THE EFFECTS OF MASSED AND DISTRIBUTED PRACTICE
UPON MOTOR PERFORMANCE AND LEARNING
IN GROUPS OF DIFFERENT INITIAL ABILITY

By

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ABSTRACT

An investigation was conducted to determine if the performance and learning of a pursuit rotor skill was a function of practice schedule and initial ability level. Two groups of 30 subjects each were given two consecutive days of practice, with 22 and 20 trials respectively, on the pursuit rotor under different schedules of practice. The performance score of the massed practice group (30 secs. work, 5 secs. rest) was found to be significantly lower than that of the distributed practice group (30 secs. work, 30 secs. rest) on the first day of practice. However, after 24 hours of interpolated rest, both groups were statistically equal in terms of the amount learned. A further analysis of the first day's performance scores of the 10 high initial ability and the 10 low initial ability subjects from each of the two main groups found no differential effect of practice schedule attributable to initial ability level. Further, there was no significant ability levels by practice schedules interaction for learning. However, reminiscence was found to be related to ability level as low ability subjects reminisced significantly more than high ability subjects.
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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

In a great deal of the experimental literature concerned with variables such as motivation, fatigue and distribution of practice and their influences upon motor performance and learning, there has been a gross neglect of a possible interaction occurring between individual differences and experimental variables of interest. The fact that little attention has been paid to individual differences as a quasi-independent variable in learning studies is probably attributable to the fact that workers in the field of learning have usually been interested in formulating general laws for behavior, with the implicit assumption being that these laws will hold throughout the range of learning ability. There is, however, little experimental basis for this assumption. In fact, it has been shown by Pew (57, 58) that this assumption does not hold for the temporal organization of the components of a continuous motor skill. He found that when subjects (Ss) had to control the position of a target dot on an oscilloscope by alternately switching between two keys, better control over higher levels of response organization were acquired earlier in training by Ss with an initially high ability level as compared with Ss of initially low ability. As a result of the high ability Ss' superior temporal organization of the response patterns (open-loop behavior), it appeared that, late in practice, these Ss were able to perform the crite-
rion task almost automatically. However, the strategy used by low abili-
ity Ss (closed-loop behavior) required much more concentration and thus
they were unable to attain the responding rate of the superior Ss. The
differences between these two groups resulted in quantitative and qual-
itative differences in performing the motor skill.

If individual differences in ability like those described by Pew
exist in other skills of a continuous nature, the question might be asked
as to what effect different practice schedules would have on differential
ability groupings in relation to performance and learning. Past investi-
gations (13, 24, 31, 69) into the effects that massed practice (MP) and
distributed practice (DP) schedules have on motor performance and lear-
ning have shown that MP, while considerably inhibiting performance had
little or no influence on learning. These studies showed that when a
rest interval was introduced, to allow for dissipation of fatigue that
resulted from MP, post-rest performance of the groups previously practi-
cing under massed conditions was nearly equal to groups that had pre-
viously practiced under distributed conditions. This occurred despite
the fact that the pre-rest performance of the MP groups was significant-
ly lower than the DP groups. However, a recent study by Marteniuk and
Carron (52) has found results contrary to these findings. While a MP
group performed just as well as a DP group on the first day of practice,
after 24 hours of interpolated rest, the MP Ss demonstrated significant-
ly greater amounts of learning.

An important consideration in the Marteniuk and Carron study was
the fact that they used a work-rest ratio for MP that was different from
the classical design used in distribution of practice studies. Past investigations (3, 13, 20, 24, 50, 66, 69) have utilized constant work intervals for MP and DP while differentiating between these groups in terms of the rest intervals. However, Marteniuk and Carron used constant rest intervals while the work intervals were varied. Thus, the results obtained by Marteniuk and Carron suggest that the issue in the study of the most efficient schedule of practice lies in the practice length rather than the length of the rest intervals, providing that the rest intervals allow for periodic dissipation of any inhibitory effects from previous practice. (52: 147)

Combining the fact that low-ability Ss are more likely to operate on a closed-loop basis with the fact that MP inhibits performance, Marteniuk and Carron (52) have suggested that, fatigue, especially a central-type of fatigue resulting from MP on the Pursuit Rotor, may interfere with the continuous monitoring behavior of the low-ability Ss to a greater extent than with the more automated behavior of high-ability Ss. Further, it was suggested that this central type of fatigue might influence the low-ability Ss' potential to learn a motor task in that it might inhibit the development of hierarchical processes. However, Marteniuk and Carron's results were contrary to their hypothesis in that the low-ability MP group learned considerably more than the low-ability DP group.

To follow up the above hypothesis, the present investigation has been carried out to see if the classical use of work-rest ratios might produce the effects that were hypothesized by Marteniuk and Carron (52).
The Problem

The purpose of the present study was to investigate the effects that MP and DP schedules have on the performance and learning abilities of Ss differing in their initial abilities on the Pursuit Rotor task.

Theoretical Expectations

On the basis of the theoretical formulations elaborated previously, two specific hypotheses will be investigated.

1. Concerning performance, the working hypotheses will be the following.

   a) Performance scores (PSs) for low-ability Ss under MP will be lower than the PSs for low-ability Ss under DP; the PSs for high-ability Ss under the MP schedule will be lower than the PSs for high-ability Ss under the DP schedule.

   b) Further, it is expected that the PSs for low-ability Ss under DP will be lower than PSs for high-ability Ss under MP. Also it is expected that total PSs (MP + DP) for low ability Ss will be lower than the total PSs (MP + DP) for high ability Ss.

Table 1 schematically summarizes these working hypotheses for the PSs by ranking the scores (1 is best) and comparing them on a relative basis.
TABLE I

SUMMARY OF THE THEORETICAL EXPECTATIONS FOR PERFORMANCE SCORES

<table>
<thead>
<tr>
<th>Group</th>
<th>Massed Practice</th>
<th>Distributed Practice</th>
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<tbody>
<tr>
<td>High Ability</td>
<td>2</td>
<td>&lt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Low Ability</td>
<td>4</td>
<td>&lt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
</tr>
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It is expected that fatigue build up during MP will depress performance when compared to performance under DP. The DP schedule is such that fatigue dissipates during the frequent rest periods and thus never reaches a level that affects performance.

2. Concerning learning the working hypotheses will be the following:

a) The learning scores (LSs) for low-ability Ss will be lower under MP than under DP. There will be no difference in the LSs of high-ability Ss for both the MP and DP schedules.

b) Further, it is expected that the LS for low-ability Ss under DP will be lower than the LS for high-ability Ss under MP.

Table II schematically illustrates the working hypothesis for the LSs in a manner similar to that followed for PSs.
TABLE II

SUMMARY OF THE THEORETICAL EXPECTATIONS
FOR LEARNING SCORES

<table>
<thead>
<tr>
<th>Group</th>
<th>Massed Practice</th>
<th>Distributed Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Ability</td>
<td>1 = 1</td>
<td></td>
</tr>
<tr>
<td>Low Ability</td>
<td>3 &lt; 2</td>
<td></td>
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</table>

Since closed-loop behavior, which especially characterizes low-ability Ss early in practice, is a conscious phenomenon probably requiring considerable concentration, learning should be adversely affected by the fatigue built up under MP as compared with DP. However, high-ability Ss working on open-loop behavior, which requires relatively little concentration when compared to Ss working on a closed-loop basis, should not be affected by MP and thus it is expected that no difference will occur between high-ability Ss working under MP or DP schedules.

Definitions of Terms

Massed practice. This is a practice schedule where the work periods on the criterion task are greater than the rest intervals. Since the rest interval is rather short, fatigue tends to accumulate and as a
result performance deteriorates.

**Distributed practice.** This is a practice schedule where the work periods on the criterion task are equal to or shorter than the rest intervals. Performance is at a maximum level at all times because it is assumed that no fatigue accumulates.

**Performance.** "This is the score received on a single discrete trial, or the average of a specific number of such trials during the testing or measuring period." (23:27) Performance refers to a momentary ability level that could not only reflect learning but also the temporary effects of fatigue, boredom or motivation. Thus when learning is inferred from performance all other variables that could inhibit or facilitate performance must be controlled.

