PURSUIT ROTOR PERFORMANCE UNDER ALTERNATE CONDITIONS OF DISTRIBUTED AND MASSED PRACTICE

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PURSUIT ROTOR PERFORMANCE UNDER ALTERNATE CONDITIONS OF DISTRIBUTED AND MASSED PRACTICE

By

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INTRODUCTION

Experimentation over the last fifty years has resulted in the accumulation of a great deal of data on motor learning. Two basic variables which were noted early and still remain significant are the length of the practice interval and the rest interval. Certain phenomena which seem to be specifically related to these variables are the following: (1) the advantage of spaced practice (interpolated rest periods) over massed practice (continuous practice); (2) reminiscence, or the gain in performance over a rest period without additional practice; and (3) the relatively rapid increase in performance, early in performance after a rest, as compared with initial learning. The latter phenomenon has been called regaining of set, or warm-up by various experimenters. Another characteristic of the post-rest curve is a gradual decline after this abrupt rise before a resumption of gradual improvement such as is observed in the pre-rest curve.

An adequate theory of motor learning should be able to account for these performance phenomena, apply to all other available data, and stimulate further research.

Early theoretical attempts to account for the superiority of distributed over massed practice and reminiscence have been reviewed by McGeoch and Irion (9), and for one reason or another are deemed inadequate. More recently we have the application of the inhibitory concept of Hull's (3) behavior theory to the area of motor learning.

Hull divides inhibition into two components, reactive inhibition (I_R) and conditioned inhibition ($_SI_R$). Reactive inhibition is a negative drive state produced by response which reduces the tendency to repeat that response. I_R accumulates with continued response being a positive function of the number of reactions and the amount of work involved in response. I_R, however, is a temporary state, dissipating rapidly with the passage of time. The other major concept, conditioned inhibition, is a learned resting response which reduces the drive of reactive inhibition and is reinforced by its dissipation. Moreover, I_R and $_SI_R$ are assumed to have all the characteristics respectively of other drives and habits.

The superiority of distributed practice over massed practice in motor learning may be attributed to the total inhibition present in the massed practice situation which consists of the permanent $_SI_R$ and the temporary I_R. Reminiscence is due to the dissipation of I_R over a rest period. Any more or less permanent difference between massed and distributed practice is attributed to the development of $_SI_R$ under massed conditions. There are no concepts explicit in Hull's system which can be used to explain the initial sharp rise in the post-rest performance curve.

Ammons (1), on the other hand, has a concept to handle this phenomenon. His comprehensive system for explaining rotary pursuit performance contains three variables: (1) a temporary work decrement which dissipates over rest and is similar to Hull's reactive inhibition; (2) a permanent work decrement similar to Hull's conditioned inhibition; and (3) a decrement due to necessity to "warm-up" after rest which is used to explain the initial sharp rise in post-rest performance through regaining of set.

Kimble (4, 5) has done much to extend and apply Hull's concepts to motor learning phenomena. He reasons that since I_R is a drive the accumulation of a certain critical amount will produce resting and once the I_R is reduced below the critical level the organism will resume working until this level of I_R is again attained. The critical level of I_R will probably not be reached if the inter-trial rest periods are of more than a few seconds duration. In fact, Kimble has shown in one motor learning situation that no conditioned inhibition can develop unless the inter-trial rest is less than 5 seconds.

In relation to Kimble's hypothesis, the work of Weaver (11) has indicated that a near maximal value of I_R is reached in approximately 30 seconds of work and is almost completely dissipated in a rest period of the same duration.

Both Hull and Ammons postulate that the index of their respective permanent work decrements will increase as a negatively accelerated (habit) function of the amount of practice. Kimble and Weaver both have shown that $_{S}I_{R}$ shows some tendency to develop as a negatively accelerated (habit) function of the number of trials. In addition, Weaver has shown a curve for the extinction of $_{S}I_{R}$ which is a decay function similar to curves found for the extinction of other habits.

The theories of Hull, Kimble and Ammons are basically similar and constitute the theoretical foundation for the present investigation. However, because Hull's system is intended for wider application, the terminology of Hull plus the concept of warm-up will be employed.

STATEMENT OF THE PROBLEM

This study is an attempt to isolate and specify the three constructs which have been postulated to account for motor learning phenomena. These are conditioned inhibition, reactive inhibition, and warm-up or set. To accomplish this purpose the effect of alternate conditions of distributed and massed practice on pursuit rotor performance was investigated, and a measure of performance at 10-second intervals within the work periods was obtained. The design of this experiment and the analysis of the data, but for a few exceptions, closely paralleled an investigation conducted by Weaver (11), on a pursuit rotor rotating in a counter-clockwise direction.

Reactive inhibition dissipates rapidly during the inter-trial rest periods. Therefore, due to the lack of inhibitory potential in distributed practice, we predict:

1. The pre-rest performance of groups under distributed conditions will be superior to that of groups under massed conditions.

Due to dissipation of I_R during rest, we predict:

2. More reminiscence will be present in the massed groups than in the distributed groups after an equal amount of rest.

Inhibitory potential will develop readily during the post-rest trial in the distributed-massed group and $_{S}I_{R}$ will be extinguished in the massed-distributed group. Therefore:

3. After the variable of distribution of practice has had a chance to operate in post-rest performance, groups practicing under like conditions will converge and remain together; and at the end of the period the distributed groups (distributed-distributed; massed-distributed) will be superior to the massed groups (massed-massed; distributed-massed).

On the basis of the previous discussion we also predict that:

4. The index of conditioned inhibition will increase as a negatively accelerated (habit) function of the number of trials, and

5. The extinction curve of conditioned inhibition will be a decay function similar to extinction curves for other habits.

Formulation of the following hypothesis is made possible through using the 10-second unit of measurement within a 30-second trial of distributed practice. Because of the variable of set or warm-up we predict:

6. On the first post-rest 30-second trial the performance on the third 10-second unit will be higher than on the first 10-second unit. The opposite

relationship will be true in the pre-rest 30-second trials.

Due to the fact that I_R builds up rapidly to a critical value and dissipates rapidly with rest, reminiscence will be evident over the 30-second rest periods in the distributed groups soon after the first pre-rest 30-second trial. On the basis of findings by Weaver we predict:

7. The amount of reminiscence displayed in the distributed groups over the last 30-second pre-rest interval will not differ significantly from that found over the 5-minute rest period for the same group.

Conditioned inhibition has been previously built up in the first massed practice session and extinguished in the subsequent distributed session in the massed-distributed-massed group. Since reconditioning is typically a rapid process, ${}_SI_R$ should build up very rapidly in the third work period and as a result we expect:

8. The massed-distributed-massed group will show the most immediate and greatest decline in performance of any group working under massed practice in the third work period, particularly when compared with the massed-massed-massed and distributed-massed-massed groups.

