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THE EFFECT OF SHIFTS IN REWARD MAGNITUDE  
AND CHANGES OF SCHEDULE OF REINFORCEMENT  
ON RESISTANCE TO EXTINCTION

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A Thesis  
Presented to  
the Graduate Faculty  
Central Washington State College

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In Partial Fulfillment  
of the Requirements for the Degree  
Master of Science

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by  
Richard James Boylan  
August, 1967

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APPROVED FOR THE GRADUATE FACULTY

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## Abstract

The problem concerned the resistance to extinction of an alley running response as a function of various combinations of reward sizes (1 or 10 pellets) and schedules of reinforcement (50 or 100%). Three experimental phases were used (acquisition, shift of reward, and extinction). Three measures were taken in the alley (start, alley, and goal speed). Animals trained under partial reinforcement (PRF) showed no significant differences in acquisition running speed over animals trained on continuous reinforcement (CRF). Depression effects (decreases in running speed) were observed for both CRF and PRF trained animals during the shift phase. Overall tests between PRF and CRF groups revealed no significant differences in number of trials to extinction. The results were discussed in terms of operant conditioning theory. Ideas for further research involving shift periods of varying lengths were offered.

## Introduction

One of the early experiments in the area of reward magnitude comparison was performed by Grindley (1929), using chicks as subjects and popcorn as reward. The chicks were placed in a wooden passage, out of which they ran to a feeding dish when a release door was opened. Grindley found that a group receiving six pieces of popcorn ran faster to the food dish than a group receiving one piece of popcorn. Wolfe & Kaplon (1941) did a study similar to Grindley's, but employing a runway, a detour to the reward, and a single unit T-maze. Two types of incentives were presented: one whole grain of popcorn, or four  $\frac{1}{4}$  grain pieces of popcorn. The chicks ran faster for the four  $\frac{1}{4}$  grain pieces than for the single one-grain piece, suggesting to the investigators that amount of consummatory activity is an important variable in incentive change.

Soon after this experiment, the results of Crespi's work (1942) on incentive change were published. In his experiment, Crespi used food deprivation schedules, uniform amounts of reward, and statistical analysis of the results, procedures not utilized in previous experiments on incentive comparison or incentive change. Crespi employed four different incentive groups in his study (1, 4, 64, 256 incentive units). After a training period in the straight alley,

the lower incentive groups (1, 4) were shifted to high reward magnitude (16 units), and the higher incentive groups shifted to lower reward (16 units). Crespi observed an "elation effect" in the low-to-high group, so named because of the decrease in running times for this group. The high-to-low groups showed a decrement in runway performance, termed the "depression effect" by Crespi.

Zeaman (1949) expanded upon this work by adding an extinction period following the shift in reward. His results showed decreased alley speed measures during extinction for the groups initially receiving a large reward in the training phase. Another experimental group received a .6 gm. reward during acquisition and was subsequently divided into five different reward groups during the shift phase (.05, .20, .60, 1.20, 2.40 gm.). Analysis of alley speeds during the extinction phase revealed that the .05 groups ran fastest, followed by the .6, 1.2, 2.4 and .2 gm. groups. Zeaman observed "elation" and "depression" post-shift effects for small and large reward groups that were shifted to the opposite magnitude of reward during the shift phase.

Crespi (1942) accounted for the "elation" and "depression" effects in terms of the animal's reward expectancy. Pereboom (1957) took issue with this notion and proposed, instead, that behavioral effects following changes

in reward magnitude are due to differences in initial exploratory behavior of the various incentive groups. A subject receiving a large initial reward will have less opportunity to explore the experimental apparatus than a subject receiving a small initial reward, because of the greater initial dominance of the goal response. When a shift in the reward magnitude occurs, exploratory behaviors will appear in the repertoire of the high-low subject, interfering with the goal response and resulting in poorer post-shift performance. The low-high animal, however, having already explored the apparatus during the pre-shift phase, will perform better on post-shift measures due to the increased dominance of the goal response over exploratory behavior.

The "elation" and "depression" effects became the objects of much experimental inquiry. Some investigators confirmed these effects while others did not. DiLollo & Lumsden (1962) performed a replication of Crespi's basic procedure, obtaining evidence for both the "elation" and "depression" effects. Goldstein & Spence (1963), however, did not observe the "elation" effect. A straight alley was divided into two lanes, each with a different size reward in its respective goal box, separated by a partition. Running speeds based on a given reward magnitude were the same regardless of whether larger or smaller of

the two rewards was involved. If one lane of the alley had two pellets in the goal box and if the other had eight during the training phase, a subsequent reversal of these rewards had no effect on shift phase running speeds.

Gonzalez and Gleitman (1962) offered a somewhat different interpretation, speculating that behavior instigated by change in reward might persist only because it gets reinforced--analogous to the phenomenon of superstitious behavior observed by Skinner (1956). To test this hypothesis, three different reward size groups were trained in a straight alley. One group received an abrupt shift in reward magnitude, with the second group receiving a gradual shift. The third (control) group received equal pre-and-post-shift rewards. Results indicated that the magnitude of the depression effect increased with the magnitude of the decrement in reward. Gradual changes in reward shift did not immediately reinforce new (superstitious) behaviors, and, hence, resulted in a smaller decrement in performance.

Collier & Marx (1959) postulated the effectiveness of a reinforcer to be a function of the present value of its stimulus characteristics and previous contacts with these values. Reinforcement was seen as having the properties of a sensory scale, with judgements of the "sweetness" of various sucrose concentrations serving as defining

reinforcement in relational terms. Reinforcement was thus said to have "psychological dimensions" analogous to Crespi's "reward expectancy" concept.

One of the many variables that was experimentally manipulated in studying incentive shift phenomena was that of acquisition training. Ashida & Birch (1964) used a straight alley to study runway performance as a function of variation in number of rewarded trials and size of reward. A one-pellet series of trials was followed by a ten-pellet series. All groups got forty trials, with some getting rewarded only on one or ten pellet trials. The other three experimental groups received various combinations of one and ten pellet reward trials. The only post-shift differences observed were between the group receiving reward only on one-pellet trials and the rest of the four experimental groups. Ashida & Birch concluded that the effect of shifting from one to ten pellets depended on the number of one-pellet trials preceding the shift.

Wagner (1961) studied the relation of percentage of reward (100% or 50%), magnitude of reinforcement (.08 or 1.0 gm.), and number of acquisition trials (6 or 60) on conditioning and extinction of an alley-running response. No significant differences were found between groups receiving differing numbers of acquisition trials. The group that received a 1.0 gm. pellet under a continuous reinfor-

cement schedule ran significantly faster than the other groups during extinction.

Another experiment dealing with the number of acquisition trials was performed by Vogel, Mikulka & Spear (1966). A second variable, pre-shift frustration experience, was introduced in the form of an interpolated extinction period following acquisition and preceding the shift period. Experiment II of Vogel et al. studied the effects of interpolated extinction trials on a lesser or greater number of pre-shift training trials. It was observed that runway performance was unaffected in Experiment I by the interpolated extinction period. In the second experiment it was found that the depression effect was more pronounced if the number of interpolated extinction trials was less than the number of pre-shift trials.

A study by Williams (1938) manipulated the number of reinforced bar presses in an experiment concerned with resistance to extinction. Williams found that groups receiving a total of 90 pellets during the training period made significantly more responses during the extinction period than animals receiving a total reward of five pellets during training.

Ison (1962), studied running performance in a straight alley. Six training groups received either 10, 20, 40, 60, 80 or 100 rewarded acquisition trials. The 100 trial

group showed the greatest decrement in running speed during extinction. The 10 trial group ran faster than all other groups during extinction. An extinction criterion of 120 secs. was chosen. If an animal did not reach the goal box within this time, it was considered extinguished. Groups receiving 10 and 20 reinforced acquisition trials did not differ in number of trials to extinction, but took a significantly greater number of trials than the remaining groups.

Additional work on resistance to extinction was performed by Weinstock (1954), who studied the effects of different schedules of reinforcement on the resistance to extinction of a running response. Four values of percentage of reinforcement were employed in the experiment (100, 80, 50 and 30%), with an intertrial interval of 24 hours. Animals that received smaller percentages of reinforcement ran faster during extinction than the larger percentage groups, a finding compatible with that of Ison (1962).

The work of Bower (1962) is similar in nature to that of Weinstock, in that partial reinforcement schedules are employed, but different in that graded reductions in reward are also presented to the S. Three runways were joined in a U-shaped arrangement, with a goal box at the end of each alley ( $G_1$ ,  $G_2$ , and  $G_3$ ). Bower hypothesized



that graded reductions in reward in the first and second goal boxes would affect performance in the third alley. He further speculated that the frustrating effects of partial reinforcement in  $G_1$  and  $G_2$  would summate in effect and result in a decrement in runway performance in the third alley. Results indicated that the effects of partial reinforcement in  $G_1$  but not  $G_2$ , carry over to the 3rd runway, and that the frustration effects resulting from graded reductions in reward magnitude in  $G_1$  are graded functions of such reduction.