**Learning.** "This is operationally defined as improvement in performance consequent upon practice." (23:27) In terms of the present study, learning is the acquisition of a hierarchical process in the organization of response patterns through practice. This implies that early in practice the learner executes each response as a separate unit, or on a closed-loop basis, waiting for the feedback (F) from a response (R) and then initiating a new response. (i.e. R→F→R→F→etc.) Later in practice the learner programs several responses together before using error feedback, thus working on an open-loop basis. (i.e. R₁→R₁→F₁→R₂→R₂→F₂→etc.)

Learning, as traditionally defined, is a relatively permanent change in behavior resulting from practice. (67:3)
Reminiscence. This is operationally defined as an improvement in performance over rest without overt practice. It is presumably due to the dissipation of reactive inhibition and/or fatigue which have accumulated during the practice session. (67)

Fatigue. In the present study, fatigue, reactive inhibition and performance decrement are used interchangeably. Practice under massed conditions results in poorer performance than practice under distributed conditions. There is some controversy as to whether performance decrement is actually due to a peripheral mechanism or to the inhibition of a central nervous mechanism. This issue, however, cannot be resolved in the present study.

Warm-up decrement. "... is defined as a sudden initial rise in performance after a rest." (35:350) The concept of warm-up implies that had the subject not lost his "set" during the rest (i.e. attitude toward the task or the posture adopted), his performance on the initial postrest trial or trials would have been better.

Ability level. "Abilities are variables postulated to account for individual differences in scores when experimental conditions are held constant." (49:536)

In the present study, relative ability level was determined by ranking individuals in terms of performance scores derived under controlled conditions.

Limitations of the Study

1. Sixty volunteer undergraduate physical education students
were used as subjects.

2. Only right-handed, naïve subjects were used.

3. Each subject was tested on two consecutive days but no attempt was made to control the subjects' activities during the interpolated rest.

4. The effects of changing the Day 1 MP schedule group to a DP schedule for Day 2 cannot be ascertained.

Delimitations of the Study

1. The only motor skill used was the pursuit rotor tracking skill at a speed of 60 rpm.
CHAPTER II

REVIEW OF THE LITERATURE

The first section of the following review of literature, describes prior research in motor learning related to practice schedule and its effects upon motor performance and learning. This review is mainly limited to those studies published since the major work of Ammons (6) in 1947. The second section of the review covers temporal organization in skilled performance and ability level.

Performance versus Learning

Theories concerned with the distinction between performance and learning. Current theoretical approaches to motor learning (6, 37, 50) based mainly on Hull's (29) work have distinguished between performance and learning. It has been demonstrated repeatedly with various verbal and motor tasks (13, 31, 59, 66, 69) that the performance curve, for MP Ss is depressed relative to the performance curve for Ss practicing under a DP schedule. However, these studies also have shown that if a long enough rest period is introduced, the post-rest performance level for the MP group improves to a level approximating the performance level of the DP group. Such an improvement over rest without overt practice is referred to as reminiscence.

Thus whether performance represents amount learned depends upon the presence or absence of certain performance variables. In particular, these include reactive inhibition, conditioned inhibition, reminiscence
and warm-up decrement.

Kimble (50), extending upon the Hullian concepts (29:122) of conditioning phenomena such as extinction and spontaneous recovery, has attempted to elaborate a theory that would account for the phenomena occurring under MP conditions. Kimble (50) stated that the consistent superiority of DP over MP during skill acquisition results from the MP producing a peripheral type of inhibition called reactive inhibition (Ir) which has the effect of reducing the work output of the performer. As a result of Ir buildup, a second decremental process identified as conditioned inhibition (sIr) is produced.

According to Kimble, Ir is essentially a negative drive which resembles fatigue. It is temporary in nature and dissipates with rest. However, if the voluntary rest intervals imposed by the experimenter during the practice schedule are too short to allow for the dissipation of the majority of the accumulated Ir (as in the case of MP), then Ir continues to accumulate and greater need to rest develops. At this point an involuntary rest pause occurs, performance decreases, and part of the Ir dissipates, causing a need, reward, or reinforcement. This reinforcement produces a habit of not responding called sIr. Since sIr is a habit, and thus permanent, it is unaffected by the rest periods introduced in the practice schedule and still operates to depress performance when learning is resumed following an interpolated rest period.

This two-factor theory (i.e. Ir and sIr) of inhibition elaborated by Kimble has been extensively used in the literature to explain temporary and permanent decrement in studies dealing with the relative efficiency
of MP and DP upon motor performance and learning. However, this theory has been subject to criticism for its failure to account for the specific post-rest phenomena which characterized the post-rest performance curve for the MP group. These post-rest phenomena identified by Ammons (6) include: (1) a sharp initial rise (warm-up) in the performance curve, which is followed (2) by a relative decrement, and then (3) a resumption of the initial rise. Further, it has been shown by Adams and Reynolds (3) that permanent work decrement (sIr) is not really permanent. Shifts from massed to distributed practice leads to shift in performance such as to make the performance of the shifted group resemble the performance of the other group until there is actually no difference between the two groups. Similar findings have been reported by Archer and Willig (14), Denny, Frisbey and Weaver (30) and Reynolds and Adams (62).

Eysenck (37), in a thorough review of the literature dealing with this two-factor theory of inhibition presents some evidence that argues against the inhibition theory postulated by Kimble (50). Using Kimble's formulation, Eysenck (37) prefers to explain Ir as the result of a central type of fatigue rather than the peripheral type that Kimble has postulated. Thus Eysenck related the amount of inhibition to the duration of continued attention required by the task (i.e. a "mental work" hypothesis rather than a "physical" one). Evidence for the existence of reminiscence effects in almost purely perceptual task (11) and studies of bilateral transfer effects (10, 42), further serve to discredit the peripheral hypothesis. To explain the "mental work" hypothesis, Welford (72:260-262) states that the presence of fatigue or Ir would imply some temporary central impairment either caused by local neural impairment
where groups of nerve cells concerned with performance become insensitive or by an increase of "neural noise" where fatigue resulting from the accumulated after-effects of stresses and annoyances would cause overactivity in the brain or parts of it.

To close the discussion on the nature of Ir, Ammons and Ammons (12) after twenty years of research dealing with the problem have concluded that temporary work decrement is partially central in nature and seems to affect skilled performance by causing a partial distortion or disintegration of habits through a kind of filtering process. Thus according to Ammons and Ammons, Ir would be more related to a perceptual problem where the S perceives the wrong cues instead of the proper ones which are necessary to perform the task properly.

Although the information presented here does not offer any final solution concerning the nature of temporary work decrement, it does clarify in more precise terms, Kimble's two-factor theory of inhibition.

Experimental studies concerned with massed vs. distributed practice. Singer (66) investigated the effects of massed and distributed practice upon the performance and learning of a novel basketball skill. The skill involved bouncing a ball off the floor into a basket. One hundred and twenty male Ss were divided into 3 groups of 40 Ss each and each group was assigned to MP or DP conditions. One group continuously attempted 80 shots at the basket while a second group paused 5 min. after each 20 continuous attempts and a third group rested 24 hr. between each of the four sessions. An analysis of variance for performance scores upon completion of practice and for learning scores after a 24 hr. inter-
polated rest period revealed that the most DP schedule (the 24 hr. rest group) performance was statistically superior. However in terms of learning no significant differences between groups were found.

The efficiency of two practice schedules on two large muscle motor tasks (stabilometer and ladder climb) was examined by Stelmach (69). One hundred and sixty subjects divided into four groups were assigned to one of the two motor-tasks under one of two practice schedules. Distributed practice consisted of a work-rest ratio of 30 sec. work- 30 sec. rest; MP was continuous for 8 minutes. Comparisons made during the last minute of practice prior to a major rest pause revealed that the MP group showed a significant decrement in performance level. In contrast, when practice was resumed under a DP schedule, following 4 min. of interpolated rest, no difference was found in the amount learned. The findings applied to both the stabilometer and the ladder climb.