Any statement regarding the final 3-minute work period must be recognized as tentative due to the size of the groups and the length of the period.

EXPERIMENTAL PROCEDURE

Subjects

A total of 76 college students was used as subjects. Four were graduate students and the remainder were from introductory psychology classes. No subject had had prior pursuit rotor experience. Twelve of the subjects' records were omitted in order to match the groups. The present data were based on 64 subjects (8 groups of 8 subjects each), 36 of whom were women. The sexes were distributed as evenly as possible throughout the groups. Mean age was 20.6 years.

The subjects worked singly in a quiet room. The first 48 subjects were assigned randomly to one of the eight groups, while the remainder were assigned to the various groups on the basis of the first 30 seconds of performance. This was done without interruption of the practice session.

Apparatus

The apparatus consisted of a Koerth-type circular pursuit rotor, two Standard Electric timers which measured to the nearest 0.01 second the subject's time on target, a hinged stylus, a stopwatch, and a double-throw four pole toggle switch. The equipment was mounted on a wooden table 30 inches high. The rotor disk was wood finished with black paint and varnish. The rotor disk was 28.5 cm in diameter with a circular brass target 1.9 cm in diameter set flush with the larger disc 8.5 cm from its center. The rotor turned in a clockwise direction at 60 rpm.

Experimental Design

The total time on target was recorded for each subject every 10 seconds. Thirty second intervals were obtained by simply adding 3 successive 10-second intervals. The recording was accomplished by manual operation of the toggle switch every 10 seconds which simultaneously stopped one timer and started the other. The experimenter recorded the time on target and reset the timer to zero every 10 seconds while the other timer was in the circuit. With a little practice this was easily done in the allotted 10 seconds.

The stopwatch was used to indicate the length of the 10-second intervals, to measure the 30-second trials and 30-second rest intervals, and to measure the over-all time for the practice and rest sessions.

The measurement of pursuit rotor performance by means of 10-second intervals within 30-second performance trials in the distributed practice groups is a new technique used first by Weaver (11). It was introduced with the hope that it would permit a more detailed analysis of the characteristic phenomena of the learning curve.

During the entire experimental session all subjects worked a total of 21 minutes. The practice time was divided into three periods of 6, 12 and 3 minutes separated by two rest periods of 5 and 3 minutes, respectively. The length of the various work and rest periods was determined on the basis of previous research and expedience of experimentation. The length of the 6-minute work period was chosen to provide maximal reminiscence which Ammons (2) showed occurred after approximately 8 minutes of pre-rest practice. The 5-minute rest period was also used to provide maximal reminiscence from pre-rest to post-rest performance, as indicated in studies by Kimble and Horenstein (8), Ammons (2) and Weaver (11). The second work period was extended four minutes beyond that used by Weaver to allow time for groups practicing under like conditions to converge. It might have been more desirable to have extended the 3-minute rest period and final 3-minute work period but it was necessary to keep the length of the entire practice session of the distributed groups within 50 minutes in order to obtain subjects during hours between classes.

The various groups worked under different conditions during the practice periods of 6, 12 and 3 minutes. Massed practice (M) consisted of continued practice while distributed or spaced (D) practice consisted of alternating intervals of 30 seconds of work and 30 seconds of rest. Table 1 gives a concise picture of how the groups were arranged.

TABLE 1

SCHEMA OF THE EXPERIMENTAL DESIGN

Group number	6 min. practice	5 min. rest	12 min. practice	3 min. rest	3 min. practice
1	D	-	D	-	D*
2	D	-	D	-	M*
3	D	-	M	-	D
4	D	-	M	-	M
5	M	-	M	-	M
6	M	-	M	-	D
7	M	-	D	-	M
8	M	-	D	-	D

*Hereafter D signifies distributed or spaced practice and M signifies massed or continuous practice.

It is readily observed that even though 8 groups were used the conditions were not separated into 8 as such until the final 3-minute period. During the first 6-minute period we had only two conditions, D and M. With the addition of the 12-minute period there were four conditions, D-D*, D-M, M-M, and M-D. The final 3-minute period brings the total of different conditions to eight as shown on the chart.

Instructions to Subjects

Each subject was given the following written instructions:

*D-D means distributed-rest-distributed, etc.

PURSUIT ROTOR EXPERIMENT

INSTRUCTIONS

The object of this experiment is to see how well you can follow a moving target with a hand stylus. Stand in front of the pursuit rotor with the stylus grasped firmly but in a relaxed manner in your preferred hand. Keep the stylus horizontal and move it around the turning disk with lazy rotary movements. Do not begin until I tell you to start, and stop only when I say stop.

The experimenter then demonstrated the operation as the instructions were repeated. The subjects were told not to begin until the experimenter said "start" and to stop when he said "stop". The subjects were given the "ready" signal two seconds before the starting signal and were permitted to pick up the stylus in preparation.

After the first work period in the distributed practice groups, the subject was informed that he would alternately work and rest. When a subject who had formerly worked under distributed conditions was put on massed practice he was told there would be a period of continuous work.

The subject stood quietly in front of the rotor during the rest interval in the case of distributed groups. During the 5 and 3-minute rest periods, all subjects were allowed to sit down and converse or read. If the subject violated any of the instructions during the practice period, he was corrected at once without interruption of activity.

RESULTS AND DISCUSSION

The subject's time on target was recorded to the nearest 0.01 second. The performance curves in Figs. I and II were obtained by converting the time on target for the groups into percent of time on target as has been the usual procedure of other investigators. Analysis of variance was used as the statistical technique for comparisons between groups wherever appropriate. A fundamental condition for validity of the F-test is that the two mean squares be independent. This condition was not met in the case of percentages. Therefore, the percentages were transformed into angles with mean and variance independent as recommended by Snedecor (10). Reminiscence, or gain over rest, was measured as the difference between the last pre-rest trial and the first post-rest trial. Here the gain was measured as the difference in time on target for each individual and was not converted into percentages. The gain distributions appear to have independent mean and variance; consequently, a transformation was not deemed necessary and the analysis was performed on the raw data. In each case where analysis of variance was used Bartlett's test of homogenity (10) was first applied to assure that the data were sufficiently homogeneous to make the F-test applicable.