A similar study was performed by Amsel & Roussel (1952) using two straight alleys in an 'L' shape. The animal was first trained under a continuous reinforcement schedule for both goal boxes ( $G_1$  and  $G_2$ ). Following this period, a partial reinforcement schedule was instituted for  $G_1$  only. Response speed was observed to increase in the second alley as a result of the "frustration effect" produced in  $G_1$  by the partial reinforcement schedule.

Lewis (1956) studied acquisition and extinction of a running response as a function of percentage of reinforcement (50 or 100%) and intertrial interval (15 min. or 15 secs.). Acquisition running times were significantly faster for the 100% than the 50% group, while during extinction the 50% group ran significantly faster ( $p < .05$ ) than the continuously reinforced group. It was also observed that partial reinforcement led to significantly

greater resistance to extinction if followed by a spaced extinction interval than under massed trials of 15 sec. intervals.

The effects of drive, reinforcement schedule, and subsequent changes of schedule were investigated by Badia (1965) using a straight alley. Percentage of reinforcement was found to be independent of drive level which was measured in terms of hours of food deprivation. Three performance measures were taken: start speed, alley speed and goal speed. The data for the first two measures showed an increase in running speed following shift from continuous to partial reinforcement. Continuous reinforcement groups under high drive (22-1/2 hours as opposed to 2-1/2 or 11-1/2 hours) showed an initial superiority over the high drive partially reinforced groups in acquisition, on all three measures. At the end of acquisition, however, the partial groups were posting better start speed times, and equaled the alley speed performance of the continuous reinforcement groups. The goal speed measure still favored the continuous reinforcement groups at the end of acquisition.

An experiment by Mikulka, Lehr & Pavlek (1967) studied the influence of partial reinforcement on the "depression" effect. The "depression" was operationally defined by these investigators as the decrement in runway

performance observed after animals receiving a large reward under continuous reinforcement were shifted to a smaller reward under the same schedule.

Two reward magnitudes (one or ten 45 mg. Noyes pellets), two schedules of reinforcement (50 or 100%) were manipulated in the two phases of the experiment, acquisition and reward shift. A seven foot straight alley was used, divided into three sections in which start, alley and goal speed measures were taken. Six experimental groups of five subjects each received various combinations of reward magnitudes and schedule of reinforcement during the acquisition phase. All groups received one pellet reward during the shift phase, under the same or different reinforcement schedule that had been in effect for the acquisition phase. Results showed that groups initially trained under partial reinforcement showed no evidence of the depression effect during the shift phase. Groups initially trained under continuous reinforcement showed the "depression" effect decrement, but only in the goal speed measure of the shift phase.

Rubin (1953) trained rats to run in a straight alley, employing schedules of reinforcement (100 and 50%) as dependent variables. If a subject did not enter the goal box within 60 secs. it was considered to have extinguished. The group initially trained under a partial reinforcement

schedule took significantly more trials ( $p < .01$ ) to reach extinction than the group trained under continuous reinforcement.

Tyler, Wortz, & Bitterman (1953) studied the effects of random and alternating partial reinforcement on resistance to extinction of a running response. A series of 120 extinction trials were given (10 per day). The group initially receiving random reinforcement during acquisition ran significantly faster ( $p < .01$ ) during the extinction phase.

Hulse (1958) varied amount (1.0 or .08 gm.) and percentage of reinforcement (100 or 46%), to study the resultant effects on extinction performance in a straight alley. It was found that large rewards during acquisition produced faster running speeds during extinction if the animals had been under partial reinforcement schedules during acquisition. Slower speeds were observed for animals receiving continuous reinforcement during acquisition.

The present experiment is a replication of the Mikulka et al. (1967) study with the addition of an extinction period.

The following hypotheses are made concerning this extinction period: (1) subjects initially trained under partial reinforcement and ten pellet reward, and shifted to a continuous reinforcement schedule receiving a one

pellet reward show greater resistance to extinction (run to the goal box faster and more often) than subjects initially trained under a continuous reinforcement schedule to a ten pellet reward, and later shifted to a one pellet reward under either a partial or continuous reinforcement schedule; (2) the subjects trained to a ten pellet reward under a continuous reinforcement schedule, and shifted to a one pellet reward under a continuous reinforcement schedule show greater resistance to extinction than subjects trained to a ten pellet reward under continuous reinforcement schedule, and later shifted to a one pellet reward under a partial reinforcement schedule; (3) subjects trained to a one pellet reward under a partial reinforcement schedule, and shifted to a one pellet reward under a continuous reinforcement schedule show greater resistance to extinction than subjects initially receiving a one pellet reward under a continuous reinforcement schedule, and later shifted to a one pellet reward and partial reinforcement schedule; (4) subjects initially receiving a one pellet reward under a partial reinforcement schedule show no significant decrements in performance during learning and extinction.

### Method

Subjects The subjects were 30 naive male Long-Evans rats. Twenty of the rats, all 120 days old at the onset of the study, came from the Simonson Laboratories in Gilroy, California. The remaining one-third, 270 days old, were raised in the animal colony of Central Washington State College. All subjects were housed in individual cages during the experiment.

Apparatus The apparatus was a straight alley (Figure 1) with a 12 in. start box, 70 in. alley and 12 in. goal box. The entire apparatus was painted grey. The inside dimensions of the apparatus were 4 in. wide by  $4\frac{1}{2}$  in. high. Two guillotine doors were used in the alley, the first at the entrance to the alley and the second at the entrance to the goal box. Start time was manually recorded with a stopwatch by the E from the time the start box door was raised until the nose of the S crossed a line painted on the plexiglas cover of the alley 12 in. down the runway. Alley running time was manually recorded by the E from the line 12 in. down the runway to a photocell beam 6 in. from the entrance to the goal box. Recording of the goal speed measure began when the S interrupted the first photocell beam 6 in. from the goal box which activated a relay that started a Lafayette electrical timer. When the S broke the second photo-cell beam 2.5 in. from the distal end

of the goal box, another relay was activated which turned off the timer. Food reinforcement consisted of 45 mg. Noyes pellets placed by the E in a raised food cup mounted against the back wall of the goal box.

Procedure The animals were placed on a 23 hr. food deprivation schedule three weeks prior to the onset of the study, receiving water ad-lib. During this time the animals received a daily ration of four Purina Lab Chow pellets which were left in the cage until the animal had consumed them.

Six groups of five Ss each were randomly chosen from the rat population. One animal from each treatment group was assigned to one of six running groups. The treatment groups were coded as follows: Group C<sub>10</sub>P received a ten pellet reward under a continuous reinforcement schedule during the acquisition phase and a one pellet reward under a partial reinforcement schedule during the shift phase. Following this example the remaining groups were: C<sub>10</sub>C, P<sub>10</sub>C, C<sub>1</sub>P, P<sub>1</sub>C and P<sub>1</sub>P. The animals were individually run and started under a staggered procedure. Running group one was composed of six animals, one from each treatment group. The first of the two animals of this running group began exploratory trials at 4:30 p.m. When the first animal had completed its trial, the other S of running group one was given its exploratory trial. The next pair

of animals from this running group began their exploratory trials one hour later on the same day, with the third pair beginning their exploratory trial one hour after the second pair at 6:30 p.m. The next day the first two animals of running group two ran their individual exploratory trials following the Ss of group one that were scheduled to run during that hour. The second pair of animals from running group two started at 5:30 p.m. that day and, similarly, the third pair of running group two animals started at 6:30 p.m. The staggered running and starting procedure was followed for the remainder of the running groups. Each S was fed a four pellet Purina Lab Chow ration in the home cage, each day, 30 minutes after completing the last daily trial. The animals were thus fed between 23 and 24 hours after the last feeding, depending on the length of the trials that day.

Two five-minute exploratory trials were given each S in the apparatus, with both doors raised. Each S received one trial a day for two consecutive days. At the conclusion of each trial the S was placed in the goal box with the door closed, and fed three of the 45 mg. pellets in the raised cup.

Acquisition began 24 hours after a group had completed the final exploratory period. The animals were given five spaced acquisition trials a day for eight con-



secutive days, receiving a total of 40 acquisition trials. The minimum intertrial interval during this period was five minutes. A trial consisted of placing the S in the start box and raising the first door as soon as the S was facing towards the alley. Continuously reinforced Ss were allowed to remain in the goal box until they had consumed the food reward, or for 10 minutes, whichever came first. On nonrewarded trials, partially reinforced Ss were confined in the goal box for 20 seconds.

A subject began the shift phase 24 hours after the final day of acquisition trials. The Ss were given five trials a day for eight consecutive days, completing a total of 40 trials in this phase. There was a minimum inter-trial interval of five minutes. All animals received a one pellet reward during the shift phase.

Each S began the extinction phase 24 hours after the final day of the shift phase. The Ss were run until the extinction criterion was met, which consisted of two consecutive trials in which a S took 60 seconds or more to reach the goal box.