An unpublished study by Pouliot (59) found results similar to those of Stelmach's. Fourteen male students were evenly divided into MP and DP conditions for learning a pursuit rotor skill. It was found that the DP group (20 sec. work, 30 secs. rest) performed significantly better (p<05) than the MP group (20 secs. work, 0 sec. rest) prior to a 10 min. rest period allowed at the end of session one. However, after the interpolated rest, no statistical difference was found between the performance scores of the two groups.

Carron (23) using the peg turn apparatus, which is a discrete motor task, involving a short linear movement, tested 300 male Ss under two different highly massed schedules and three different distributed
schedules. The results support the hypothesis that while increasing the amount of massing does have a deleterious effect on performance, it does not reduce the amount learned.

On the other hand, a recent investigation by Marteniuk and Carron (52) has presented findings contradictory to the above findings. One hundred volunteer university females were assigned randomly to either a MP or DP schedule. Both groups performed 15 trials on each of 2 successive days (24 hr. rest was allowed between the two sessions) on the Pursuit Rotor. Massed practice on the first day had a work-rest ratio of 40 secs. work, 20 secs. rest. On Day 2, the MP group practiced under the same work-rest ratio as the DP group (20 secs. work, 20 secs. rest). On Day 1, it was found that the MP group performed just as well as the DP group with a substantial portion of the MP group's scores being superior to those of the DP group. Following the 24 hr. interpolated rest, the MP Ss demonstrated significantly greater amounts of learning on Day 2. The results obtained here for performance scores and learning scores contradict past investigations. It would seem that the difference in methods of distributing practice may have been a contributing factor in yielding these results. In fact, the schedules used were different from the schedules used in traditional methods of distributing practice where the intertrial rest is varied and the work interval is kept constant. The authors concluded that "the relevant issue in the study of the most efficient schedule of practice is not whether or not fatigue is present during performance but whether there exists some optimum practice length after which there occurs maximum benefits from an interpolated rest". (52:147)
Temporal Organization and Hierarchical Control in Skilled Performance.

The following review of literature dealing with skilled performance and its temporal organization has the purpose of attempting to present a general view of the acquisition of skilled performance. In so doing it is hoped that the reader will better understand the problem and the theoretical expectations of the present study as stated in Chapter One.

In an attempt to understand skilled motor performance and learning, several researchers (39, 40, 56) have formulated theories explaining the organization of the mechanisms responsible for the execution of skilled behavior. The effector system as seen by these models executes a sequence of commands issued by the central decision mechanisms. In essence they explained how the responses of an individual are precisely matched to the task and to the dynamic properties of body and limbs. It is assumed that all the information necessary to perform a motor task, having been acquired through practice and past experiences, are directed by effector programmes. Most of this information according to Crossman (28:35), is held in a permanent store built up during the acquisition of various skills. Further, it would seem that his information which is stored and responsible for the control and coordination of muscular movement is organized in a hierarchical manner as advanced by Lashley (51), Miller, Galanter and Pribram (56), and Hearnshaw (43).

To best describe how skilled performance is organized in man and by extension, how the effector mechanism operates, Fitts (40, 41)
has made an analogy to a computer. According to Fitts, information necessary to perform a particular skill is selected and governed by a program or sequence of instructions. These short, fixed sequences of instructions or operations are written as subroutines which may be called into play by an overall program which controls a particular motor activity. These subroutines may be repeated over and over again until some predetermined point is reached or until it is interrupted by the overall program. The executive program provides the overall logical or decision framework that gives the system its flexible and adaptive characteristics.

Learning, then, as seen by Fitts would involve a new integration and ordering of these fixed subroutines, many of which may be transferred as a whole from other activities. (41:10-11) Crossman (28) has pointed out that the basic skills or subroutines are acquired piecemeal during the lengthy period of trial and error behavior in childhood.

This account of skill acquisition gives an overall view of the sequential and hierarchical organization of skilled performance. In essence the basic subroutines are at the lowest order of organization, while higher level programs or plans can modify the lower ones on the basis of accumulated information acquired from past experiences.

Support for viewing behavior as involving temporal and hierarchical organization has come from Woodworth (76) when he pointed out that behavioral activities are frequently organized in two or more stage. In a well determined activity, like the golf swing for instance,
each part, such as the grip, the stance, the backswing, etc., may be identified as a stage. These stages or subroutines represent a hierarchy of motor units oriented towards a specific goal.

One of the first studies to investigate this temporal organization in skilled learning was the classical work of Bryan and Harter (21, 22). Their papers contained the first known records of learning in sending and receiving Morse Code. The learning curves for receiving Morse Code showed that one acquires a hierarchy of habits. According to these results, Bryan and Harter (22:356) concluded: "... that the telegrapher must acquire besides letter, syllable and word habits, an array of higher language habits, associated with the combination of words in connected discourse. Mastery of the telegraphic language involves mastery of the habits of all orders." This means that letters must first be mastered, then syllables and words, and finally, phrases and sentences. Further, it appeared that mastery of the higher-order habits depended on the mastery of the lower-order ones. To receive sentences, that is, one must first have acquired the component word-habits; to receive words, one must have acquired the letter-habits.

Further evidence for the building up of sequences of action into higher units of performance has also been provided in an experiment by Book (19) concerned with learning to typewrite. The stages in learning to typewrite by the "touch method", with the keyboard concealed by a screen were as follows: Early in learning, the Ss acquired the letter-habits where one letter at a time was struck, and the response checked for its accuracy. Later on, the word-habits were acquired. Now that
each letter and its place on the keyboard had been learned, the Ss were able to program and execute a series of letters together without interruption. This enabled them to type a series of words at a faster rate. Finally, a continuous sequence of words or even a phrase was struck as an entity without interruption. In other words, as the typist became skillful, she took words and phrases as a single complex response.

(54:66-67)

Control of details by broader aspects of performance was further illustrated in a series of experiments by Pew (57,58) whose Ss attempted to control position of a target dot on an oscilloscope by alternately switching between two keys. When the left-hand key was depressed, the target accelerated to the left. When the right-hand key was pushed the target decelerated, reversed direction, and accelerated to the right. The S's task was to keep the target dot as near the centre to the screen as possible for the duration of each trial. Accurate performance demanded a rapid alternation between the two keys.

Pew noted that the strategies used in dealing with this task could be divided into three types. Early in training, the simplest, but least effective, was to observe the effect of pressing each key before pressing the other; this resulted in a series of large overshoots. Pew classified this particular strategy as a "closed loop" mode of operations in which the student responded, waited for feedback about the results of this response, and then initiated a new response the intent of which was to compensate for the inadequacies of the previous one. Pew (57,58) called this mode of responding "closed-loop" behavior. A second strategy,
used late in practice, occurred when the student utilized error feedback over a longer time span which Pew (57,58) called "open-loop" behavior. The third strategy again involved pressing the keys alternately in rapid succession but adjusting the intervals between each response so that the spot remained approximately at the center of the target. With this mode, identified as a modulation-mode, there were no pauses for corrections. It involved a continuous modulation of the inter-response time. Thus the S appeared to observe and control not instantaneous target position, rate, or acceleration, but the mean result which was achieved by a sequence of responses. The Ss using this kind of responding-mode imposed a pattern of timing upon their performance which ordered the individual actions so as to maintain a uniform overall result. (57:53) This introduction of higher-order control meant that the S was able to organize a sequence of responses at a higher level, taking into account the effects of more than one response at one time.

