AN ANALYSIS OF THE EFFECT OF SEQUENCE LENGTH ON THE ACQUISITION AND RETENTION OF A SEQUENTIAL TRACKING SKILL

by

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INTRODUCTION

Recent reviews of the motor skills literature call for increased attention to a class of variables, termed intratask composition by Bilodeau (1961), constituent mechanisms by Adams (1964) or task variables by Fitts, Noble, Bahrick and Briggs (1959), and their role in learning and retention. One of the most neglected of this class of variables is length of task. In learning it has been generally conceded that the longer the task the more difficult it is to learn. The extent of this relationship however, is not clearly understood. Such an understanding is essential in motor skills research because "the number and type of S-R sequences, and their rate, that S can process per unit of time is fundamental to a theory of a quantified sort in this area" (Adams, 1964, p. 197).

The verbal learning researchers have long been concerned with the length of lists in serial learning. It has generally been found that lengthening lists disproportionately increases difficulty of learning and, hence, time to learn (McGeoch & Irion, 1952). In 1917, Lyon's classical monograph summarized much of this early verbal evidence. The evidence indicated that with longer lists, total time to learn increased, but the time per item did not increase appreciably. With short lists, the addition of only a few items did increase time per item; but the addition of the same number of items to longer lists made no difference in time per item to learn. Deese (1958) suggested that while this did not indicate the commonly accepted disproportionality it was in line with Thurstone's 1930 general learning equation which stated that time per item should increase as the square root of the number of items beyond the immediate memory span.

Another aspect of learning difficulty that is affected by length of the task is the number of repetitions required to learn. Deese (1958) has pointed out that if time of item exposure is controlled then the number of repetitions to learn is proportional to the total time to learn. Thus, if task difficulty disproportionately increases total learning time it should also disproportionately increase the number of repetitions required to reach criterion. However, Deese found that if Lyon's data is replotted over the number of repetitions per item the result is a very different function than that of the total learning time data. The number of repetitions per item increases rapidly at first, reaching a maximum of approximately 1.4 repetitions per item for a list of 20, and then rapidly declining to an asymptote of about .5 repetitions per item. In Lyon's data fewer repetitions per item were required to learn a list of 200 items than were required for a list of 16 items, although the total number of repetitions was greater for the longer lists. Deese (1958) concluded that, "the results of the available experimental evidence clearly suggest that the amount of material does not necessarily disproportionately increase difficulty of learning as has commonly been supposed both by learning theorists and those only casually interested in learning" (p. 212).

There is very little empirical evidence in the area of motor skills related to the effects of task length upon motor learning. It is not clear whether increasing task length has the same effect on difficulty in motor learning as it does in verbal learning. The scanty evidence available suggests the effect may be the same, at least for a motor task of a discrete sequential nature. Scott and Henninger (1933) examined the length-difficulty relationship for both verbal and motor serial tasks. They compared the verbal data from a study by Robinson and Heron (1922) with data they collected in which several different finger mazes served as the motor tasks. Their findings were comparable to those of Lyon in that <u>total time</u> and trials (repetitions) to learn were both increased by increasing the length of the task. However, when they plotted the maze data as a function of increases per unit (per cul-de-sac) the resulting functions were very similar to Deese's per-unit analysis of Lyon's data. That is, the time to learn was no longer disproportionate and the trials to criterion increased with small increases in length but then tended to asymptote, showing relatively little or no effect of increases in length. They concluded that, "when this relationship [in the motor task] is compared to that found to exist in verbal learning, a marked similarity is evident" (p. 678).

A recent motor skills study (Trumbo, Noble & Ulrich, 1965) examined the effects of different sequence lengths in an irregular step-function tracking task. The sequences were 5, 10, and 15 units (targets) in length and performance was measured by absolute integrated error scores over a 60 sec. (60 target) period. At the end of training there were no differences in tracking error scores between the 5 and 10 target sequences, but both groups had significantly lower error scores than the group with the 15-target sequence. These groups, however, received equal numbers of 60 sec. trials rather than equal repetitions of their sequences. When comparisons of performance are made by interpolation at 400 repetitions for each group the error scores for all three sequence lengths are nearly equal. McGeoch and Irion (1952) have pointed out that disproportionality between length and time to learn may be less with higher levels of practice even though it may still change the slope of the time-length curve. Since high levels of practice are a characteristic of most motor skills this may be an important distinction for assessing the relative effects of task length on motor and verbal learning.