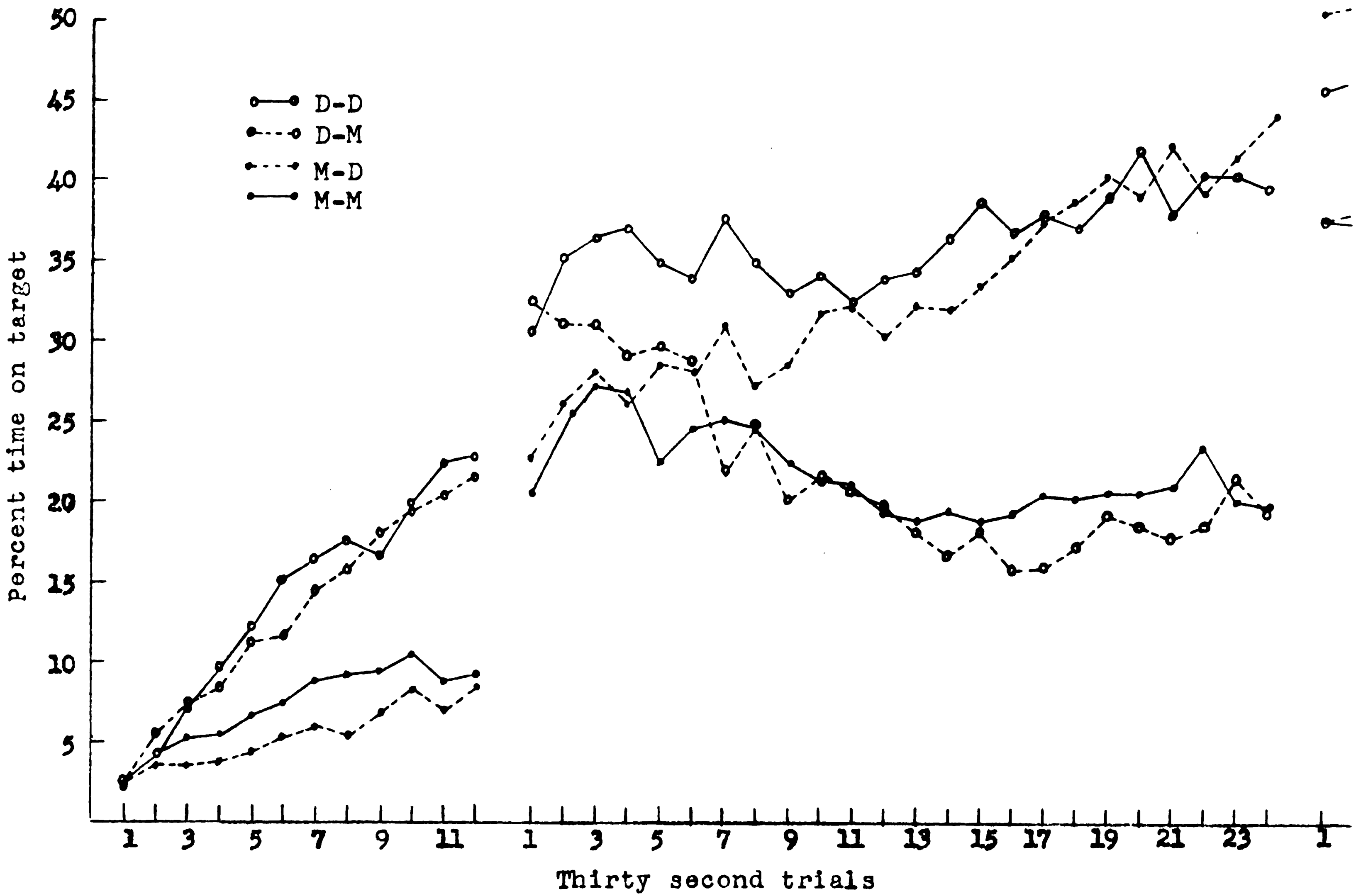


Figure I. Performance curves for four groups for the first and second practice sessions (6 and 12 minutes, respectively) and first trial of third practice session as based on the means of 30-second trials