Finally, Ammons (9) investigated the temporal patterning of the contacts or "hits" for the Pursuit Rotor under different distributions of practice. According to the author, a simple time on target is not sufficient to study the nature of the rotary pursuit response and its acquisition. The purpose of the study was to determine the effects of distribution of practice upon performance in rotary pursuit as measured by the number of hits, variability in number of hits, mean duration of hits, variability in mean duration of hits, mean duration of misses, and variability in mean duration of misses. Due to the fact that twelve to fifteen hours were required to read and evaluate each record, only
10 Ss per group were used. The massed group was given 36 trials of 22 secs. duration without a rest between trials while the distributed group rested 5 min. between each pair of 22 sec. trials. Results indicated that the mean duration of hits showed a negatively accelerated increase during practice for both groups. The number of hits and mean duration of hits was greater for the DP group than for the MP group. Finally, mean duration of misses were less during DP, decreasing quickly to a stable minimum of about 4 secs.\(^1\) Ammons concluded that the hit indices permitted clear differentiation between performance under MP and DP schedules. In terms of temporal organization, this study showed that Ss learn to make longer and longer unbroken sweeps and to correct more quickly for deviations from these movements which would take him off the target. Thus, Ammons maintained that the Ss learned to make longer and longer sweeping type movements of both eyes and the tracking hand and that they also learned to correct "errors" in a shorter time, both because they were sensitive to more cues than initially and because they had learned more efficient corrective movements. Improvement took place because the Ss were able to make longer and longer movements without direct "voluntary" control. (9:21)

\(^{(1)}\) A miss roughly represents the duration of a combination visual and kinesthetic reaction time to the start of a movement of the stylus tip off the target plus the duration of the corrective movement. It appeared that this adjustment could not be made, on the average, in less than about .4 sec. It is interesting to note that Craik (25,26) and Vince (71) found that it took from .4 to .5 sec. to make similar corrections during linear tracking.
In summary of this section it can be stated that commands responsible for the execution of movement are issued by the central mechanisms, and are directed by stored effector programmes. These commands comprising the effector programmes have been stored through learning and are organized in a hierarchical manner. The acquisition of higher response patterns, such as open-loop mode and modulation mode is based on the fact that basic subroutines involved in movement are automatically executed. Further, Welford (71:194) points out that the level at which awareness is centered should rise as the operator becomes more expert and masters larger and larger units. Thus performance tends to become stereotyped in the course of practice, and the whole cycle can be run off very much as a chain response with each member acting as the cue for the one that follows. At this performance level, it is possible to organize a sequence of action without immediate feedback so that performance is essentially anticipatory and ballistic. This has been verified by Pew (57,58) when he found that Ss were able to free themselves from the need of continuously monitoring the most elementary parts of their own performance and thus were able to exert control over larger sets of responses at the higher level of organization.(57:70)

Ability Level and Performance

When individual differences in the acquisition of a psychomotor response are studied, one question arises: What is the nature of the acquisition curves for Ss having different levels of initial ability in the task? This question bears on such problems as the interaction between ability measures and learning variables, and what might be expected in the training of Ss differing in initial ability in a task.
In an extensive study, Reynolds and Adams (2, 63) investigated the interaction between individual differences and distribution of practice on the Pursuit Rotor. Nine-hundred and sixty Ss were assigned in equal numbers to either DP or MP schedules and were trained under these schedules throughout three or four sessions respectively, with each session consisting of twenty trials. The duration of each trial was 20 secs. for both groups. The intertrial rest was 5 secs. for the massed group and 60 secs. for the distributed group. There was a 30 min. rest between sessions. Upon completion of the study, Ss within each experimental group were stratified into deciles on the basis of their cumulative scores for the first five trials. Thus 10 subgroups were obtained for each practice schedule.

Total group comparisons showed that the curves obtained under the two conditions of practice distribution were similar to those usually observed with MP and DP on the rotary pursuit test.

Comparisons between performance curves were then done among subgroups for each practice condition. In other words, performance curves for low and high deciles under MP conditions were compared for differences in their slopes throughout each session. The same was done for low and high deciles under DP conditions. Within each group, under both MP and DP, the initial slope in the first session appeared to be much steeper for high-ability Ss than the low-ability Ss. In other words, greater improvement took place during the early trials for Ss having initially a high-ability level. Under MP, the curve for the lower decile tended to be linear in form with a slow rate of rise.
throughout. The curve for the highest decile showed rapid increases initially, and then essentially zero slope. Under DP, the curves differing in slope-constants were essentially the same as in the case of MP. The combined curves for the two main groups were quite representative of the curve for each of the deciles. Finally, the mean curves were essentially parallel in the final session, with little tendency to converge. It appeared that all Ss did not attain the task-assymptote but rather attained an assymptote commensurate with their own ability.

The results of this study are consistent with those of Farmer (38) who showed parallel performance curves for groups of different initial ability and supports the assumption of Hull (45) that individual differences affect the constants of a behavioral equation but not the general mathematical form.

The relationship between certain measures of ability and the acquisition of a four-unit discrimination reaction time test (where speed of an arm-hand response to a visual discrimination is measured) has been investigated by Adams (5). Eight hundred and sixty Ss were tested and all Ss performed 160 trials continuously. The Ss were stratified into deciles on the basis of their score on trial one. The performance curves indicated that generally the deciles maintained their initial rank order throughout training. The curve for the lowest decile showed a great deal of improvement early in training. As the level of initial ability increased, the performance curves tended to be linear throughout practice. The 10 curves obtained were essentially parallel in the final trials and there was little indication that they
were going to eventually converge to a common level since each group appeared to be approaching its own asymptote. A certain number of initially poor Ss in decile one made a transition to the level of initially proficient Ss (decile 10) as training progressed. As a matter of fact, by trial 16, a substantial number of decile one Ss were equal or superior to the performance of decile 10 Ss.

The findings of this study are similar to those of Reynolds and Adams (2, 63). However, it is difficult to interpret these results in terms of performance and learning since practice was continuous and only included a single session.

The results obtained by Reynolds and Adams (2, 63) and Farmer (38) are consistent with Hull's (45) postulate that all individuals behave the same way, in a given condition, according to a set of established primary laws which are expressed under the form of an equation (that is: \( E_r = H_r \times D \)). Further, Hull postulated that Ss with innate differences, mostly due to differences in past experiences, will behave according to the general laws established while only the constants of this general law will be affected.

A recent investigation by Marteniuk and Carron (52), which was discussed previously (p. 14) in this chapter, looked at the effect of MP and DP upon pursuit rotor performance and learning in groups of different initial abilities and found results somewhat different to those discussed above. Marteniuk and Carron formulated the following hypothesis:
If individual differences in ability, ... exist in other skills of a continuous nature, then the question might be asked as to whether schedules of practice which differ in their work-rest ratio differentially affect low and high-ability Ss in relation to performance and learning. ... if it can be assumed that low-ability Ss are more likely to operate on a closed-loop basis early in practice, then fatigue, especially a central type of fatigue that results from MP on the pursuit rotor, could interfere with this continuous monitoring behaviour to a greater extent than with the more automated behaviour of high-ability Ss. It might also be expected that fatigue would influence the low-ability Ss' potential to learn a motor task in that the presence of fatigue would inhibit the development of hierarchical processes. (52:141)

To test this hypothesis, the mean of the first two trials performed under a DP schedule was used to divide, within each group, the MP and DP groups into low and high-ability subgroups of 15 Ss each. Upon completion of the practice sessions, an analysis of variance revealed a significant ability level by practice schedule interaction late in practice. It appeared that the low-ability Ss under the MP schedule learned more than the high-ability Ss under MP when compared to the corresponding scores of the two DP groups. Of interest was the fact that late in learning the performance curve for the low-ability MP subgroup was essentially equal to that of the high-ability DP group. The greater learning of the low-ability Ss under MP was not expected and could not be explained. However, these results are consistent with findings reported by Reynolds and Adams (63) and Adams (5) when they observed throughout their study that a substantial number of initially low-ability Ss performed, late in practice, as well as high-ability Ss. Adams (5) has suggested that this transition may be caused by the fact that some Ss have low initial status because of lack of prior experiences in one or more extra-experimental situations. When given the opportunity to practice, however, a
number of these initially poor Ss achieve a performance level that is equal to or superior to that of initially proficient Ss because of rapid acquisition rates and/or because of possession of a high level of one or more factors necessary to perform the task.