The partial reinforcement schedule was devised through a random selection of 16 permutations of the 120 possible permutations of the digits 1, 2, 3, 4, 5: examples of which are 2, 1, 3, 5, 4 or 3, 5, 4, 2, 1. One permutation was used for each block of five partially reinforced

trials each day for all partially reinforced groups being run in that session. Two and three reinforced trials were given on alternate days. To accommodate this procedure, the odd numbers of the permutation represented reinforced trials on one day and nonreinforced trials on the next day. This procedure was followed during both the acquisition and the shift phases.

Design and Statistics The statistical procedure is based on a factorial design described by Lindquist (1956), in which comparisons of the treatment effects may be subjected to analysis of variance procedures. The statistical procedure is schematized in Table 1.

TABLE 1  
 Derivation of Experimental Groups  
 Through Acquisition Shift  
 Combinations

		Acquisition Phase Treatments			
		C <sub>10</sub>	C <sub>1</sub>	P <sub>10</sub>	P <sub>1</sub>
Shift					
Phase					
Treatments	C <sub>1</sub>	G <sub>3</sub>	--	G <sub>1</sub>	G <sub>4</sub>
	P <sub>1</sub>	G <sub>2</sub>	G <sub>5</sub>	--	G <sub>6</sub>

Since not all possible acquisition-shift combinations are utilized, two remaining cells are blank and, hence, are not included in the analysis. The following measures of the three dependent variables were taken: start speed (S), alley speed (A), and goal speed (G). The measures of each dependent variable, for each group, were recorded in the appropriate cell in Table 1 for purposes of statistical comparison of possible differences between the groups. The possibility of inter-group differences was statistically tested through comparisons of the measurements within the cells of Table 1. The inter-group differences in number of trials to reach extinction were analyzed through the use of  $\chi^2$  tests of differences between groups for such trials.

## Results

Statistical analysis of the four measures of the dependent variables was accomplished through comparisons of the treatment means using Lindquist's (1956) critical difference ratio. Group means and standard deviations for the acquisition phase are given in Table 2.

### Performance During Acquisition

Start speed. Analysis of acquisition start speed measures revealed no significant differences between groups, schedules of reinforcement, or reward size. Results from the last day of acquisition (Figures 2 and 5, and Table 3) indicated that the large reward groups showed a nonsignificant increment in running speed on the start speed segment of the alley than their respective small reward groups. No significant differences were found between PRF and CRF groups.

Alley speed. A comparison of runway speed between the P<sub>10</sub>C and C<sub>10</sub>P groups during the acquisition period revealed significantly faster CD (24) = 22.1,  $p < .05$ , running speed for the C<sub>10</sub>P subjects. Analysis of mean differences between schedules (PRF vs. CRF), reward size or between the remaining groups produced nonsignificant results. A plot of the runway speeds (Figures 3, 6, and Table 3) shows the groups relatively clustered on day eight of the acquisition phase, with the C<sub>10</sub>P and C<sub>10</sub>C groups somewhat, but

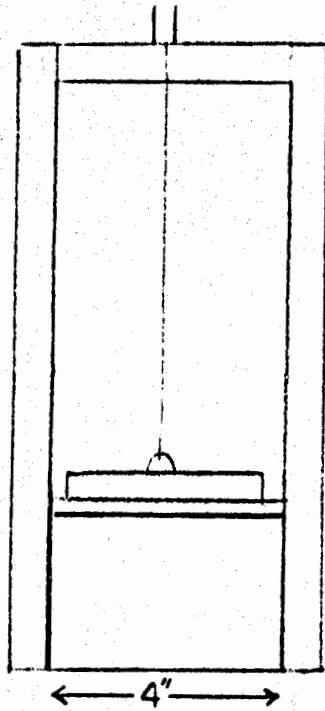
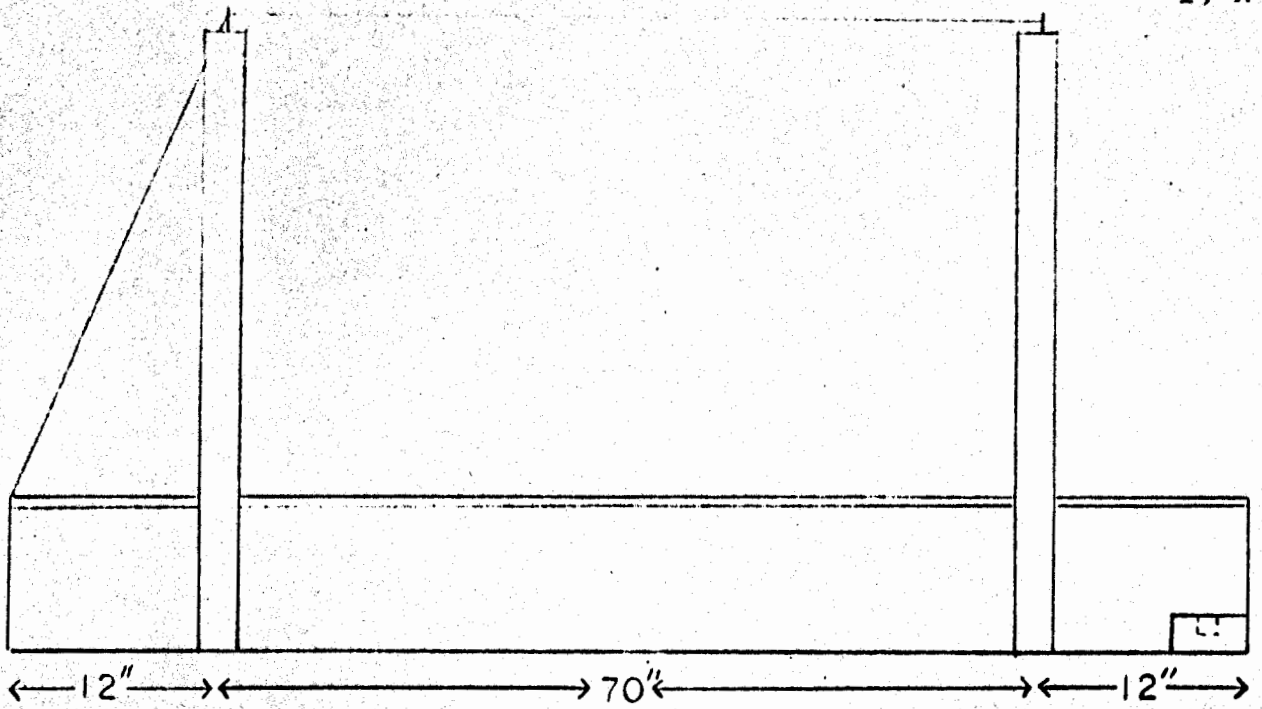


FIG.1 STRAIGHT ALLEY APPARATUS

not significantly, faster.

Goal speed. Data for the goal measure during acquisition showed a greater performance variance than the two previous measures (Figures 4, 7 and Table 3). The C<sub>10</sub>P group ran significantly faster  $CD(24) = 19, p < .05$ , than the P<sub>10</sub>C group during this phase. The overall effect of schedules (PRF vs. CRF) was not significant. A comparison between the P<sub>1</sub>C, P<sub>1</sub>P, and C<sub>1</sub>P groups showed significantly faster speeds  $CD(24) = 21.7, p < .01$ , for the groups initially trained under partial reinforcement. The effect of reward in the goal measure reached significance  $CD(24) = 21.6, p < .01$ , in the C<sub>10</sub>P-C<sub>1</sub>P comparison, indicating faster speeds for the ten pellet group. This effect was reversed in the partial reinforcement (PRF) groups with the one pellet animals showing better performance than the ten pellet group  $CD(24) = 19.1, p < .01$ .

#### Performance After Shift in Reinforcement

The comparisons made in this phase were identical to those made in the Mikulka et al. study, namely: (1) performance of groups initially receiving continuous reinforcement (CRF), (2) performance of groups initially receiving PRF, and (3) the effect of schedule shifts on the one pellet groups. Group means and standard deviations for the shift phase are shown in Table 6.

CRF Groups

Start speed. Table 5 shows the critical differences between group means for this phase. Group C<sub>10</sub>P ran significantly faster  $CD(12) = 6.2, p < .05$ , than C<sub>10</sub>C during this phase. A comparison of group C<sub>10</sub>P with group C<sub>1</sub>P failed to reach significance, as did the C<sub>10</sub>C-C<sub>1</sub>P comparison. The position of the groups at the end of the shift phase is shown in Figure 2. A non-significant decrement in performance was observed for group C<sub>10</sub>P over days 10-13, followed by a return to the pre-shift level of responding. The largest "depression" effect of the CRF animals was seen in group C<sub>10</sub>C, whose performance fell off markedly  $CD(4) = 7.1, p < .05$ , from day nine to the end of the shift period. Group C<sub>1</sub>P maintained a stable performance level up to day 15, at which time a substantial drop in running speed was observed.