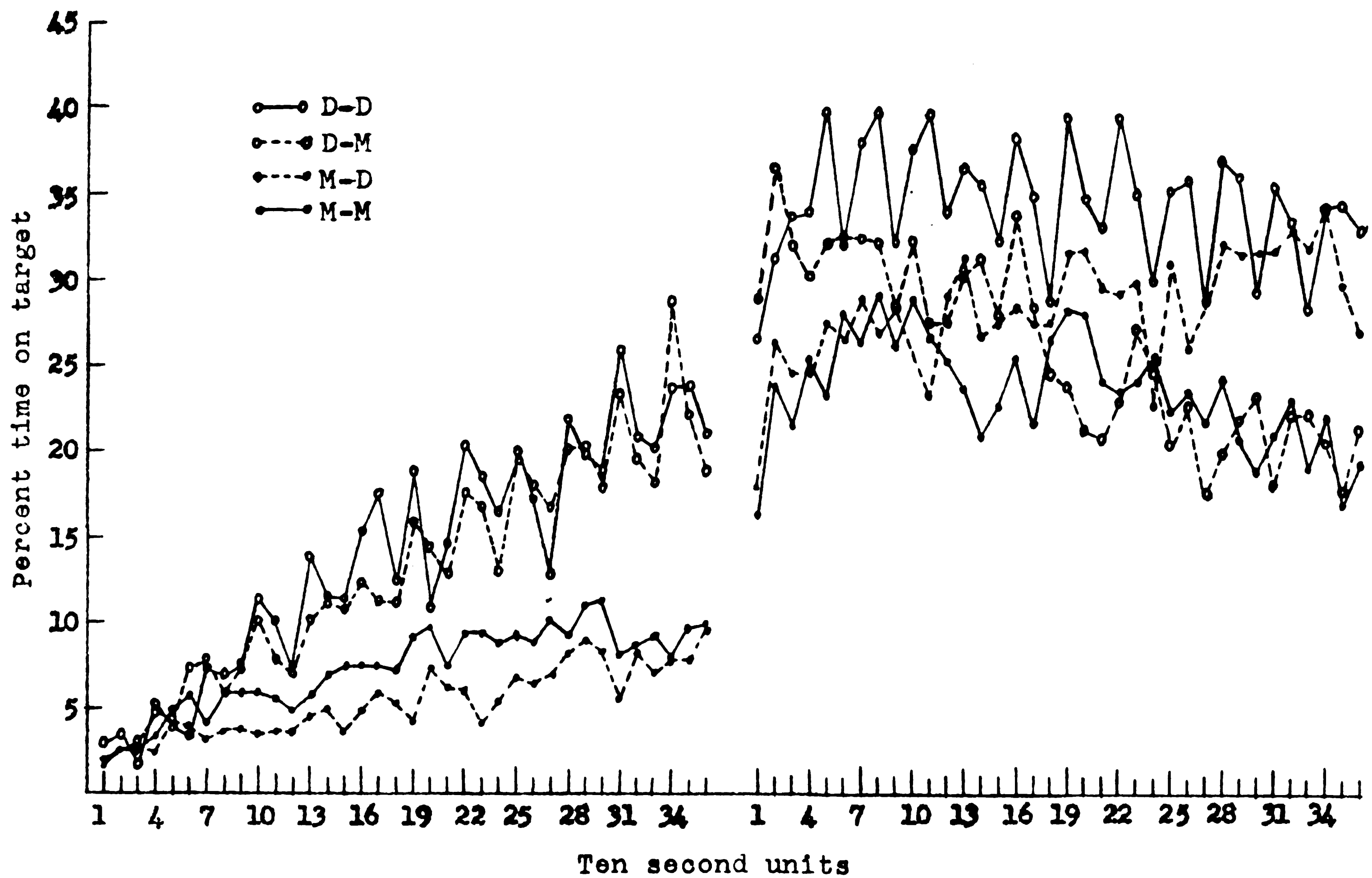


Figure II. Performance curves for four groups for the first (pre-rest) practice session and 6 minutes of the second (post-rest) practice session as based on the means of 10-second units

Individuals were assigned to groups on the basis of their performance during the first 30-second work period in such a manner as to match the groups. The graph in Figure I and the statistical analysis in Table 2 give evidence that the groups were well matched at the beginning of practice.

TABLE 2

ANALYSIS OF VARIANCE OF THE FIRST 30-SECOND WORK PERIOD FOR 8 GROUPS WITH DATA CONVERTED TO ANGLES

Source of variation	d.f.	Sum of squares	Mean square	F
Between groups	7	17.29	2.471	0.106
Within groups (error)	56	1307.58	23.350	
Total	63	1324.87		

For d.f. 7 and 56, $F_{.05} = 3.32$, $F_{.01} = 5.85$

The superiority of groups working under distributed conditions over groups working under massed conditions during the first 6-minute practice period is clearly evident from Figure I and Table 3. Also, there is no significant difference between the groups working under like conditions, D-D and D-M, M-M and M-D. Therefore, hypothesis 1 is confirmed. This phenomenon was one of the first observed to be typical of motor learning situations and the results here are in agreement with those of other investigators.

TABLE 3

ANALYSIS OF VARIANCE OF THE LAST 30-SECOND WORK PERIOD OF 6-MINUTE PRACTICE FOR 4 GROUPS WITH DATA CONVERTED TO ANGLES

Source of variation	d.f.	Sum of squares	Mean square	F
D groups vs. M groups	1	1922.05	1922.05	32.825**
Groups treated alike	2	7.87	3.94	0.067
Total between groups	3	1929.92	643.31	10.986**
Error	60	3513.31	58.56	
Total	63	5443.23		

For d.f. 1 and 60, $F_{.05} = 4.00$, $F_{.01} = 7.08$
For d.f. 2 and 60, $F_{.05} = 3.15$, $F_{.01} = 4.98$
For d.f. 3 and 60, $F_{.05} = 2.76$, $F_{.01} = 4.13$
**Significant beyond .01 point

Gain in performance level over the 5-minute and 3-minute rest periods is obvious from Figure I and the statistical evidence for reminiscence is given in Tables 4 and 5. All four groups with both rest periods show a significant amount of reminiscence. The gain in each case is a comparison of the last 30-second pre-rest trial with the first 30-second post-rest trial.

Due to the dissipation of I_R during interpolated rest intervals under distributed conditions we would expect the massed groups to show more reminiscence than the distributed groups over the same rest period. These

TABLE 4

MEAN REMINISCENCE SCORES IN .01 SECOND OVER THE 5-MINUTE REST PERIOD AS BASED ON 30-SECOND TRIALS

	Groups			
	M-M	M-D	D-D	D-M
Mean	339.00	431.63	233.13	326.50
Standard error of the mean	55.94	55.27	72.74	69.49
t	6.060	7.808	3.236	4.698
P	$<.01$	$<.01$	$<.01$	$<.01$

TABLE 5

MEAN REMINISCENCE SCORES IN .01 SECOND OVER THE 3-MINUTE REST PERIOD AS BASED ON 30-SECOND TRIALS

	Groups			
	M-M	M-D	D-D	D-M
Mean	540.62	190.62	211.56	547.00
Standard error of the mean	54.83	49.71	45.57	81.51
t	9.860	3.834	4.643	6.711
P	$<.01$	$<.01$	$<.01$	$<.01$

comparisons are presented in Tables 6 and 7. The difference between groups practicing under like conditions is not significant. However, hypothesis 2, that massed groups will show greater reminiscence than distributed groups, is confirmed. Weaver found the massed groups showed greater reminiscence than the distributed groups only at the 10 percent level of significance. This lower level of significance may be due to the fact that counter-clockwise rotation increased the difficulty of the task and consequently set up more I_R in the distributed groups within a 30-second work period.

The graph in Figure II which shows the 6-minute practice period and 6 minutes of the 12-minute period was obtained by plotting performance level of the 4 groups using 10-second units of measurement. A statistical analysis of reminiscence gain from the last pre-rest 10-second unit to the first post-rest 10-second unit is presented in Tables 8 through 11. Tables 8 and 9 indicate that when only the right tail of the t distribution is considered, the hypothesis of no gain can be rejected at least at the 5 percent level of significance for all groups except the M-D group over the 3-minute rest period. The M-D group is approaching the maximum performance level for this task and consequently reminiscence over this and any succeeding rests may not prove to be significant.

A comparison of reminiscence between the various groups and conditions over the 5 and 3-minute rest periods is

TABLE 6

ANALYSIS OF VARIANCE OF REMINISCENCE GAIN IN .01 SECOND FOR 4 GROUPS OVER THE 5-MINUTE REST PERIOD AS BASED ON 30-SECOND TRIALS

Source of variation	d.f.	Sum of squares	Mean square	F
D groups vs. M groups	1	6,548,518	6,548,518	100.575**
Groups treated alike	2	138,386	69,193	1.063
Total between groups	3	6,686,904	2,228,968	34.233**
Error	60	3,906,680	65,111	
Total	63	10,593,584		

See footnote Table 3 for .01 and .05 F values
**Significant beyond .01 point

TABLE 7

ANALYSIS OF VARIANCE OF REMINISCENCE GAIN IN .01 SECOND FOR 4 GROUPS OVER THE 3-MINUTE REST PERIOD AS BASED ON 30-SECOND TRIALS