In summary, it has been shown that differing results have been obtained when individual differences were employed as a quasi-independent variable in learning studies. Reynolds and Adams (63) have concluded that general laws of learning based on sample statistics hold throughout the range of learning ability. Farmer (38) showed parallel performance curves for Ss differentiated on the basis of their initial level of ability. Pew (58) on the other hand had demonstrated a different temporal organization, developed through practice, for Ss with different initial ability levels. Several studies (5, 33, 73, 77) have shown a tendency for groups of different initial abilities to become closer at the end of practice without converging. One exception to these findings was Marteniuk and Carron's (52) study where a low-ability MP group demonstrated learning that was superior to a high-ability group trained under DP. These results were obtained, however, by using a distribution of practice schedule different from conventional methods of distributing practice. In fact Marteniuk and Carron varied the work interval while keeping the rest interval constant when, conventionally, the work interval is kept constant and the rest interval varies. From these findings, then, it appears that further research dealing with individual differences and practice schedules is warranted.
Subjects

Sixty volunteer right handed male Ss with a mean age of 21.77 years (SD = ± 2.88 yrs.) were used. The Ss were students enrolled in physical education classes at the University of British Columbia and were naive to the Pursuit Rotor apparatus. They were randomly assigned to either a MP or a DP schedule with the restriction that equal numbers appear in each group.

Practice Schedules

Distributed practice. The DP schedule used was based on a work-rest ratio of 30 sec. work-30 sec. rest.

Massed practice. The MP schedule used was based on a work-rest ratio of 30 sec. work-5 sec. rest.

Experimental Design

A summary of the experimental design is presented in Table III. Both the MP and DP group performed 22 trials on the Pursuit Rotor on Day 1 of the experiment. The first two trials were performed under the DP schedule for both MP and DP groups, in order to have a supposedly true score of the Ss' initial abilities. It was assumed that this score was free from any inhibitory effects such as fatigue or boredom. These two trials were followed by 30 secs. rest. The next 20 trials were performed under the MP or the DP schedule depending on which experimental
### TABLE III

**SUMMARY OF THE EXPERIMENTAL DESIGN**

<table>
<thead>
<tr>
<th>GROUPS</th>
<th>INITIAL (^1) SCORES</th>
<th>PERFORMANCE SCORES</th>
<th>FINAL SCORES (^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP</td>
<td>Two trials</td>
<td>Twenty trials</td>
<td>Twenty trials</td>
</tr>
<tr>
<td>1. High Ability</td>
<td>-30 secs. work</td>
<td>-30 secs. work</td>
<td>-30 secs. work</td>
</tr>
<tr>
<td>2. Low Ability</td>
<td>-30 secs. rest</td>
<td>-30 secs. rest</td>
<td>-30 secs. rest</td>
</tr>
<tr>
<td>MP</td>
<td>Two trials</td>
<td>Twenty trials</td>
<td>Twenty trials</td>
</tr>
<tr>
<td>1. High Ability</td>
<td>30 secs. interpolated rest</td>
<td>-30 secs. work</td>
<td>-30 secs. work</td>
</tr>
<tr>
<td>2. Low Ability</td>
<td>30 secs. interpolated rest</td>
<td>-30 secs. rest</td>
<td>-30 secs. rest</td>
</tr>
</tbody>
</table>

1. The initial scores were the means of the first two trials on Day 1.
2. Two final scores were computed:
   - final score 1 was the mean of the first two trials on Day 2,
   - final score 2 was the mean of the last two trials on Day 2.
group the S was in. The performance scores (PSs) used for comparison purposes were the average of the last two trials on Day 1.

On Day 2, following an interpolated rest of approximately 24 hrs. that permitted total dissipation of the "fatigue" accumulated during the previous day's practice, all Ss performed 20 trials under the DP schedule. Again it was assumed that performance at this stage would represent "true" performance in that no inhibitory effects would be present.

Two final scores for each group were calculated: One was the average of the first two trials on Day 2 ($FS_1$), and the other was the average of the last two trials on Day 2 ($FS_2$). The relative amount of inhibition built up during Day 1 performance was determined by the reminiscence score (RS) which was the difference between $FS_1$ and PS.

Ability Grouping

Upon completion of the practice sessions, the mean of the first two trials on Day 1 was used to determine the initial ability (i.e. the initial score -IS) of each S. The Ss from each group were then divided into two subgroups on the basis of their ISs. Those with the 10 lowest scores were assigned to the low ability group and those with the 10 highest scores to the high ability group. Thus there were four groups of 10 Ss each, a low and a high ability group that practiced under MP conditions and two similar groups that practiced under DP conditions.

Apparatus

The pursuit rotor. The learning task was the Pursuit Rotor (Figure 1). This apparatus had been purchased from the Lafayette Instrument
Co. - model 2203 - and consisted of an electrical turntable mounted on a wooden frame. The turntable of the rotor, covered by black formica, had a 25.5 cm. diameter and contained, flush to the turntable, a metal target 1.9 cm. in diameter and situated 8.3 cm. from the center of the turntable. The rotation of the turntable was set at 60 rpm. A spring loaded brass stylus was attached to a wooden handle and was connected to the rotor. When contact was made between the stylus and the metal disk, a circuit was closed and a timer activated. When the stylus was not in contact with the disc, the timing circuit was open. The turntable revolved in a clockwise direction and was situated 88 cm. from the floor.

The timer. A Klockcounter - model 120A - made by Hunter Mfg. Co. was employed. It recorded the time on target to 1/100 of a second.

Procedures

The instructions for performing the Pursuit Rotor (see Appendix A) were read by each S before performing the task. The S was then asked to verbally explain the procedures to the experimenter (E) and to feel free to ask questions. However, only questions dealing specifically with the task were answered. Questions dealing with the purpose of the task or length of the trials or rest periods were not answered. On the second day of testing, the E briefly reviewed the instructions with each S.

On the first day of testing the Ss, standing in front of the apparatus, were told to hold the stylus handle lightly in the right hand with a tennis-type grip which was then demonstrated. They were then told that the object of the task was to track the metal disk by keeping the metal
stylus in contact with it for as long as possible during each trial and that the timer would record the amount of time spent on the target. They were warned that the tracking movement should be done with an easy, relaxed swinging movement of the arm and that no extra pressure should be put on the stylus tip in any way. Performance deviating from these instructions during the experiment was corrected verbally. For the start of each trial, the Ss held the stylus tip on the right side of the turntable at an angle of $180^\circ$ from the target. When the turntable was started by E, the Ss were instructed to hold the stylus stationary until the disk came around to it, at which time they started to track the target. At the end of the trial, E called "STOP", the Ss then had to raise the stylus as fast as possible, put it down beside the rotor, turn the turntable off by flipping the starting switch, and then return the disk to its starting position. The S then turned his back to the apparatus and verbally counted backwards from a given number (from 1000 to 100) by threes until the "GET READY" signal was again given at which time S again put the tip of the stylus on the right side of the turntable, $180^\circ$ from the target.

The Ss were asked to perform their best at all times. No pre-practice on the task was allowed. No knowledge of results were given during the experiment and the Ss were never allowed to see the clock or their recorded scores.

Statistical Analysis

An analysis of variance was employed to determine if there were any differences between the total MP and DP groups for ISs, PSs, and FSs:
Each analysis of variance partitioned the total sum of squares into a main effects of Practice Schedules and an error term of Subjects within Practice Schedules.

To test differences among the subgroups in relation to the ISs, PSs, FSs and RSs, an analysis of variance for a factorial design was utilized. This design resulted in obtaining the two main effects of ability levels and practice schedules as well as the interaction between these two variables.
RESULTS AND DISCUSSION

Results

**Probability Level.** For all statistical analyses, a 5% level of significance was used.

**Total Group Comparisons.** The mean performance curves for MP and DP conditions over the two practice sessions are presented in Fig. 2. Both groups exhibited considerable differences in the form of their curves on Day 1 of practice. While the performance curve for the DP group is negatively accelerated, the curve for the MP group shows a very rapid improvement during the early trials, levels off in later trials, and then begins to rise very slowly. These curves are similar to those usually obtained with MP and DP schedules on the rotary pursuit task (6). There was, in the case of DP, a small loss in proficiency at the start of session two. The MP group shows considerable reminiscence and an initial post-rest warm-up effect.