Alley speed. No significant differences were found for effects of size of reward on this measure. Group C<sub>10</sub>P ran faster than C<sub>10</sub>C subjects  $CD(12) = 10.5, p < .05$ , but exhibited a large, non-significant drop in performance from its acquisition level of performance (Figure 4). Group C<sub>10</sub>C reached its fastest shift phase speed on day 10, showed a sudden decrease in speed on days 11 and 12, rose to equal its fastest shift phase speed on day 13, and

returned to a level just above that reached on day 12 (Figure 3). The one pellet group ( $C_1P$ ) increased its speed over the acquisition level for the balance of the shift period, experiencing a slight decline on day 16.

Goal speed. Analysis of speed data for this measure indicated no significant differences between the  $C_{10}P$  group and the  $C_{10}C$  animals. Comparison of the effects of reward size failed to reach significance. Group  $C_{10}C$  ran fastest on day eight of the acquisition phase and then exhibited a significant "depression" effect  $CD(4) = 18$ ,  $p < .01$ , from days nine to eleven (Figure 4). Speed of this group was increased thereafter, reaching a level on day 16 above the other two groups. Subjects of the  $C_{10}P$  group ran fastest on day eight of acquisition and decreased on day nine below the level of the corresponding one pellet group. Running speed was increased on day 10, and remained above the one pellet group until day 16, at which time performance fell below that of the  $C_1P$  group.

#### PRF Groups

Start speed. Comparisons between large and small pellet groups yielded contradictory results. The  $P_{10}C$  group ran significantly faster  $CD(12) = 7.4$ ,  $p < .05$ , than the  $P_1P$  group, but only slightly faster than  $P_1C$  subjects (Table 5). No decrements in performance were observed for this group, with the exception of the  $P_1P$  group which



showed decreases in speed on day nine, and days 11-13 (Figure 5).

Alley speed. No significant differences were found between groups for this measure. Group P<sub>10</sub>C showed a depression effect  $CD(12) = 13, p < .05$ , on days 12-15 (Figure 6), but increased its speed on day 16 to a level slightly below its fastest shift speed. Group P<sub>1</sub>P exhibited a slight decline in performance from days 10-16, finishing slowest  $CD(12) = 14, p < .05$ , of the PRF groups at the end of the shift phase. Group P<sub>1</sub>C declined on days 10-11, and thereafter showed gradual increases in speed up to day 16, at which time it led the other two PRF groups in terms of running speed.

Goal speed. The large reward group (P<sub>10</sub>C) showed a nonsignificant increment in speed over both the P<sub>1</sub>C or P<sub>1</sub>P groups on this measure. Group P<sub>10</sub>C exhibited a significant depression effect  $CD(12) = 15, p < .05$ , on day 12, and equaled its fastest acquisition phase speed on day 15 (Figure 6). On day 16, performance of the P<sub>10</sub>C group declined to the level of the P<sub>1</sub>C group. Subjects of the P<sub>1</sub>C group ran fastest during the shift phase on day 11 and declined thereafter to a level equal to that reached on day eight of the acquisition phase. Group P<sub>1</sub>P showed a gradual rise throughout the shift phase, running fastest on day 16 (Figure 7).

### Shift Performance in One Pellet Groups

Start speed. A comparison between PRF and CRF groups revealed no significant differences in speeds between the two groups. Of the two PRF groups, the P<sub>1</sub>C ran significantly faster  $CD(12) = 5$ ,  $p < .05$ , than the P<sub>1</sub>P group. A drop in performance was observed for the P<sub>1</sub>P group over days 12-13. Group P<sub>1</sub>C showed a gradual decline from the terminal acquisition level reached on day nine (Figure 5). Group C<sub>1</sub>P maintained stable performance up to day 15, when speed decreased below that of the two PRF groups.

Alley speed. Comparison of the P<sub>1</sub>P and P<sub>1</sub>C groups did not reveal any significant differences. Similar findings were observed in the C<sub>1</sub>P-P<sub>1</sub>C comparison and between the P<sub>1</sub>P and C<sub>1</sub>P groups.

Goal speed. PRF-CRF comparisons produced no significant differences. Within group comparisons between P<sub>1</sub>C and P<sub>1</sub>P groups also revealed no significant differences.

### Resistance to Extinction

Start speed. Group means and standard deviations are shown in Table 6. No significant differences were found between groups, schedules (PRF vs. CRF) or for effects of reward size (Table 7).

Alley speed. No significant differences were found in overall tests between the CRF and PRF groups or between the one and 10 pellet groups. However, certain

comparisons did prove significant. The  $C_1P$  group ran significantly faster than the  $C_{10}C$  group or the  $P_1C$  group  $CD(24) = 11, p < .05, CD(24) = 11, p < .05$  respectively. Analysis of the data within the  $PRF$  group showed the  $P_1P$  group significantly faster than the  $P_{10}C, CD(24) = 12, p < .05$ . While the overall tests of schedules failed to reach significance, comparison between the  $P_{10}C$  and  $C_{10}P$  groups showed faster speeds for  $C_{10}P$  animals  $CD(24) = 12.2, p < .05$ .

Other within group comparisons, such as  $C_{10}C$  with  $C_{10}P, C_{10}P$  with  $C_1P$  and  $P_{10}C$  with  $P_1C$  failed to reach significance.

Goal speed. Comparisons of the effects of schedules reached significance on differences between the  $P_{10}C$  and  $C_{10}C$  groups; the  $P_{10}C$  animals showing faster running speeds  $CD(24) = 8.5, p < .05$ . Intragroup comparisons revealed faster speeds for the  $C_{10}P$  group over the  $C_{10}C$  animals  $CD(24) = 11.2, p < .05$ , and faster goal speeds for  $C_1P$  subjects when compared with animals of the  $C_{10}C$  group  $CD(24) = 10.6, p < .05$ . Intragroup comparisons among the  $PRF$  groups failed to reveal any significant differences on this measure. Overall comparisons between  $PRF$  and  $CRF$  were not significant.

Resistance to Extinction, Additional Measures

Statistical evaluation of the number of trials to extinction, and number of hesitation responses was performed through the use of  $\chi^2$  tests.

Number of trials to extinction. Table 8 shows group means and standard deviations for the snift phase. An overall test between one and ten pellet groups reached significance  $\chi^2(1) = 5.8, p < .05$ ; the one pellet animals running a greater number of trials. A test of the overall effects of schedules failed to reach significance (Table 8). Comparison of the P<sub>10C</sub> group with the two 10 pellet CRF groups (C<sub>10C</sub>, C<sub>10P</sub>) did not reach significance. Individual comparisons of these groups were then made, showing that the C<sub>10P</sub> group ran significantly more trials to extinction than the P<sub>10C</sub> group  $\chi^2(1) = 4.4, p < .01$ .

Comparisons of the one pellet animals revealed no significant differences between P<sub>1P</sub> and C<sub>1P</sub> animals. A test between the P<sub>1C</sub> and C<sub>1P</sub> groups failed to reach significance. Intra-group analysis showed that C<sub>10P</sub> animals ran more trials than C<sub>10C</sub> subjects  $\chi^2(1) = 6.2, p < .05$ . Comparison of the P<sub>10C</sub> group with its corresponding one pellet group P<sub>1C</sub>, showed a greater number of trials for the one pellet animals  $\chi^2(1) = 5, p < .05$ .

Hesitation responses. A hesitation response was recorded whenever an animal stopped or turned around

while en route to the goal box during the extinction phase. An overall comparison on this measure between CRF and PRF groups was not significant. A test between the P<sub>10</sub>C and C<sub>10</sub>C group showed a greater number of hesitation responses for the P<sub>10</sub>C group  $\chi^2(1) = 5.2, p < .05$ , but not significantly more than the C<sub>10</sub>P group.

An overall test for the effects of reward size failed to reach significance between one and ten pellet groups. Analysis of the data for the one pellet groups showed significantly more hesitation responses for the C<sub>1</sub>P group when compared to the P<sub>1</sub>P group. Tests between the C<sub>1</sub>P and P<sub>1</sub>C groups were not significant.

#### Analysis of Data for the P<sub>1</sub>P Group

The three measures (start, alley, goal) were analyzed over the acquisition and shift phases. No significant depression effects were found.

#### Summary of Results

1. PRF animals did not run significantly faster than CRF animals during acquisition.
2. C<sub>10</sub>P animals ran significantly faster than the P<sub>10</sub>C group on alley and goal measures during acquisition.
3. One pellet groups trained under PRF ran faster than the one pellet group trained under CRF during acquisition.

4. Group C<sub>10</sub>P ran faster than C<sub>10</sub>C on start and alley measures during the shift period.
5. Significant depression effects were observed for the C<sub>10</sub>C group on start and goal measures during the shift phase, and for group C<sub>10</sub>P on the alley measure.
6. One PRF group, P<sub>10</sub>C, showed a significant depression effect on the goal measure of the shift phase.
7. Groups initially trained to a one pellet reward under PRF took more trials to extinction than 10 pellet groups trained under CRF.
8. C<sub>10</sub>P animals ran more trials to extinction than the P<sub>10</sub>C group.
9. P<sub>10</sub>C animals made more hesitation responses during extinction than the C<sub>10</sub>C group.