An evaluation of the roles of a task variable involves not only its effect upon acquisition but also upon retention. McGeoch and Irion (1952) state that, "the amount of original material, or length of the original lists, constitutes an obvious variable in any systematic study of retention" (p 417).

The empirical evidence concerning length of tasks and retention is as scarce and equivocal as it is for acquisition. McGeoch and Irion (1952) summarized several early verbal studies which found that the longer lists usually resulted in greater retention, contrary to what might be expected intuitively. They attributed this superiority to higher degrees of practice on many of the items. The reasoning was that if longer lists increase difficulty and, hence, time to learn then more repetitions of the list are required. Increased repetitions would result in a higher average degree of learning, and thus be less susceptible to retroaction.

The level of learning, particularly with various amounts of overlearning, has frequently been the primary variable in both verbal and motor retention studies (Osgood, 1953; Deese, 1958; Naylor & Briggs, 1961; Bahrick, 1964; Adams, 1964; Bilodeau, 1965). Since motor tasks are characterized by high levels of practice, overlearning is usually cited as one reason that motor skills appear to be retained better than verbal material (Bilodeau & Bilodeau, 1961; Adams, 1964). Naylor and Briggs (1961), summarizing the literature on the long-term retention of motor skill, made the observation that, "there seems to be some indication that additional amounts of original learning may facilitate retention but at a decreasing rate" (p. 9).

The findings and their implications for the areas of motor and verbal retention are by no means unequivocal. Some attribute the confusion to measurement artifacts (Bilodeau & Bilodeau, 1961; Bahrick, 1964), some to a difference in the nature of the task (Naylor & Brigg, 1961; Adams, 1965), and others to the fact that retention is not a unitary process (Adams, 1965; Bilodeau, 1965). Naylor and Briggs (1961) concluded that, "the differences found [between verbal and motor retention] are most likely to be artifacts either of difficulty differences or organizational differences between the tasks" (p. 6).

Difficulty of task in longer sequences may increase retention through higher degrees of learning (McGeoch & Irion, 1952). Another view of the effect of difficulty on retention has been stated by Battig (1965). This view, based mainly on studies in verbal learning, holds that facilitation of subsequent performance (retention or transfer) may result if the original learning has taken place under conditions of high intratask interference. One of the reasons cited by McGeogh and Irion (1952) for increased difficulty due to increased length was that an increase in items increases the probability of intralist interference. Battig has indicated that the proposition that high intratask interference facilitates retention should apply equally well to complex motor tasks if the components of the task can be assessed as to their contribution to intratask interference and difficulty. Task length may be such a component.

A review of the little evidence concerning the role of length of task in learning allows no definitive generalizations. It is unclear whether the course of either acquisition or retention is altered by length, or if such alterations exist, whether they are equivalent for both verbal and motor learning. Fitts (1964) has stated that the distinction between verbal and motor learning serves no useful purpose and that the underlying processes in both are similar; therefore, "we should expect that the laws of learning are also similar" (p. 243). It is anticipated that the present study may remove some of the obscurity concerning these issues. Although the study deals with a motor task, certain parallels may be drawn with verbal learning. Hopefully, the findings may allow certain generalizations to be made concerning the role of task length in both the acquisition and retention phases of learning.

The selection of a sequential tracking task for this study makes possible the systematic variation of the length of a sequence of targets in a manner similar to varying list length in a verbal serial learning task. In the verbal serial task the subject must learn to correctly anticipate the succeeding items in order for performance to improve. In the analogous motor task, the subject learns the sequence of targets in order to anticipate regular changes in the input which permits tracking lag to be reduced below visual-motor reaction times (Helson, 1949; Poulton, 1957; Adams & Xhignesse, 1960). Thus, a relative measure of the difficulty of learning as a function of the length of the sequence should be reflected in the rate of decrease of error scores and in the terminal tracking performance.

Under conditions of equal target durations and equal trial durations, but unequal sequence lengths, subjects given equal practice will, of necessity, receive unequal repetitions of their sequences. Since sequences vary in number of targets, the longer sequences will receive fewer repetitions per trial than the shorter ones. However, if subjects receive equal repetitions of the sequences, regardless of sequence lengths, the practice time would be unequal (i.e., number of targets and total tracking time not equal). Therefore in this study both conditions of training were used.