Source of variation	d.f.	Sum of squares	Mean square	F
D groups vs. M groups	1	9,869,647	9,869,647	174.086**
Groups treated alike	2	3,832	1,916	.034
Total between groups	3	9,873,479	3,291,159	58.051**
Error	60	3,401,657	56,694	
Total	63	13,275,136		

See footnote Table 3 for .01 and .05 F values
**Significant beyond .01 point

TABLE 8

MEAN REMINISCENCE SCORES IN .01 SECOND OVER THE 5-MINUTE REST PERIOD AS BASED ON 10-SECOND UNITS

	Groups			
	M-M	M-D	D-D	D-M
Mean	62.81	82.19	56.06	99.87
Standard error of the mean	35.66	21.64	30.78	30.50
t	1.761	3.797	1.821	3.274
P	< .05	< .01	< .05	< .01

TABLE 9

MEAN REMINISCENCE SCORES IN .01 SECOND OVER THE 3-MINUTE REST PERIOD AS BASED ON 10-SECOND UNITS

	Groups			
	M-M	M-D	D-D	D-M
Mean	122.81	40.31	83.37	119.12
Standard error of the mean	20.48	36.64	38.22	29.65
t	5.998	1.100	2.182	4.018
P	< .01	> .05	< .05	< .01

TABLE 10

ANALYSIS OF VARIANCE OF REMINISCENCE GAIN IN .01 SECOND FOR 4 GROUPS OVER THE 5-MINUTE REST PERIOD AS BASED ON 10-SECOND UNITS

Source of variation	d.f.	Sum of squares	Mean square	F
D groups vs. M groups	1	478	478	0.330
Groups treated alike	2	17,359	8,680	0.599
Total between groups	3	17,837	5,946	0.410
Error	60	869,216	14,487	
Total	63	887,053		

See footnote Table 3 for .01 and .05 F values

TABLE 11

ANALYSIS OF VARIANCE OF REMINISCENCE GAIN IN .01 SECOND FOR 4 GROUPS OVER THE 3-MINUTE REST PERIOD AS BASED ON 10-SECOND UNITS

Source of variation	d.f.	Sum of squares	Mean square	F
D groups vs. M groups	1	55,932	55,932	3.032
Groups treated alike	2	14,944	7,472	0.405
Total between groups	3	70,876	23,625	1.281
Error	60	1,106,834	18,447	
Total	63	1,177,710		

See footnote Table 3 for .01 and .05 F values

presented in Tables 10 and 11, respectively. The analysis shows that no significant difference is found between distributed and massed groups or between groups under like conditions in either case. These data substantiate the results obtained by Weaver when he calculated reminiscence gain by means of 10-second units of measurement.

Examination of Figure I shows that after approximately 6 minutes of post-rest practice the performance of the D-M group has fallen to that of the M-M group and the performance of the M-D group has risen to the level of the D-D group and that groups practicing under like conditions remain at the same levels of performance. Table 12 compares the groups at the end of the practice period and indicates that the D groups are superior to the M groups and that groups under like conditions are not significantly different. Therefore, hypothesis 3 is confirmed. The length of the second practice period used by Weaver was 8 minutes. At the end of the period his groups practicing under like conditions had not converged although they were not statistically different. An unpublished study conducted at Michigan State College which also used clockwise rotation found as in the present investigation that the like groups converge in less than 8 minutes. The discrepancy between these results and those found by Weaver may be due to the fact that counter-clockwise rotation generates a higher level of conditioned inhibition.

Figures III and IV are developmental curves of con-

TABLE 12

ANALYSIS OF VARIANCE OF THE LAST 30-SECOND WORK PERIOD OF 12-MINUTE PRACTICE FOR 4 GROUPS WITH DATA CONVERTED TO ANGLES

Source of variation	d.f.	Sum of squares	Mean square	F
D groups vs. M groups	1	3465.24	3465.24	76.546**
Groups treated alike	2	68.07	34.03	0.752
Total between groups	3	3533.31	1177.77	26.016**
Error	60	2716.19	45.27	
Total	63	6249.50		

See footnote Table 3 for .01 and .05 F values
**Significant beyond .01 point

ditioned inhibition. The curve in Figure III shows the development of $_{S}I_{R}$, during the pre-rest 6-minute practice, in the groups practicing under M conditions. It was constructed by using the data from Figure II. The successive differences between mean performance level of the distributed groups and the massed groups were taken starting with 10-second unit #6 and using every third 10-second unit thereafter. These differences were plotted and a free-hand curve was drawn. This method is based on the assumptions that I_R develops to a maximal value in approximately 30 seconds of work in the distributed practice group and dissipates almost completely in 30 seconds of rest.