TABLE 2  
 Group Means and Standard Deviations  
 For Running Time Data

Acquisition Phase						
Group	Start		Alley		Goal	
	M	S.D.	M	S.D.	M	S.D.
C <sub>10</sub> P	10	13.8	9	10.7	10.4	17.8
C <sub>10</sub> C	29	21.3	30.9	38	19.2	25
P <sub>10</sub> C	16.7	24	31.1	42	29.4	34
C <sub>1</sub> P	10.2	10.2	22.4	18.7	32	9.7
P <sub>1</sub> P	27	49	17.6	25.9	13.4	12.6
P <sub>1</sub> C	14	25	16.2	24.1	14.6	15.6
CRF	16.4	11.1	27.5	11.6	20.5	10.2
PRF	19	9.7	21.3	9	19.1	9.8

TABLE 3  
 Critical Differences Between Group Means  
 For Running Time Data

Acquisition Phase			
Groups	Start	Alley	Goal
P <sub>10</sub> C-C <sub>10</sub> C	12.3	1.1	10
P <sub>10</sub> C-C <sub>10</sub> P	6.7	22.1*	19*
P <sub>1</sub> C-C <sub>1</sub> P	4	6	17.4**
P <sub>1</sub> P-C <sub>1</sub> P	21.8	7	21.7**
P <sub>10</sub> C-P <sub>1</sub> C	2	14.9	14.8*
P <sub>10</sub> C-P <sub>1</sub> P	15	15	19.1**
C <sub>10</sub> C-C <sub>1</sub> P	19.2	13.4	12.8
C <sub>10</sub> P-C <sub>1</sub> P	.2	8	21.6**
PRF-CRF	4.5	12.6	2.4

\* p .05

\*\* p .01



TABLE 4  
 Group Means and Standard Deviations  
 For Running Time Data

Group	Shift Phase					
	Start		Alley		Goal	
	M	S.D.	M	S.D.	M	S.D.
C <sub>10P</sub>	7.5	6.7	5.8	2.2	3	.3
C <sub>10C</sub>	11.4	5	17.7	26.8	3.3	3.6
P <sub>10C</sub>	5.2	4.4	7.2	8	2.2	2.2
C <sub>1P</sub>	7.4	10.7	8.8	9.7	7.2	10.7
P <sub>1C</sub>	6.4	12.5	8	8	3.6	4.8
P <sub>1P</sub>	12.6	12.4	13.4	16.9	6.2	7.1
CRF	8.7	2.2	10.7	10.3	4.5	3.1
PRF	8	4	9.5	3.1	4	4.8

TABLE 5  
 Critical Differences Between Group Means  
 For Running Time Data

Shift Phase			
Groups	Start	Alley	Goal
P <sub>10</sub> C-C <sub>10</sub> C	6.2*	1.4	1.1
P <sub>10</sub> C-C <sub>10</sub> P	2.5	10.5*	.8
P <sub>1</sub> C-C <sub>1</sub> P	2	7.9	3.6
P <sub>1</sub> P-C <sub>1</sub> P	5*	1	1.0
P <sub>10</sub> C-P <sub>1</sub> C	1.2	.8	1.5
P <sub>10</sub> C-P <sub>1</sub> P	7.4*	6.2	4.1*
C <sub>10</sub> C-C <sub>1</sub> P	4	8.9	3.9
C <sub>10</sub> P-C <sub>1</sub> P	1	3	4.2*
CRF-PRF	.7	1.2	.3

\* p .05

\*\* p .01

TABLE 6  
 Group Means and Standard Deviations  
 For Running Time Data

Extinction Phase						
Group	Start		Alley		Goal	
	M	S.D.	M	S.D.	M	S.D.
C <sub>10</sub> P	10.8	8	11.8	4.4	7.2	5.3
C <sub>10</sub> C	17.6	24	23.5	17	9.8	12.9
P <sub>10</sub> C	22	34	19	21.4	7.2	6.2
C <sub>1</sub> P	16.7	13	11.5	4.8	7.8	6.7
P <sub>1</sub> C	16.6	13.8	22.5	13.4	10.9	22.8
P <sub>1</sub> P	20.6	35	12	11.6	7.2	8.1
CRF	14.1	4	15.6	6.7	8	1.4
PRF	11.8	8.4	10.6	9.2	5	4.5

TABLE 7  
 Critical Differences Between Group Means  
 For Running Time Data

Extinction Phase			
Groups	Start	Alley	Goal
P <sub>10</sub> C-C <sub>10</sub> C	6.5	.5	8.7*
P <sub>10</sub> C-C <sub>10</sub> P	10.6	12.2*	2
P <sub>1</sub> C-C <sub>1</sub> P	.1	11*	3
P <sub>1</sub> P-C <sub>1</sub> P	3.9	.5	.5
P <sub>10</sub> C-P <sub>1</sub> C	5	2.5	1.3
P <sub>10</sub> C-P <sub>1</sub> P	1.2	12*	2
C <sub>10</sub> C-C <sub>1</sub> P	2	12*	10.6*
C <sub>10</sub> P-C <sub>1</sub> P	6	.3	.5
PRF-CRF	4	3.7	1.7

\* p .05

\*\* p .01

TABLE 8  
 Group Totals and Differences  
 For Running Time Data

Group	Number of extinction trials	Number of hesitation responses
C <sub>10</sub> P	77	83
C <sub>10</sub> C	39	50
P <sub>10</sub> C	54	88
C <sub>1</sub> P	95	105
P <sub>1</sub> C	91	104
P <sub>1</sub> P	70	57
PRF	215	249
CRF	211	238
Group Differences	Number of extinction trials	Number of hesitation responses
P <sub>10</sub> C-C <sub>10</sub> P	23*	5
P <sub>10</sub> C-C <sub>10</sub> C	15	38**
C <sub>10</sub> C-C <sub>10</sub> P	36**	33**
P <sub>1</sub> C-C <sub>1</sub> P	4	1
CRF-PRF	4	16