Another task variable, predictability or task coherence (Fitts, et al, 1959) which has recently been investigated in skill acquisition and retention by Trumbo, Noble, Cross & Ulrich (1965), will be examined as a second independent variable. The previous findings involving this task organization variable have shown that tracking performance is positively related to the proportion of repeating elements in sequences of equal length and that retention was negatively related to predictability (Trumbo, et al, 1965). In this study an analysis will be made to determine whether task predictability interacts with sequence length, either in terms of criterion tracking performance or in spatial-temporal response patterning.

In summary, this study was designed to investigate the role of the task variable, sequence length, in the acquisition and retention of a sequential tracking skill. An assessment of the interaction between sequences of different lengths and a second task variable, predictability will be made using two different training criteria; equal practice and equal repetitions. The primary purpose is to determine the effect of an increase in the task length (i.e., amount to be learned) upon task difficulty through analysis of acquisition and retention tracking performance.

METHOD

Subjects

The subjects were 120 undergraduate, right-handed male students enrolled at Kansas State University. The subjects ranged in age from 17 to 24 years. Each subject received either research participation credit in an introductory psychology course or was paid 75¢ for each one-half hour session in which he served.

Apparatus

The task display consisted of targets appearing as a narrow 1/2 inch vertical line which moved in discrete jumps across the face of an oscilloscope (Tektronix Model S61A with two type 3A72 plug-in units). The position of the target was determined by an irregular step-function input programmed through a six-channel binary tape reader (Digitronic Model 3718) and a digital to analog converter. A subject controlled cursor appeared as a second 1/2 inch vertical line below, and with a 1/8 inch overlap of, the target. The position of the cursor was determined by the output of a potentiometer attached to a pivoted shaft of the arm control, which provided a linear voltage output. The arm control consisted of a light weight aluminum lateral arm rest, with an adjustable hand grip, pivoted at the elbow and attached to the right side of an adapted steel dental chair.

The target could appear at any one of 15 equidistant positions along the horizontal axis of the 11.4 cm scope face. The distance between target positions was .53 cm. There was a maximum target excursion of ± 4 cm from the center. A control movement of ± 22.5 degrees was required to track the maximum amplitude of target movement or a control-to-display ratio of 11.25^o arc to 2 cm. The scope face was completely surrounded by flat black poster board and the viewing distance was approximately 28 inches.

The basic scoring unit of the system consisted of two operational amplifer manifolds (Philbrick Model 6009) with 10 amplifers and 10 stabilizer and a power supply. This scoring unit provided the momentary error in voltage units as the absolute difference between the target and the cursor voltages. This absolute error, without regard to sign, was fed into an integrator circuit to provide absolute error integrated throughout the trial. Integrated error data was immediately and continuously available to the experimenter via two voltmeter displays (Heath Model 1M-10), one for each subject booth.

On selected trials, the input (target) voltage and the output (cursor) voltage were recorded on separate channels of a 1/2 inch magnetic tape data recorder (Minneapolis-Honeywell Model 8100 F-M). Three channels recorded simultaneously, the common input (target) and the output (cursor) of the two booths. The data stored on the magnetic tapes was then fed into an oscillograph (Minneapolis-Honeywell Model 90C Visicorder) which permitted visual inspection and hand scoring of continuous response records.

The target durations, intertrial intervals, and the subject's warning buzzer were automatically controlled by a series of four Hunter Interval Timers.

Identical displays and controls were located in two 6' x 8' tandem subject booths. The illumination in each booth was provided by a small 10 watt night light with a red bulb. The light was located to the left and above the subjects with a reflector turned toward the wall providing a low level of reflected illumination. To reduce the distraction of outside noise, white noise was piped into each booth via a speaker mounted to the right and above the subject. A squirrel cage blower fan used to maintain a constant room temperature of 80° F $\pm$ 5° produced additional noise. The ambient noise level was approximately 75 decibels. Communications between the subject booths and the experimenter-control room was provided for by a two-way intercom system.

Task

The task was a one-dimensional sequential pursuit tracking task requiring discrete responses corresponding to a series of direction and extent changes in the target. The target changes occurred at a constant rate of one step per second. A series of 48 step changes constituted a trial and trials were separated by a 12 second rest period. A two-second warning buzzer signaled the beginning of each trial.

Experimental Variables

Sequence length. Sequence length was defined as the number of targets in a basic sequence repeated within and throughout all trials. Specific values of this variable were: 8, 12, 16, 24, or 48 targets. Thus, a sequence of 8 targets repeated six times per trial, a sequence of 12 repeated four times per trial, and so on. The first target of each sequence appeared in the middle of the scope. The middle target position was used exclusively for the first target of a sequence.