During post-rest performance the D-M group should

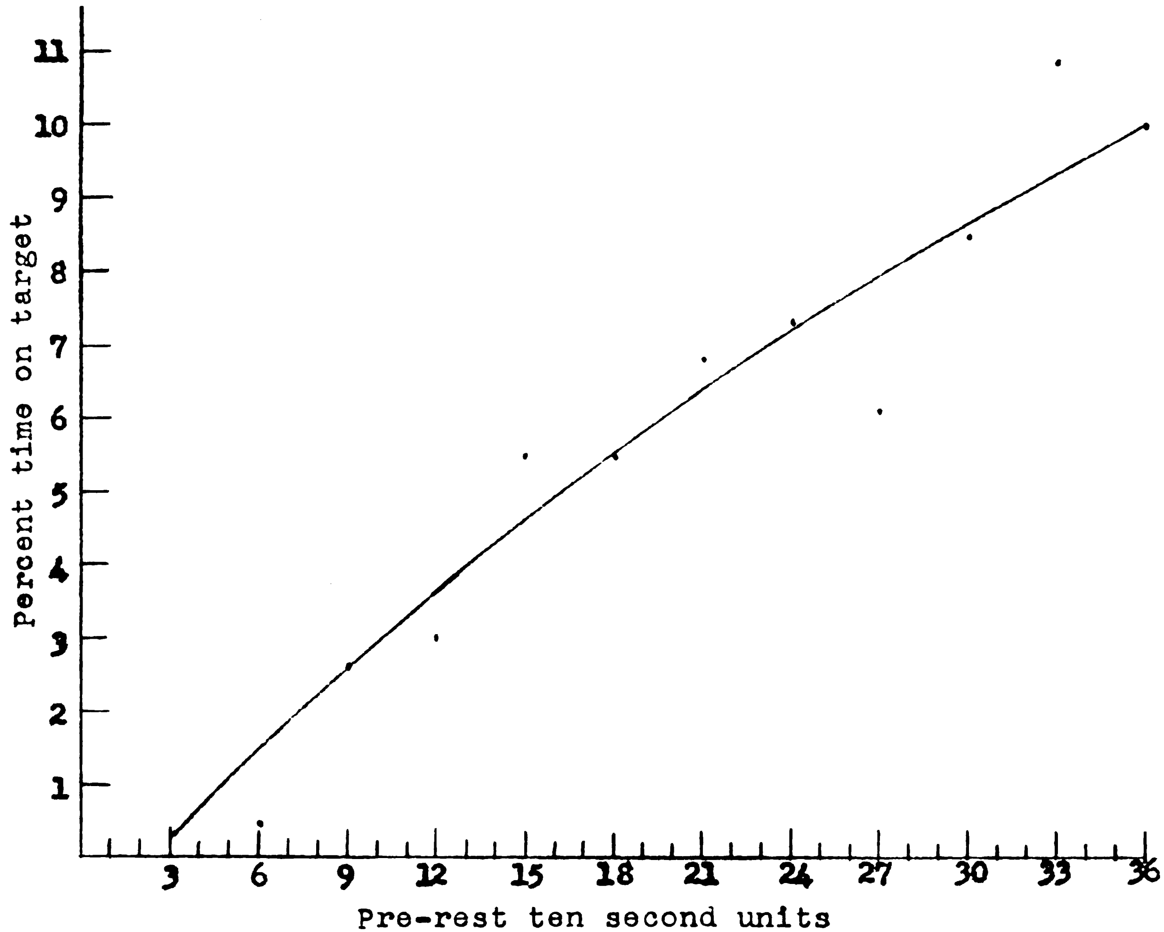


Figure III. Theoretical developmental curve of ${}_{S}I_{R}$ in pre-rest practice as based on 10-second units

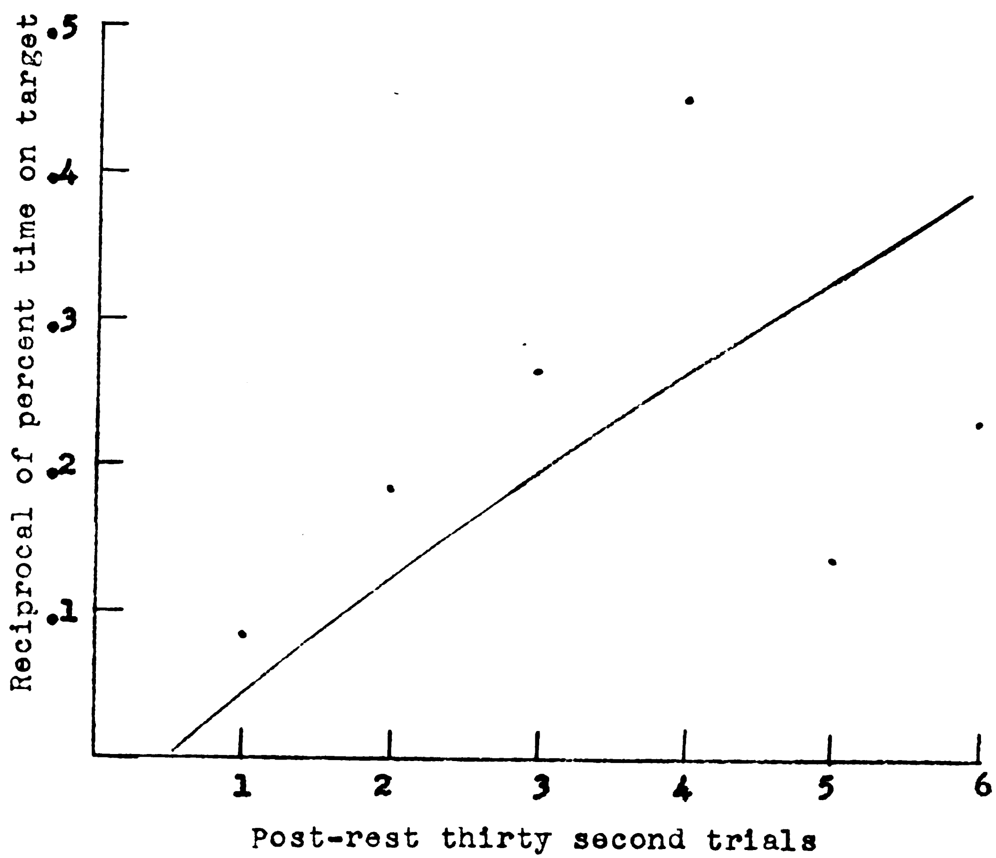
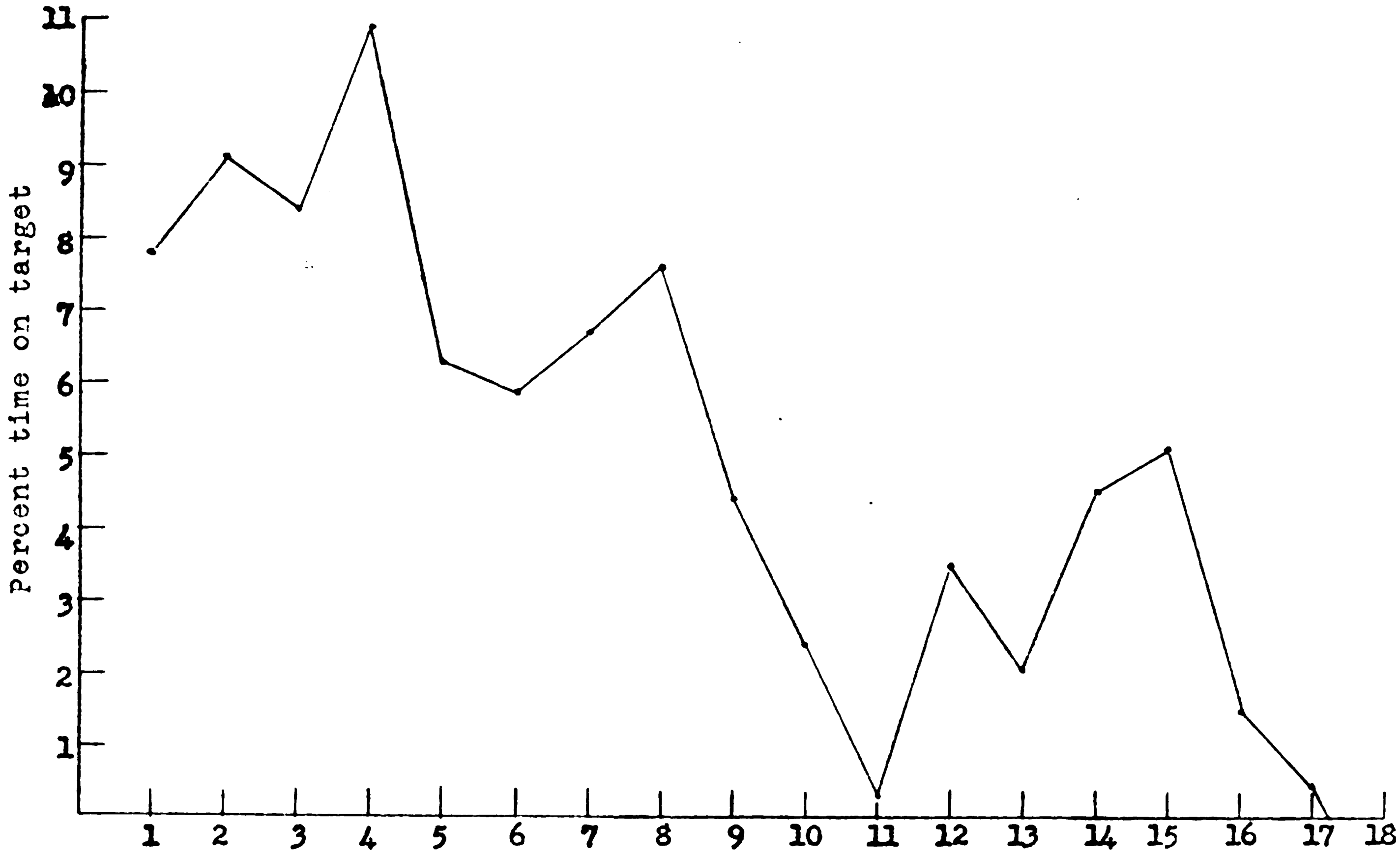