\* p .05

\*\* p .01

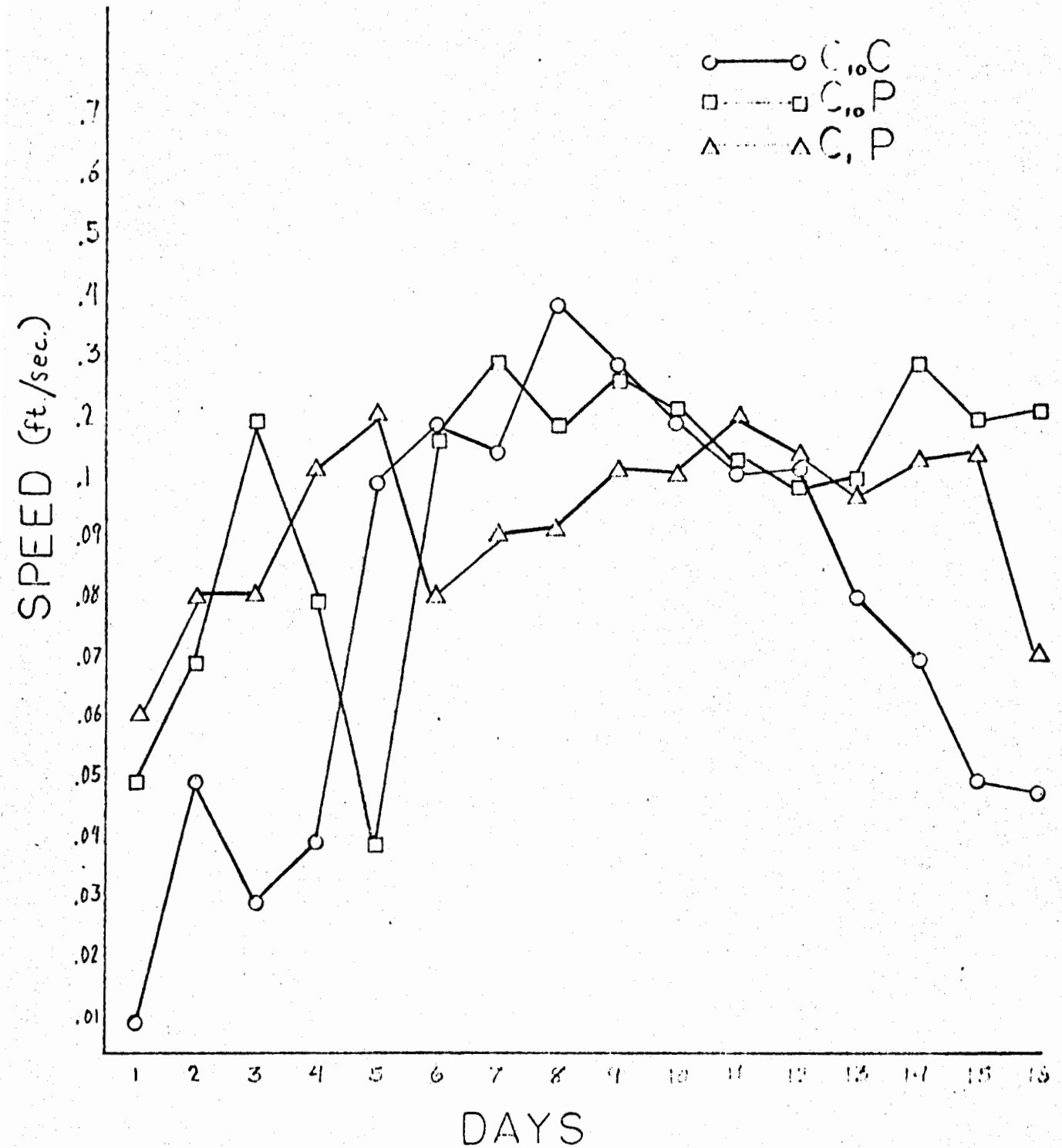


FIG. 2 GROUP MEANS FOR START SPEED MEASURE

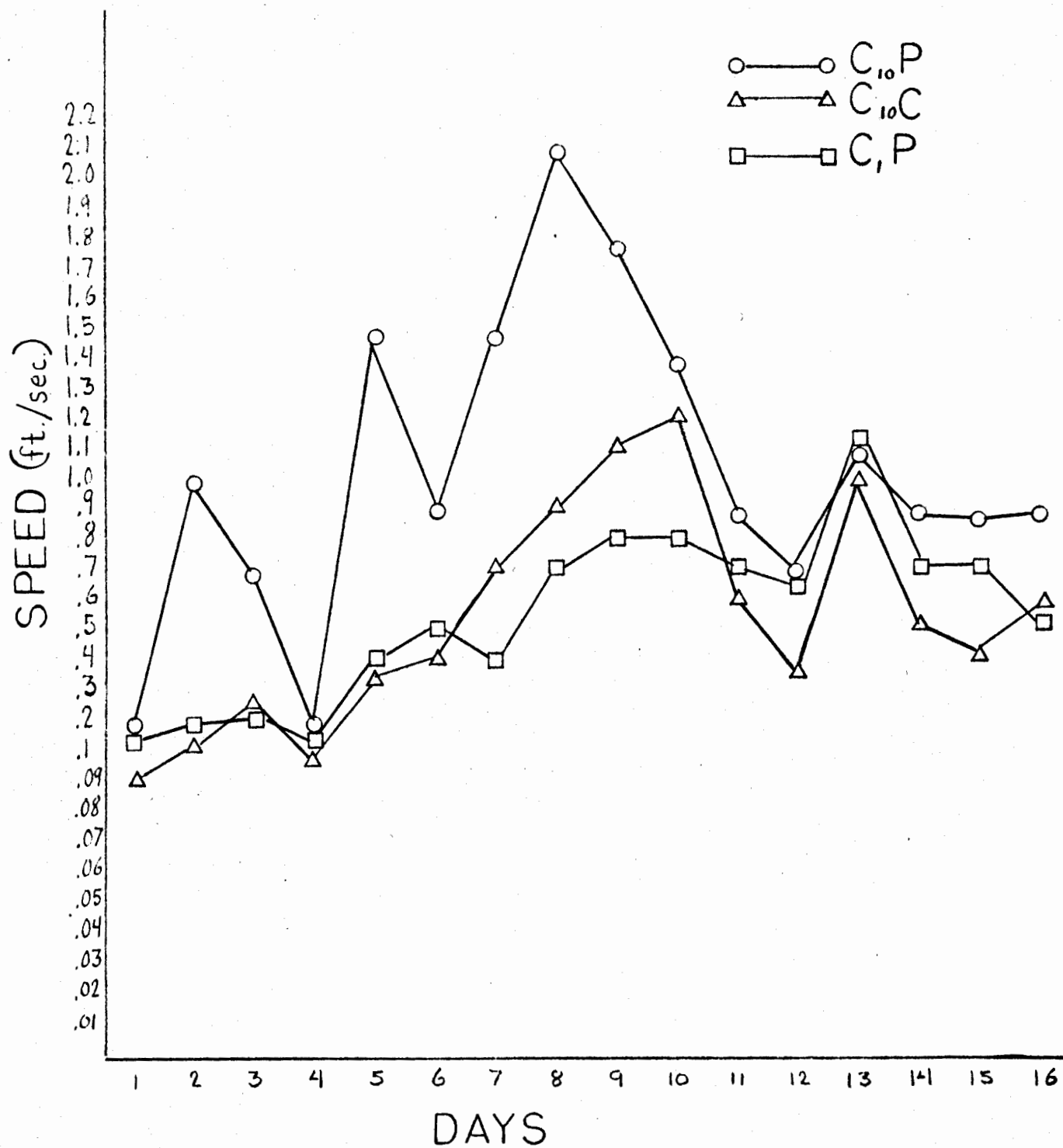


FIG. 3 GROUP MEANS FOR ALLEY SPEED MEASURE

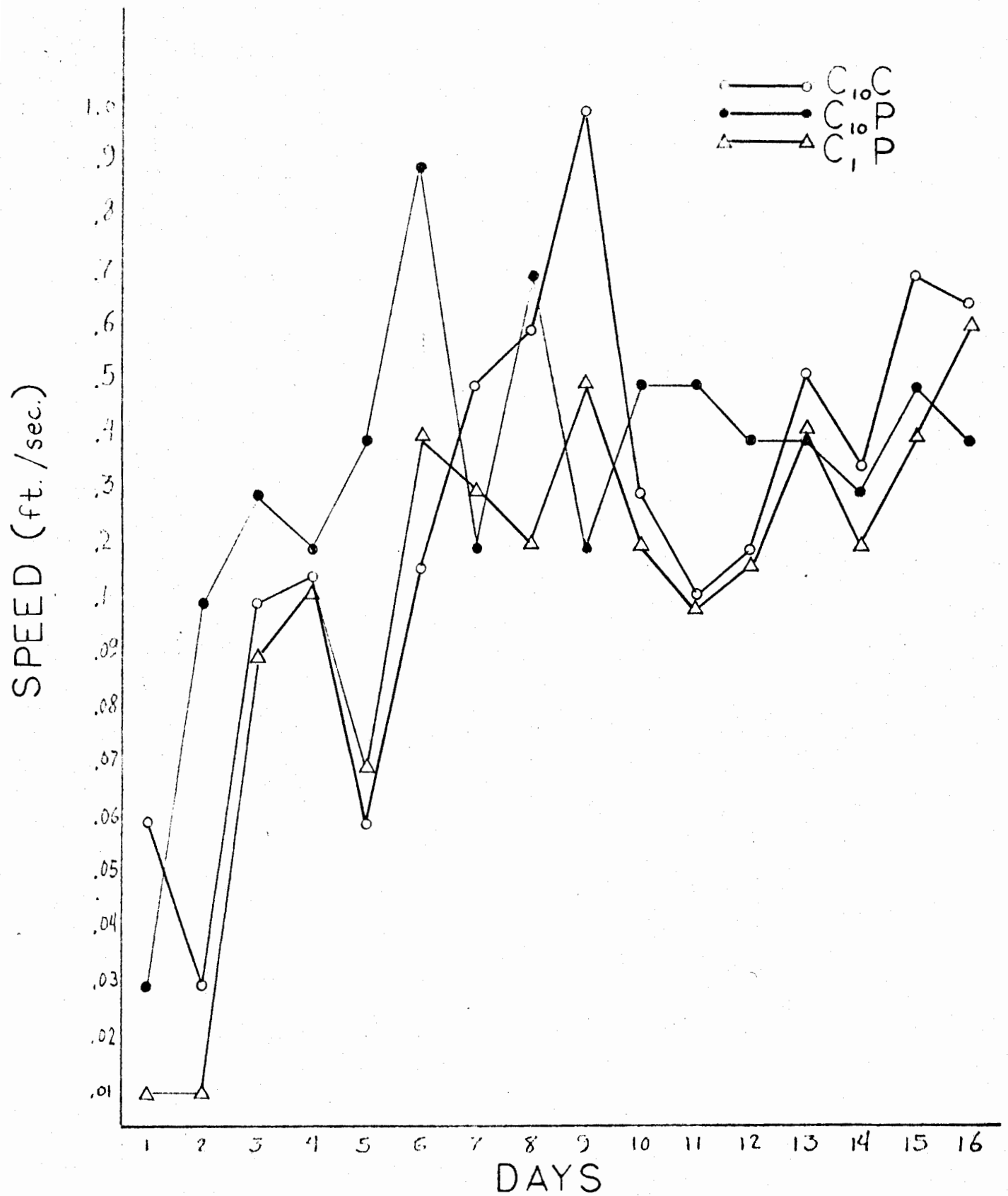


FIG. 4 GROUP MEANS FOR GOAL SPEED MEASURE



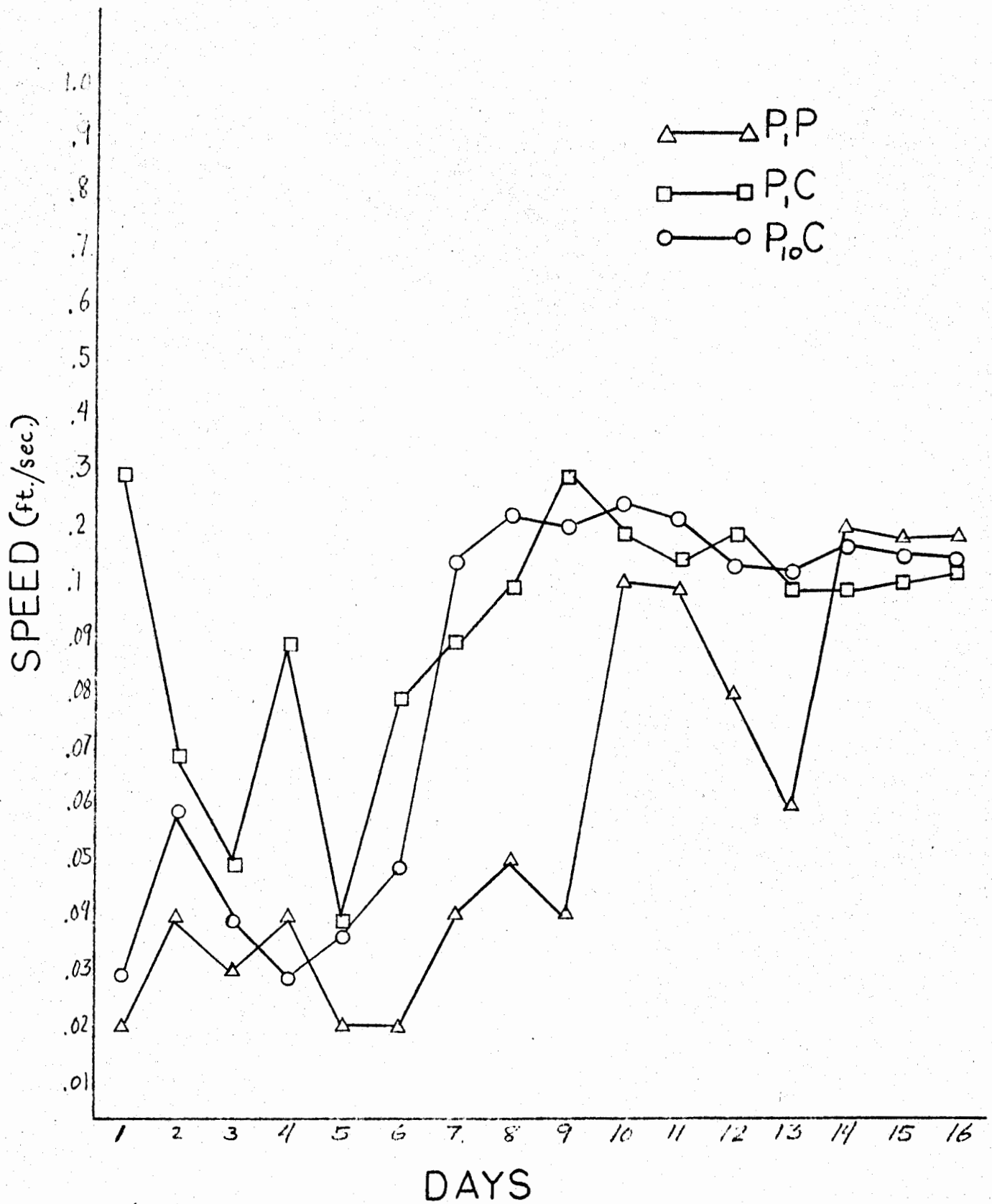


FIG.5 GROUP MEANS FOR START SPEED MEASURE

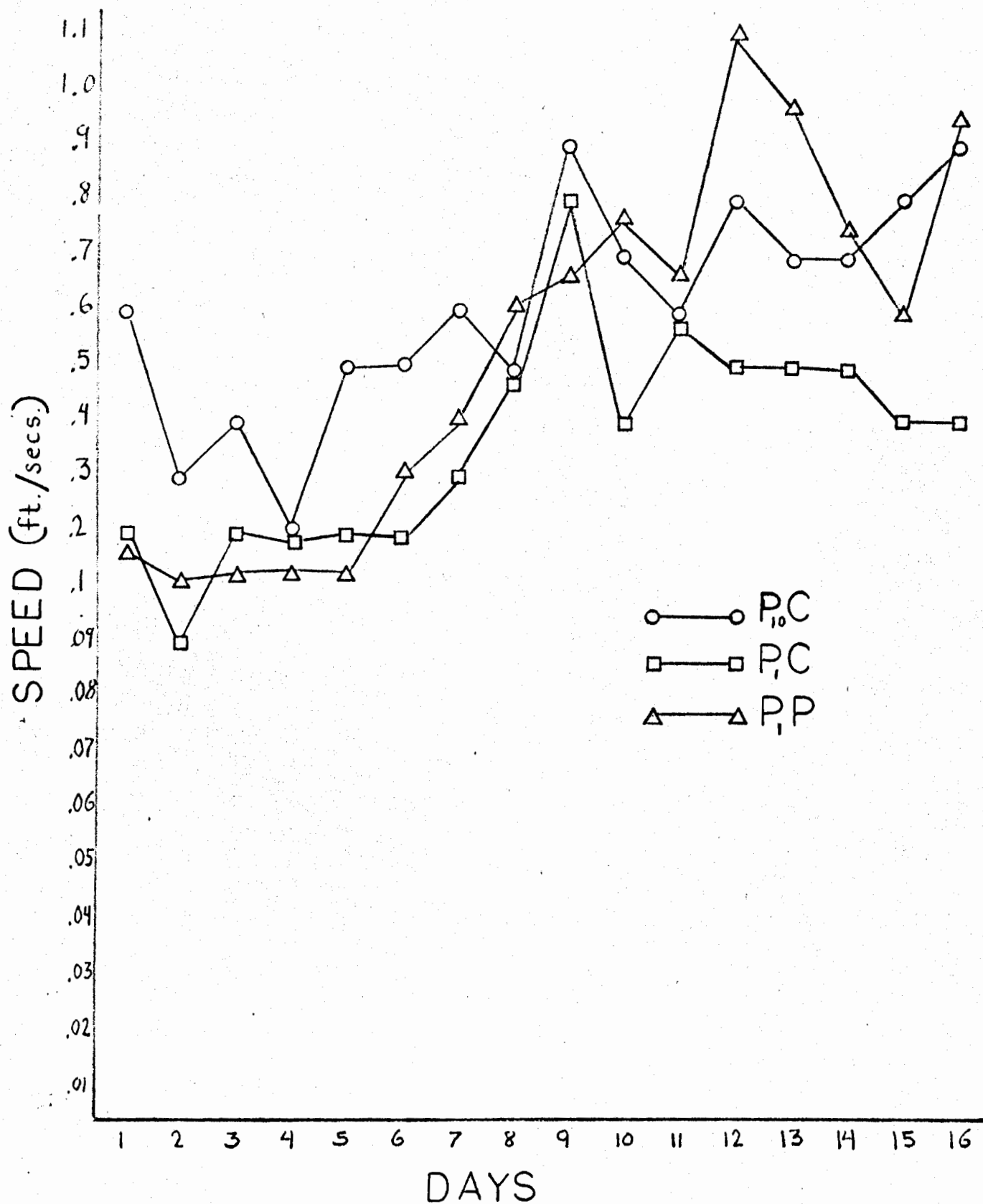


FIG. 6 GROUP MEANS FOR ALLEY SPEED MEASURES

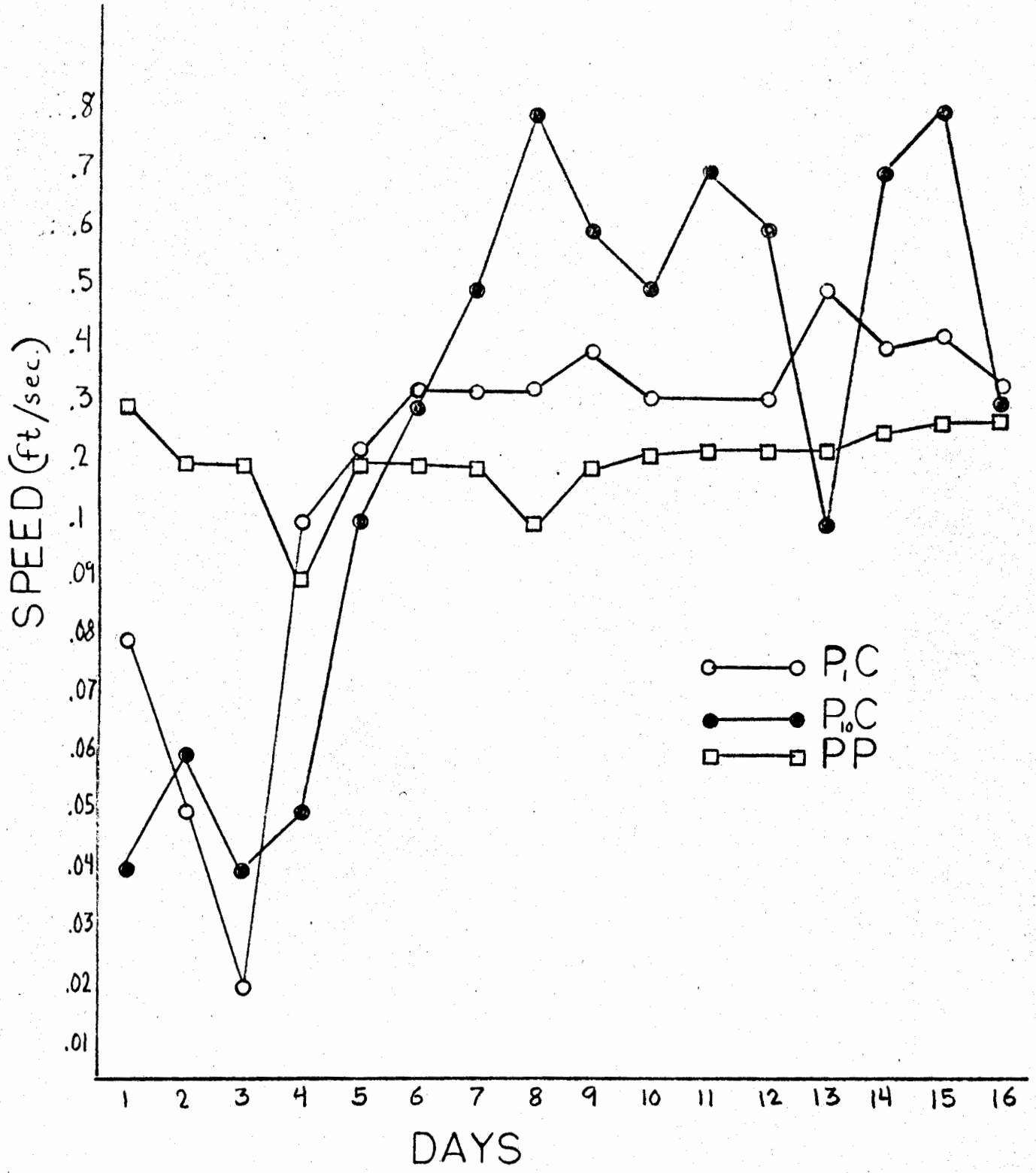


FIG. 7 GROUP MEANS FOR GOAL SPEED MEASURE

## Discussion

Table 9 shows the various measures on which the hypotheses were tested, and the results of the critical difference tests.

TABLE 9  
Summary of Group Comparisons

Groups compared	Start speed	Alley speed	Goal speed	Number of extinction trials	Number of hesitation responses
P <sub>10</sub> C-C <sub>10</sub> P	non significant	C <sub>10</sub> P*	non significant	C <sub>10</sub> P*	P <sub>10</sub> C**
P <sub>10</sub> C-C <sub>10</sub> C	non significant	non significant	P <sub>10</sub> C*	non significant	P <sub>10</sub> C**
C <sub>10</sub> C-C <sub>10</sub> P	non significant	non significant	C <sub>10</sub> P*	C <sub>10</sub> P**	C <sub>10</sub> P**
P <sub>1</sub> C-C <sub>1</sub> P	non significant	C <sub>1</sub> P*	non significant	non significant	non significant
CRF-PRF	non significant	non significant	non significant	non significant	non significant

\* p .05  
\*\* p .01

It can be seen from Table 9 that the first hypothesis, that P<sub>10</sub>C animals show greater resistance to extinction than the C<sub>10</sub>C or C<sub>10</sub>P groups, was upheld in the

extinction goal speed measure when compared to the C<sub>10</sub>C group. The number of hesitation responses during extinction category was intended to be a measure of resistance to extinction, and thought to show an inverse relation to the number of trials to extinction. The rationale behind the use of this measure was based on a study by Ison (1962) in which an identical measure was recorded during extinction. This speculation was not supported by the results, however, since the two groups who took significantly more trials to extinction than their comparison group also exhibited a significantly greater number of hesitation responses.

The second hypothesis stated that the C<sub>10</sub>C animals show greater resistance to extinction than the C<sub>10</sub>P group. This hypothesis was not upheld on the speed or trials to extinction measures. The rationale behind this hypothesis was an interpretation of the depression effect by Skinner (1956) who spoke of emotional behaviors interfering with an instrumental response following a shift from continuous to partial reinforcement. In the present experiment, the shift from C<sub>10</sub> to P<sub>1</sub> with a further shift to the extinction phase seemed to produce a greater interference with the running response than the somewhat more gradual transition of C<sub>10</sub> to C<sub>1</sub> to extinction. The experimental results for this comparison indicated that the C<sub>10</sub>P animals