The means and standard deviations for the MP and DP groups for the various conditions are listed in Table IV.
FIGURE 2: Performance curves of the MP and DP groups on the pursuit rotor for the practice sessions on Day 1 and Day 2 (N = 30 in each group).
TABLE IV

MEANS AND STANDARD DEVIATIONS IN SECS. OF THE TWO MAIN GROUPS

FOR THE VARIOUS CONDITIONS (N = 30 Ss in each group).

<table>
<thead>
<tr>
<th>GROUPS</th>
<th>PERFORMANCE SCORE IS</th>
<th>PERFORMANCE SCORE PS</th>
<th>FINAL SCORE 1 FS₁</th>
<th>FINAL SCORE 2 FS₂</th>
<th>REMINISCENCE SCORE RS</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTRIBUTED</td>
<td>Mean 5.25</td>
<td>17.78</td>
<td>18.33</td>
<td>22.17</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>S.D. 3.58</td>
<td>4.44</td>
<td>2.83</td>
<td>3.27</td>
<td>3.20</td>
</tr>
<tr>
<td>PRACTICE</td>
<td>Mean 6.34</td>
<td>12.53</td>
<td>16.80</td>
<td>22.07</td>
<td>4.27</td>
</tr>
<tr>
<td></td>
<td>S.D. 3.31</td>
<td>3.17</td>
<td>2.34</td>
<td>2.71</td>
<td>2.77</td>
</tr>
</tbody>
</table>

Table IV shows that the IS for the MP group was somewhat above that of the DP group. An analysis of variance revealed that this difference was not significant (Table V).

TABLE V

ANALYSIS OF VARIANCE FOR THE INITIAL SCORE

<table>
<thead>
<tr>
<th>SOURCE OF VARIATION</th>
<th>df</th>
<th>MEAN SQUARE</th>
<th>F</th>
<th>PROBABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRACTICE SCHEDULES</td>
<td>1</td>
<td>17.97</td>
<td>1.51</td>
<td>&gt; .05¹</td>
</tr>
<tr>
<td>SUBJECTS within PRACTICE SCHEDULES</td>
<td>58</td>
<td>11.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹. An F-ratio of 4.02 was required for significance.
Table IV and Fig. 2 show that the mean PS of the MP group is considerably smaller than the corresponding score of the DP group. An analysis of variance (Table VI) showed that this difference was significant.

### TABLE VI

**ANALYSIS OF VARIANCE FOR THE PERFORMANCE SCORE**

<table>
<thead>
<tr>
<th>SOURCE OF VARIATION</th>
<th>df</th>
<th>MEAN SQUARE</th>
<th>F</th>
<th>PROBABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRACTICE SCHEDULES</td>
<td>1</td>
<td>143.62</td>
<td>27.81</td>
<td>&lt; .05&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>SUBJECTS within</td>
<td>58</td>
<td>14.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRACTICE SCHEDULES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. An F-ratio of 4.02 was required for significance.

A further examination of these PSs indicated that the DP group was on target 41.9<sup>2</sup> more than the MP group.

Following the 24 hrs. interpolated rest, performance of the two groups appeared to be relatively equal (Table IV and Fig. 2), except on the first trials where a certain amount of warm-up decrement was observed. As a result, a significant difference between DP and MP was found between the groups for FS<sub>1</sub> (Table VII) with the DP's FS<sub>1</sub> being greater than that of MP.

(2) The superiority of one group over an other group in % is equal to:

\[
\text{greatest score} - \text{lowest score} \times \frac{100}{\text{lowest score}}
\]
TABLE VII

ANALYSIS OF VARIANCE FOR FS₁

<table>
<thead>
<tr>
<th>SOURCE OF VARIATION</th>
<th>df</th>
<th>MEAN SQUARE</th>
<th>F</th>
<th>PROBABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRACTICE SCHEDULES</td>
<td>1</td>
<td>34.98</td>
<td>5.15</td>
<td>&lt; .05¹</td>
</tr>
<tr>
<td>SUBJECTS within</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRACTICE SCHEDULES</td>
<td>58</td>
<td>6.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. An F-ratio of 4.02 was required for significance.

By the end of the second day of practice, however, the difference between these groups disappeared. An analysis of variance on FS₂ (Table VIII) revealed that the Ss in both groups learned the same amount in that a nonsignificant F was achieved.

TABLE VIII

ANALYSIS OF VARIANCE FOR FS₂

<table>
<thead>
<tr>
<th>SOURCE OF VARIATION</th>
<th>df</th>
<th>MEAN SQUARE</th>
<th>F</th>
<th>PROBABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRACTICE SCHEDULES</td>
<td>1</td>
<td>0.15</td>
<td>0.02</td>
<td>&gt; .05¹</td>
</tr>
<tr>
<td>SUBJECTS within</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRACTICE SCHEDULES</td>
<td>58</td>
<td>8.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. An F-ratio of 4.02 was required for significance.
Subgroup Comparisons. Figure 3 presents the performance curves throughout the training sessions for the 4 subgroups trained under either the MP or DP schedules. The performance curves appeared to have the same general characteristics as those obtained for the total MP and DP groups.

The ISs, PSs, FSs and RSs obtained for each subgroup are listed in Table IX.

**TABLE IX**

MEANS AND STANDARD DEVIATIONS IN SECS. OF EACH SUBGROUP

FOR THE VARIOUS CONDITIONS (N = 10 Ss in each group)

<table>
<thead>
<tr>
<th>GROUPS</th>
<th>INITIAL PERFORMANCE SCORE</th>
<th>FINAL PERFORMANCE SCORE</th>
<th>REMINISCENCE SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IS</td>
<td>PS</td>
<td>FS₁</td>
</tr>
<tr>
<td>High Ability</td>
<td>Mean</td>
<td>1.74</td>
<td>13.76</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>0.61</td>
<td>4.00</td>
</tr>
<tr>
<td>Low Ability</td>
<td>Mean</td>
<td>9.53</td>
<td>20.89</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>2.24</td>
<td>3.48</td>
</tr>
<tr>
<td>High Ability</td>
<td>Mean</td>
<td>3.32</td>
<td>11.46</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>1.15</td>
<td>1.60</td>
</tr>
<tr>
<td>Low Ability</td>
<td>Mean</td>
<td>10.30</td>
<td>15.21</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>2.18</td>
<td>3.37</td>
</tr>
</tbody>
</table>
FIGURE 3: Day 1 and Day 2 performance curves for the 4 subgroups as a function of their initial ability level on the pursuit rotor. (N = 10 in each group).
Since the interaction was a direct test of the hypothesis that performance and learning for low-ability Ss would be hindered to a greater extent under MP when compared to high-ability Ss under the same practice schedule, this was the only component of the total analysis of variance that was tested for statistical significance in this particular analysis. Differences between the total groups in terms of distribution of practice were dealt with in a previous analysis.

The results of the analysis on the ISs of the 4 subgroups revealed no significant F-ratios for the interaction of Practice Schedules and Ability Levels (Table X), which indicated that the subgroups within each practice schedule were statistically equal at the beginning of practice.