Figure IV. Theoretical developmental curve of $_SI_R$ in post-rest practice as based on 30-second trials develop $_SI_R$ and therefore the reciprocal of the difference between the D-M and the M-M groups should indicate the development of $_SI_R$. This was the method used to obtain the curve in Figure IV.

Figure III indicates that the growth of conditioned inhibition may well be a negatively accelerated (habit) function. Figure IV lacks sufficient points to be a good indicator because the groups converged rapidly. However, hypothesis 4 is adequately confirmed.

Figure V is an extinction curve of $_SI_R$ derived by taking successive differences between 30-second work periods of groups M-D and D-D during the post-rest practice period. The curve is a decay function similar to curves found for the extinction of other habits. This supports hypothesis 5. These curves are similar to those found by Weaver in his study and the $_SI_R$ curve resembles those found by Kimble (4) using a considerably different method of derivation.

The use of 10-second measuring units within the 30-second work intervals permits further analysis of the performance not otherwise available. From Figure II it can be seen that the third 10-second unit of the first 30-second post-rest trial is higher than the first 10-second unit. Also the graph shows that in the case of the pre-rest 30-second trials the opposite relationship is true. The statistical analysis is given in Table 13. This finding confirms hypothesis 6 concerning the variable of warm-up.



Post-rest thirty second trials

Figure V. Theoretical extinction curve of ${}_{S}I_{R}$ in post-rest practice as based on 30-second trials

TABLE 13

MEAN DIFFERENCE BETWEEN FIRST AND THIRD 10-SECOND PERIODS FOR FIRST POST-REST 30-SECOND PERIOD FOR ALL GROUPS IN .01 SECOND

	All groups
Mean	57.95
Standard error of the mean	16.18
t	3.583
P	$< .01$

The results at this point are predicatable from the theoretical analysis of Hull (3), Ammons (1), and Kimble (4, 5) and are in basic agreement with the empirical findings of Ammons (2), Kimble (4, 5, 6), Kimble and Horenstein (8), and Weaver (11).

Still other observations are made possible using the 10-second unit of measurement as a basis for analysis. Figure II shows that reminiscence is present after the first 30 seconds of work in the distributed practice groups as indicated by the gain in performance level between 10-second units #3 and 4. The distributed groups continue to show considerable reminiscence over each succeeding 30-second rest while no such increases are evident in the massed practice groups. These results are in agreement with the findings of Weaver (11) upon which hypothesis 7 was based.

A comparison of the amount of reminiscence in the distributed groups between 10-second units #33 and 34 and between 10-second unit #36 and the first 10-second unit of the 12-minute post-rest practice period is made in Table 14. The last 30-second rest period was chosen for this comparison because the performance level at this point closely approximates that of the 5-minute rest interval.

TABLE 14

ANALYSIS OF VARIANCE OF REMINISCENCE SCORES OVER THE 30-SECOND AND 5-MINUTE REST PERIODS FOR THE DISTRIBUTED GROUPS

Source of variation	d.f.	Sum of squares	Mean square	F
30-Second vs. 5-minute rest	1	13,806	13,806	0.892
Groups with same interval	2	23,490	11,745	0.759
Total between groups	3	37,296	12,432	0.803
Error	60	928,707	15,478	
Total	63	966,003		

See footnote Table 3 for .01 and .05 F values

Hypothesis 7 is confirmed as Table 14 indicates no significantly different amount of reminiscence over the two rest periods.

The breakdown of the four groups into eight groups for the final practice period of 3 minutes is presented in

Figure VI. In the M-D-M group conditioned inhibition was built up in the first practice session and extinguished in the following distributed session. Because reconditioning is a rapid process, ${}_{S}I_{R}$ should build up quickly and consequently this group should show the greatest decline in performance of any group under massed practice in the third work period. This is evident from Figure VI and thus hypothesis 8 is substantiated. The characteristic post-rest hump phenomenon predicted and found by Ammons (1, 2) is also definitely observed in the D-M-D, M-D-D, M-M-M, M-M-D, and D-M-M groups.

In addition to supporting Ammons' notion of warm-up decrement (1), use of the 10-second unit has made possible three important findings. First, reminiscence in the distributed groups is not significantly less than that found in the massed groups over rest periods of the same length. This implies, among other things, that when measurement is made at the last 10-second unit before rest the difference in performance level between the distributed and massed groups is due entirely or almost entirely to the presence of ${}_{S}I_{R}$. Second, the distributed groups show reminiscence after the first 30 seconds of work in the pre-rest period. Third, in the distributed groups reminiscence over the 5-minute rest does not differ significantly from the reminiscence over the last 30-second rest period in the pre-rest practice session. Consideration of these points lead us to conclude in accord with Kimble (4) that there is a critical level to which I_R can rise. Also, the maximal