were sufficiently conditioned to the partial schedule at the end of the eight day shift period to enable them to continue running longer when reward was withheld in extinction. The extinction period was, thus, more aversive to the C<sub>10</sub>C animals having had no prior experience with intermittent reinforcement.

The third hypothesis was that P<sub>1</sub>C animals show greater resistance to extinction than C<sub>1</sub>P animals. This was not upheld in the number of trials to extinction measure or in the speed data where it was reversed in the extinction alley speed measure. It is speculated that a shorter shift period would have led to results favorable to the several hypotheses, since the eight days that it involved seemed sufficient to negate any effects of acquisition schedules. In terms of this explanation, extinction performance can be thought of as almost wholly a function of shift schedule. The transient depression effects noted by Mikulka et al. would have had ample time to extinguish, thus bringing performance under the control of schedule alone.

The fourth hypothesis stated that P<sub>1</sub>P animals do not show significant decrements in performance in the acquisition and shift phases. This hypothesis was supported, in that no significant "depression" effects were found.

The results of the study are somewhat at variance

with Mikulka et al. who found no "depression" effect for animals initially trained under partial reinforcement. However, it should be noted that Mikulka et al. defined the "depression" effect in terms of comparison of a ten pellet group with its corresponding one pellet group. The present study did not employ a one pellet group corresponding to every ten pellet group, and, hence, compared a group's performance between the highest and lowest levels reached during the shift phase. Goal speed data indicated a significant decrement in performance for the P<sub>10C</sub> group on day 12 of the shift phase. A possible explanation for these results may be found in the environmental conditions of the testing room. The ventilation of this room was necessarily poor due to several layers of heavy paper that had been fastened over the window to darken the room. The door was also covered with a cloth curtain that further decreased ventilation. Although temperature readings were not taken, the experimental room appeared to be much warmer than the animal room in which both the door and window were open. The E felt that the temperature in the experimental room was constant throughout all experimental phases.

