121211121431111211111111121111221111112111211111212111112111111
232442111111111111111112111212111212
3059 4414114343414131341314421141111114111411122221314111414112111111131144241
324421111111121111211121121111211112
3071 2111141231111441411411142242132141444114241114224121141144121312114111141
112111211143114111411121111312111112
3104 2441111121111121211111111221111111221121111121211241141111121111111212111
1111141211122141211411121114211111212
4106 1133444411421441144412113224444144112433441413441221441411411411143211314
1121141114141231112131111244114213414
4012 41111121443134424441413421444414134412431111443414114442424441443314441142
4411244314112414412424444441121431222
4017 31111324111144111114112111314341111123441131142131111143144444411311114132
1111122111414211131441111211121114122
4040 4111244411111221111211224111111112111111221111221112111111121111111211211
1111121121121111212112111111111112111
4075 43414411411234134144321144124141414444424331141421213414111111311111122111
11211111211111211111111111112221111221
4076 12111124114444241411211312141112321411444141111121133111111124141122114411
1111241112142141431141311443114214111

APPENDIX.--Continued

Rat
No.

4080 44444244113244143311444414111214412314141412114344244414121211111211111421
2421411211111214141124121111121121212
4013 111121412441331444111121411112111211121111111111112112221211141211111
1214111211211111111112111224111111112
4015 41124411112241434411241141142111411111112131214441411124342134111111111122
1412141121211111123111111121111112112
4063 1414224111121111111112211121111121114112211111111211211121111111111211
2111122111111112111121122111111112112
4088 3143411414441122111111122441111111111112123111121111112124431111111111121
2112411121112111112111411112211411122
4103 41111112314124411111132141112121111111112211111211141112421112112112111111
1211111111111122111212111114112221111

Group I N = 8

7051 13431142334444124141442112124313141111423243422141444143431212442421242141
433444344444432112132111144343431434143422444413
7061 44343121412344421112433141241141211143322411121423441123441111211212441321
121424442413134144123344124413132121111424211132
7091 44244131121234143113243141344434224441422144442313311444434133114441312344
421134432443141113114144442122331342434443444423
7024 33111121123114111112241212141234212141134111311211112111223421141112231111
224411123244211121112443213144411124443334241131
7097 421412311124211112121222141111114211111221312111122211121121121112111321111
224211111122412111114214222211121123111112211122

APPENDIX.--Continued

Rat
No.

7055 43112124124214412111121211112211212131211141221224111311111212111111121212
234341222144141121212111121111241111112222211111
7078 44142423114424244141311211221212112121111223111114211221211423414411244311
221111112212121111211211211412212112122111112131
7042 3442141211241121111222114131122224321111111111112123121112111112211122111
212242111122111122122111211111112411212121111212

Group L N = 10

8006 41421223444424424413412344123431221311111211124214124141133122111434444443
324243411211144212122241211411411212124412241112
8011 21311212414441221413214143341413221411121311121111123112121121111122111112
321121221121111121211214212111122421112112111112
8053 41341243134134433314311414111211211111113122221421211142114212131124112111
211221112111122112112112121124141112111112221211
8094 21341144132241124141344324121113111221241131121211121421113112111111122211
212211111211221111224314211111212241211131121114
8008 11211432412344114214442442312441434244234143443324443442244444413444434342
344442441143342334441422411423434342444434124444
8041 24414141224312111214214323144411244434344343431443344143341141113142442133
124142114314314241132111221124424411332411211111
8107 34434144113132141212341211112122243112144111113411114212112222112111111122
112112112122111414112421211212112112121121121121122

APPENDIX.---Continued

Rat
No.

8068	44114241334413342443121124413143423441443134143244441112311324431144112421 222441122411442432441421241124131141121231111241
8022	11243411224113144444421212121211211113431314343434443331414113124142341434 434314134334111113234114221441112221114211111312
8065	14311343241131412111444123434344431313413111241443321341441243231122114411 42112211111221111121212111212141212211112111211

AUTOBIOGRAPHICAL STATEMENT

The candidate, Janet Robbins, was born in New York City on November 23, 1940. She attended Brooklyn College and received a Bachelor of Science graduating cum laude in 1962. While obtaining her graduate education at Brooklyn College she held a National Defense Educational Act fellowship, a National Institutes of Mental Health pre-doctoral fellowship and later taught at the college.