TABLE X

ANALYSIS OF VARIANCE FOR THE INITIAL
SCORE OF THE FOUR SUBGROUPS

<table>
<thead>
<tr>
<th>SOURCE OF VARIATION</th>
<th>df</th>
<th>MEAN SQUARE</th>
<th>F</th>
<th>PROBABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRACTICE SCHEDULES (PS)</td>
<td>1</td>
<td>13.74</td>
<td>4.80</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>ABILITY LEVELS (AL)</td>
<td>1</td>
<td>545.23</td>
<td>190.46</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>PS X AL</td>
<td>1</td>
<td>1.63</td>
<td>0.57</td>
<td>&gt; .05&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>SUBJECTS (PS, AL)</td>
<td>36</td>
<td>2.86</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. An F-ratio of 4.11 was required for significance.
An analysis of variance of the PSs revealed no significant effects for the interaction of Practice Schedule by Ability Levels (Table XI). Despite this nonsignificant F,

**TABLE XI**

ANALYSIS OF VARIANCE FOR THE PERFORMANCE SCORE OF THE FOUR SUBGROUPS

<table>
<thead>
<tr>
<th>SOURCE OF VARIATION</th>
<th>df</th>
<th>MEAN SQUARE</th>
<th>F</th>
<th>PROBABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRACTICE SCHEDULES (PS)</td>
<td>1</td>
<td>158.94</td>
<td>15.12</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>ABILITY LEVELS (AL)</td>
<td>1</td>
<td>295.80</td>
<td>28.14</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>PS X AL</td>
<td>1</td>
<td>28.56</td>
<td>2.72</td>
<td>&gt; .05(^1)</td>
</tr>
<tr>
<td>SUBJECTS (PS, AL)</td>
<td>36</td>
<td>10.51</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. An F-ratio of 4.11 was required for significance.

at this stage of practice the high-ability DP group was on target 37.3% more of the time than the high-ability MP group, while the corresponding figure for the low-ability subgroups indicated that DP was 20% superior.

The analysis of variance for FS\(_1\) failed to show a significant interaction between the two main effects (Table XII).
### TABLE XII

**ANALYSIS OF VARIANCE FOR FS₁ OF THE FOUR SUBGROUPS**

<table>
<thead>
<tr>
<th>SOURCE OF VARIATION</th>
<th>df</th>
<th>MEAN SQUARE</th>
<th>F</th>
<th>PROBABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRACTICE SCHEDULES (PS)</td>
<td>1</td>
<td>4.87</td>
<td>1.02</td>
<td>&gt; .05</td>
</tr>
<tr>
<td>ABILITY LEVELS (AL)</td>
<td>1</td>
<td>60.12</td>
<td>12.62</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>PS X AL</td>
<td>1</td>
<td>2.44</td>
<td>0.51</td>
<td>&gt; .05</td>
</tr>
<tr>
<td>SUBJECTS (PS, AL)</td>
<td>36</td>
<td>4.77</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. An F-ratio of 4.11 was required for significance.

A similar analysis of FS₂ again revealed no significant interaction (Table XIII).

### TABLE XIII

**ANALYSIS OF VARIANCE FOR FS₂ OF THE FOUR SUBGROUPS**

<table>
<thead>
<tr>
<th>SOURCE OF VARIATION</th>
<th>df</th>
<th>MEAN SQUARE</th>
<th>F</th>
<th>PROBABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRACTICE SCHEDULES (PS)</td>
<td>1</td>
<td>9.92</td>
<td>1.90</td>
<td>&gt; .05</td>
</tr>
<tr>
<td>ABILITY LEVELS (AL)</td>
<td>1</td>
<td>141.49</td>
<td>27.03</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>PS X AL</td>
<td>1</td>
<td>0.45</td>
<td>0.09</td>
<td>&gt; .05</td>
</tr>
<tr>
<td>SUBJECTS (PS, AL)</td>
<td>36</td>
<td>5.23</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. An F-ratio of 4.11 was required for significance.
Reminiscence Scores. An examination of Table IX revealed that the MP group reminisced 7.5 times more than the DP group. This difference was statistically significant since the F value for the effect of practice schedules exceeded the critical value (Table XIV).

TABLE XIV
ANALYSIS OF VARIANCE FOR REMINISCENCE SCORES
OF THE FOUR SUBGROUPS

<table>
<thead>
<tr>
<th>SOURCE OF VARIATION</th>
<th>df</th>
<th>MEAN SQUARE</th>
<th>F</th>
<th>PROBABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRACTICE SCHEDULES (PS)</td>
<td>1</td>
<td>108.19</td>
<td>11.72</td>
<td>&lt; .05¹</td>
</tr>
<tr>
<td>ABILITY LEVELS (AL)</td>
<td>1</td>
<td>89.21</td>
<td>9.67</td>
<td>&lt; .05¹</td>
</tr>
<tr>
<td>PS X AL</td>
<td>1</td>
<td>14.30</td>
<td>1.55</td>
<td>&gt; .05</td>
</tr>
<tr>
<td>SUBJECTS (PS, AL)</td>
<td>36</td>
<td>9.23</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹. An F-ratio of 4.11 was required for significance.

Further examination of RSs in Table IX revealed that low-ability Ss reminisced 5 times more than high-ability Ss. This difference was also statistically significant in that a significant F was achieved for differences in ability levels (Table XIV). Finally the analysis of the interaction between the two main effects for the RSs failed to show any statistical significance (Table XIV). However, although the low-ability Ss under both MP and DP conditions showed reminiscence, an examination of Table IX showed that the low-ability Ss under MP reminisced 82.6% more
than low-ability Ss under DP. On the other hand, examination of FS₁ for high-ability Ss revealed a small decrement in performance indicating that some forgetting had taken place over the rest period. The high-ability Ss under MP, while not exhibiting forgetting, only showed a small amount of reminiscence.

Discussion

Since the analysis of variance revealed no significant difference among the initial scores of the MP and DP groups, it was concluded that the initial abilities of these groups were approximately the same. Further, it was assumed that these initial abilities would not differentially affect any subsequent performance scores or final scores.

The present investigation into the effects that MP and DP schedules have on motor performance and learning has shown, in terms of the total groups, that MP, while considerably inhibiting performance, had little or no influence on amount learned. These results are similar to those found by past investigators (3, 13, 24, 31, 59, 66, 69) in studies dealing with MP vs DP who used the same types of practice schedules as in the present study (i.e. constant work intervals and variable rest intervals).

The significant decrement observed for the total MP group's FS₁ could be attributed to warm-up decrement and not to learning (Fig. 2). This conclusion was reached because the decrement was completely overcome in a few trials and then the performance curve tended to level off. If the immediate post-rest rise had been due to a learning effect the slope of the acquisition curve at this point would not have been as steep
and would have continued to rise over a substantial number of trials. Warm-up decrement, according to Ammons (6) and Irion (46), refers to the reinstatement of any number of secondary responses, including attitudinal and postural adjustments, which are adopted by Ss while performing the task. With the introduction of rest the acquired set is partially or completely lost. When practice resumes, this set must be re-acquired during the course of practice and it is this regaining of set which is thought to account for the rapid improvement in the initial segment of the post-rest curve.

According to Carron (23:63), "Warm-up decrement on the pursuit rotor could be an artifact resulting from the inability of the S to commence tracking immediately" (when practice is resumed). Adams (4) and Barch (15) appear to be the only authors who have attempted to control for this factor by giving, at the beginning of each trial a warning stimulus and then allowing one free revolution before beginning to record time.

In previous studies the presence of warm-up decrement under DP was, generally speaking, non-existent. According to Ammons (6), in DP there is a learning of "methods" of warming-up, i.e., the more times practice is resumed, the easier it is to warm-up. The present results are seen as contradicting this view since warm-up decrement was also observed in the DP group. The fact that warm-up decrement occurred in both experimental groups could have been attributed to the length of interpolated rest. Past investigations (6, 36, 63) have usually only given up to 30 minutes rest before resuming practice. Since the present experiment gave 24 hours interpolated rest, both groups could conceivably have forgotten the correct set for pursuit rotor tracking and thus both would need a few trials to reinstate the appropriate set.
By the end of the second day of practice the difference in FSs between MP and DP had disappeared (Table VIII). This non-significant difference indicated that Ss under MP, while their PSs were considerably lower than the DP Ss, learned as much as did the Ss under the DP schedule. These results are consistent with previous findings (13, 23, 31, 59, 66, 69) which showed that distribution of practice is a variable that affects performance and not learning.

The results of the subgroup analysis supported the hypothesis which predicted that the PSs for high and low-ability Ss would be hindered under MP conditions. It was interesting to note that the PSs of the high-ability Ss under MP showed a 37% decrement when compared to the high-ability DP Ss, whereas the corresponding difference between the low-ability groups showed the MP group to be only 20% inferior. While this interaction did not reach statistical significance the trend which suggested that MP affected performance of high-ability Ss to a greater extent than low-ability Ss was exactly opposite to what had been hypothesized. Except for the fact that these differences were probably caused by sampling error, no further explanations of these results can be given at this time.