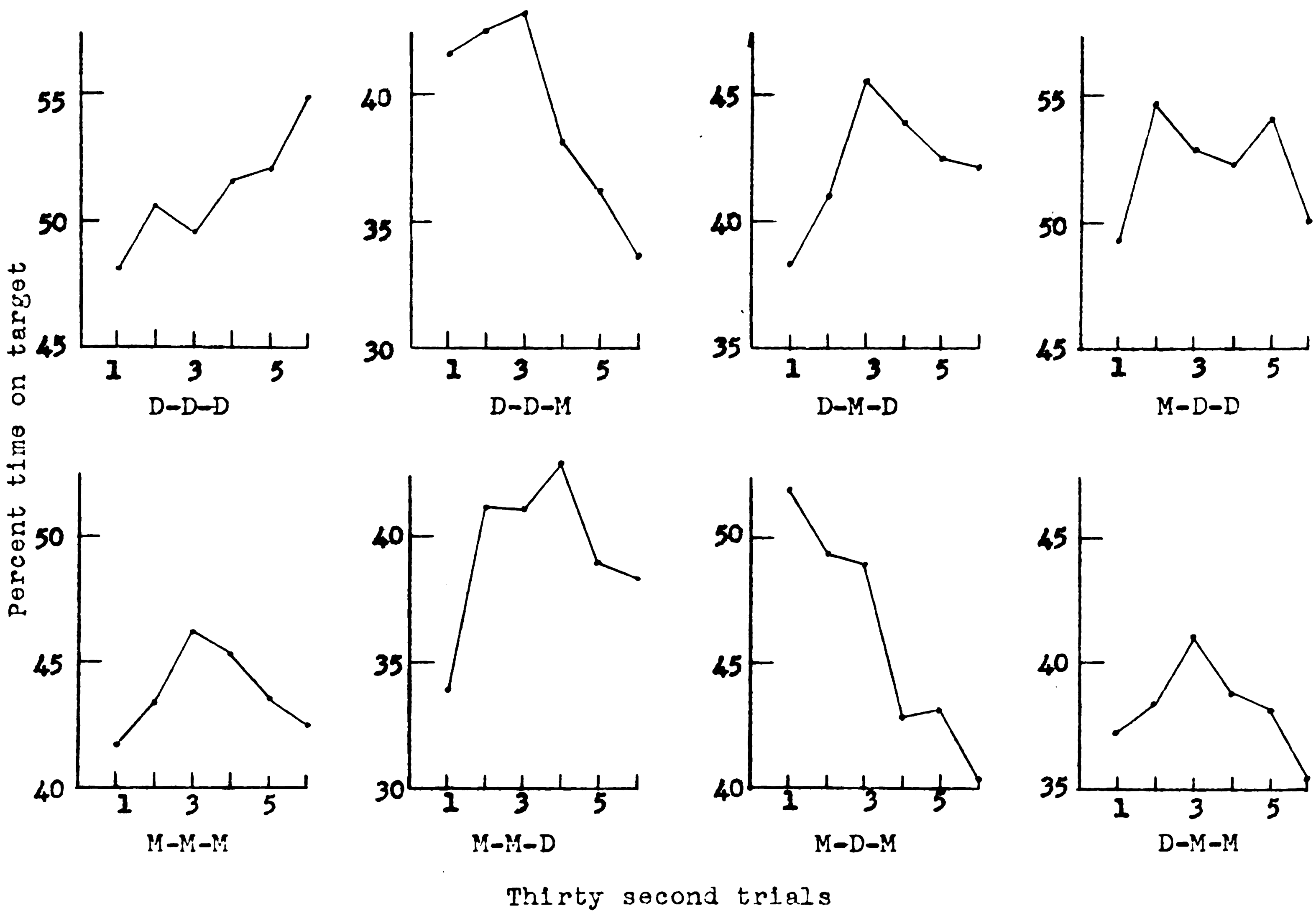


Figure VI. Performance curves for eight groups for the third (3 minute) practice session as based on the means of 30-second trials value of I_R possible under well distributed conditions is approximately equal to the maximal value possible under massed conditions. In other words, I_R builds up rapidly to this maximal level - in approximately 30 seconds; and with 30 seconds of rest shows almost complete dissipation.

Conditioned inhibition has been postulated to be a habit as defined by Hull (3). Consequently, curves of development and extinction of ${}_SI_R$ should resemble those of other habits. We have presented two curves showing the development of ${}_SI_R$ derived by different methods. The derived curve of extinction resembles that of other extinction curves and the expectation of rapid reconditioning is fulfilled. These various lines of independent evidence clearly substantiate the concept of conditioned or learned inhibition as postulated in the recent theoretical treatments of motor skills phenomena.

SUMMARY

Eight groups of 8 subjects each worked on the pursuit rotor task under alternate conditions of distributed and massed practice. The groups were: (1) massed-massed-massed, (2) massed-massed-distributed, (3) massed-distributed-massed, (4) distributed-massed-massed, (5) distributed-distributed-massed, (6) distributed-massed-distributed, (7) massed-distributed-distributed, and (8) distributed-distributed-distributed.

There were three practice sessions of 6 minutes, 12 minutes, and 3 minutes separated by two rest periods of 5 and 3 minutes, respectively. Massed conditions were continuous practice, while distributed conditions were alternately 30 seconds of work and 30 seconds of rest. The pursuit rotor disk rotated in a clockwise direction at a speed of 60 revolutions per minute.

The most important experimental technique involved measurement of performance in 10-second units of work within a 30-second work trial for the distributed practice groups.

Eight statements relating to the constructs of reactive inhibition, conditioned inhibition, and set were tested and confirmed. They are:

1. Pre-rest performance of groups under distributed conditions will be superior to that of groups under massed conditions.

2. More reminiscence will be present in the massed groups than in the distributed groups after an equal amount of rest.

3. In post-rest practice groups practicing under like conditions will converge and the distributed group's performance will be superior to that of the massed at the end of the period.

4. The developmental curve of conditioned inhibition will increase as a negatively accelerated (habit) function of the number of trials.

5. The extinction curve of conditioned inhibition will be a decay function similar to extinction curves of other habits.

6. On the first post-rest 30-second trial the performance on the third 10-second unit will be higher than on the first 10-second unit. The opposite relationship will be true in the pre-rest 30-second trials.

7. The amount of reminiscence displayed in the distributed groups over the last 30-second pre-rest interval will not differ significantly from that found over the 5-minute rest period for the same group.

8. The massed-distributed-massed group will show the most immediate and greatest decline in performance of any group working under massed practice in the third work period.

The conclusions regarding reactive inhibition were:

1. There is a maximal level to which reactive inhibition can rise which is approximately the same under distributed or massed conditions.

2. Reactive inhibition builds up to a maximal value in approximately 30 seconds.

3. Reactive inhibition dissipates almost completely in 30 seconds.

With regard to conditioned inhibition it seems that several independent lines of evidence substantiate the notion of a learned type of inhibition in motor learning.

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