Another procedure that may have influenced performance was the inspection of the food cup when the S was in the goal box, through the use of a small penlight. This was necessary during acquisition to insure that the animal

was not removed from the goal box before eating the food during the maximum ten minutes he was allowed. However, it was noted by E that the animals made no observable response to the light. The manual timing of the start and alley segments may have introduced an error into the recording of running times for certain groups. The Mikulka et al. study used automatic timing procedures in all segments of the runway. The present study would have employed automatic timers, but such were not available. Automatic timing of the goal speed was selected because it was the significant aspect of the Mikulka et al. study.

An analysis of data for the last ten trials of the acquisition and shift periods was attempted, to discriminate between fast and slow learners. However, preliminary tests for homogeneity of variance reached significance, indicating heterogeneity of variance for this segment of trials. Further tests on all 80 trials of each phase indicated homogeneity of variance over all groups, thus making each entire phase the unit of analysis. The final performance or asymptotic level of the animals' running time was not used as a basis of comparison because of this heterogeneity of variance.

Shift data for CRF animals showed "depression" effects for the C<sub>10</sub>C group on the start speed measure, and for group C<sub>10</sub>P on the alley measure. A plot of the goal



speed data (Figure 4) indicated performance decrements for group C<sub>10C</sub>, a finding also observed by Mikulka et al. It should be noted, however, that Mikulka et al. found evidence for the depression only in the goal measure. The present experiment found evidence for these effects in both start and goal measures.

The two consecutive 60 second periods of the extinction criterion applied to animals who failed to reach the goal box, either by refusing to leave the start box or by hovering in the alley.

Further work involving the effect of shifts in schedule and reward on resistance to extinction might involve shift periods of varying lengths. An experiment using various shift phase lengths would test the earlier speculation that extinction performance was a function of how well the shift phase reinforcement schedule had been conditioned. Most experiments in this area have employed 50% PRF schedules. An extension of the previous work might utilize variable ratio schedules whose overall percentage of reinforcement differed from say, 10 to 75%.

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