The second hypothesis of the present study stated that the amount learned for initial low-ability Ss would be less under MP than under DP conditions. This hypothesis was not supported since there was no interaction between practice schedules and ability levels in terms of amount learned.

These results, however, are consistent with those of Farmer (38) who showed parallel performance curves for groups of different initial
ability and supports the assumption of Hull (45) that individual differences affect the constants of a behavioral equation but not the general mathematical form.

Parallel performance curves for low and high ability Ss has also been observed by Adams (5) and Reynolds and Adams (63). However, comparison of the learning curves obtained in the present study and the ones obtained by Reynolds and Adams (63) is difficult due to the fact that Reynolds and Adams observed considerable decrement between and within sessions which was caused by short interpolated rests between sessions. Further, in Reynolds and Adams' (63) study, groups were compared on the basis of different practice schedules over all sessions. Thus their study as well as the studies of Farmer (38) and Adams (5), have been concerned exclusively with performance curves and make no inferences about learning. Nevertheless, it appears that what the above authors found in regard to performance also applies to learning. This is true because on the final session on Day 2, the learning curves of the subgroups showed little tendency to converge. It appeared that the Ss did not attain the task assymptote but rather attained an assymptote commensurate with their own ability.

The fact that at the start of practice on Day Two the low-ability MP Ss reminisced to the same level as the low-ability DP Ss was contrary to the results of Marteniuk and Carron (52) who found that low-ability MP Ss learned more than low-ability DP Ss. However, these authors used a method of distributing practice that differed from the present study in that they utilized a constant intertrial interval while differentiating between MP and DP in terms of the work interval. In the present
study the work interval was kept constant and the rest interval was varied. Thus it would appear that the results of the present study do not contradict the view of Marteniuk and Carron that the relevant issue in schedules of skill acquisition is determining optimum lengths of work rather than determining optimum lengths of intertrial rest intervals. In other words instead of emphasis being placed on the length of the rest interval, as has been done in most studies dealing with the effects of distribution of practice on learning, Marteniuk and Carron advocate systematically varying the work interval while keeping the rest interval relatively constant.

In regard to reminiscence the present study found that low-ability Ss reminisced significantly more than high-ability Ss. Further, the main effect of MP versus DP was contrary to theory due to the fact that the low-ability DP group showed large amounts of reminiscence and that supposedly no temporary work decrement is built up during DP and thus no reminiscence should occur (50). However Eysenck (37) has stated that reminiscence in the pursuit rotor is entirely due to consolidation rather than being the result of dissipation of Ir. Thus it could be hypothesized that consolidation should occur to a greater extent in low-ability Ss than in high-ability Ss in that initially low-ability Ss have more chance to profit from practice. In other words it is reasoned that high-ability Ss, having already learned the appropriate responses for the pursuit rotor, are working near their maximum performance levels and thus profit very little from consolidation. The fact that the low-ability Ss of the present study reminisced to a greater extent than the high-ability Ss lends support to this viewpoint.
One exception to Eysenck's hypothesis would occur in a situation where a high-ability group of Ss, having already developed appropriate responses, were fatigued by MP and then given an interpolated rest. Under these circumstances any reminiscence effect that occurred might be attributable to the dissipation of the fatigue that depressed pre-rest performance. Presumably this would explain why the high-ability MP group of the present study showed reminiscence and the high-ability DP group did not.

The above explanation could also be used to explain why the total MP group reminisced to a significantly greater extent than the total DP group. Supposedly the DP group demonstrated reminiscence only due to consolidation and the present results indicate that this took place primarily in the low-ability Ss, with the high-ability Ss actually detracting from this effect because of forgetting. The MP group, on the other hand, had two factors contributing to their reminiscence. One factor was attributable to consolidation in much the same way as in the DP group. However a second factor caused by fatigue build-up during Day One performance also contributed to the reminiscence effect. This second factor probably accounted for the larger reminiscence of total MP group.
CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to investigate the effects of massed practice (MP) and distributed practice (DP) upon motor performance and learning in groups of different initial ability. Sixty volunteer right-handed male Ss were tested on the Pursuit Rotor. The Ss were students enrolled in physical education classes and were naive to the apparatus. They were randomly assigned to either a MP or a DP schedule with the restriction that equal numbers appear in each group. Twenty-two trials were performed on Day 1 of the experiment by both MP (30 secs. work-5 secs. rest) and DP (30 secs. work-30 secs. rest) groups. The first two trials, for all Ss, were performed under the DP schedule. The mean of these two trials was used to determine the initial ability of each S. On Day 2, following an interpolated rest of approximately 24 hrs., all Ss performed 20 trials under the DP schedule. The results were as follows:

1. Massed practice had an inhibiting effect on Day 1 performance in that the DP group performed significantly better than the MP group.

2. The reminiscence score (initial score, Day 2, minus final score, Day 1) for the MP group was found to be significantly greater than the reminiscence score for the DP group.
3. There were no differences between the MP and DP groups in final learning ability.

4. No significant effects for the interaction of practice schedules by ability levels was found for Day 1 performance.

5. Reminiscence scores were related to the initial ability level of the Ss (p < .05).

6. There was no interaction between distribution of practice and initial level of ability in terms of learning.

From these results the following conclusions can be stated:

1. Fatigue resulting from MP on the pursuit rotor inhibits performance but does not affect learning.

2. Fatigue resulting from MP on the pursuit rotor has no differential effect on Ss of different initial pursuit rotor ability, in terms of both performance and learning.

Recommendations

1. To test Marteniuk and Carron's (52) hypothesis, it would be more advantageous to use a task like those used by Pew (58) or Ammons (9), where the temporal organization of the response components is well known. Then the effects of fatigue upon performance and learning could be determined more precisely, both quantitatively and qualitatively.

2. Considering the findings that low-ability Ss reminisced more for the particular practice schedules used here, it would be desirable to investigate what effects greater massed practice would have upon motor performance and learning.
BIBLIOGRAPHY


APPENDIX
The object of the task is to track the metal disk on the rotor by keeping the metal stylus tip in contact with it for as long as possible during each trial.

You will hold the wooden handle of the stylus in your preferred hand with a tennis-type grip as demonstrated by the experimenter (look at the experimenter). The following must be done with an easy, relaxed, swinging arm movement and no extra pressure must be put on the stylus tip in any way.

You will start by holding the stylus on the opposite side from the target as demonstrated by the experimenter (look at the experimenter). Before starting the turntable, I will say "READY", then hold the stylus stationary until the disc comes around to it, at which time you will start to track the target. At the end of the trial, I will say "STOP" and you will immediately take the stylus off the rotor, put it down beside the rotor, turn the turntable off, and then return the disk to its starting position by rotating the turntable in a clockwise direction. You will then turn your back to the apparatus and start counting backwards by three from the number that I will call until the "GET READY" signal. Then you will repeat the whole procedure for a new trial.

You will find that it is difficult at the beginning to track the target but you must do your best to stay on the target as long as you can. Remember it is the time that the stylus is in contact with the target that determines how well you do.
Now I will ask you to tell me verbally what you have to do to see if you understood the instructions. (After S had finished explaining his task and E correcting him when necessary, E then asked, "Do you have any questions?"
APPENDIX "B"
RAW DATA

The following data represent the time on target in seconds for each S, on each trial.

The first four rows from the top are the data for $S_1$, the following four for $S_2$, etc.

For each S, the first two rows read by a format of (11F4.2) represent his performance, on each trial, on Day One; the second two rows read by a format of (10F4.2) represent his performance on each trial, on Day Two.

To the right of these data, in line with each row, a number appears for identification purposes. The first two digits represent S's number (1 to 30); the third digit represents the variable studied (time on target); the fourth digit is the S's card number (1 to 4); and the fifth digit is the group to which the S belongs (1 = DP; 2 = MP).