Task predictability. The predictability or coherence of a sequence refers to the percentage of targets which are invariant on each repetition of the sequence. Two degrees of predictability, 100 and 75 per cent, were used with each of the five sequence lengths. The 100 per cent (predictable) sequence was composed of targets which appeared in the same order and position each time the sequence was repeated. A 75 per cent (variable) sequence consisted of 75 per cent of the targets repeated and 25 per cent different on each repetition of the sequence. The targets appeared in a pattern of three repeating targets and one variable throughout the entire sequence. The predictable targets of all sequences were randomly drawn, without replacement, from the 14 positions (excluding the middle). For sequences longer than 14, replacement was permitted, only after all target positions had been used once. The variable targets were randomly drawn on each trial from those positions which were not used as the predictable targets where possible. No target position could immediately follow itself in any sequence. Three alternative patterns were constructed for each of the five sequence lengths and two degrees of predictability. One sample of each pattern is presented in Appendix A.

Training criteria. Under the equal practice criterion each condition received 20 trials a day for five consecutive days. Thus, an equal number of targets and equal amounts of practice time were obtained with this criterion. Under the equal repetitions criterion each condition received 360 repetitions of the sequence (note: for a sequence of 48 targets, only 180 repetitions were received). Thus, although the number of repetitions were equal for the different sequence lengths the number of targets and amounts of practice time were not.

Retention intervals. Retention was tested at two different intervals consisting of three months and five months of no practice. Retention conditions were identical for both intervals and the testing procedure was identical to the training situation.

Design

A 5 x 2 x 2 x 2 complete factorial experiment was used with a random assignment of subjects to all groups. The first factor, sequence length, involved five levels. The other factors, task predictability, training criterion and retention interval each had two levels. The complete experimental design is shown in Table 1.

Procedure

Acquisition. The subjects were scheduled two at a time and tested under identical experimental condition. They were both led into one of the two identical subject booths and given detailed instructions as follows:

> The task in which you will be participating today is what is called a tracking task. The upper line on the scope (E points to the target line) is called the target. When we begin you will see the line move right and left in discrete jumps. The lower line is called the "follower" (E points to the cursor). The position of this line is determined by the position of your control. Try moving the arm control back and forth to see how it works. Your task in this experiment is to keep the follower as nearly superimposed on the target as possible while the target is jumping about the screen and while the target is stationary. It will look like this when you have the follower positioned properly (E superimposes the cursor on the target).

Table 1

Experimental Design

Sequence Length[1]	Predictability[2]	Training Criteria[3]	Retention Interval[4]
Eight	Predictable	Equal practice	3 months
			5 months
		Equal repetition	3 months
			5 months
	Variable	Equal practice	3 months
			5 months
		Equal repetition	3 months
			5 months
Twelve	Predictable	Equal practice	3 months
			5 months
		Equal repetition	3 months
			5 months
	Variable	Equal practice	3 months
			5 months
		Equal repetition	3 months
			5 months
Sixteen	Predictable	Equal practice	3 months
			5 months
		Equal repetition	3 months
			5 months
	Variable	Equal practice	3 months
			5 months
		Equal repetition	3 months
			5 months
Twenty-four	Predictable	Equal practice	3 months
			5 months
		Equal repetition	3 months
			5 months
	Variable	Equal practice	3 months
			5 months
		Equal repetition	3 months
			5 months
Forty-eight	Predictable	Equal practice	3 months
			5 months
		Equal repetition	3 months
			5 months
	Variable	Equal practice	3 months
			5 months
		Equal repetition	3 months
			5 months

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[1] (n=24)
[2] (n=12)
[3] (n=6)
[4] (n=3)

The primary way in which your performance will be evaluated is in terms of your error score. Error in this case is the amount by which the position of the target and the follower differ. For example, if the position of the follower is here with respect to the target (E positions the follower so that it is not superimposed on the target) this difference (E points out difference between the target and the cursor) represents the error and this error accumulates all during the time the follower is not superimposed on the target. If there is a large difference between the target and the follower, the error score will build up very rapidly. If there is only a small difference, the error score will build up more slowly. But remember, any time that the two lines are not perfectly superimposed, there is always some error building up.

There are a number of strategies that can be used to keep your error score as small as possible. One valuable strategy is anticipation. As you have more and more experience with a pattern you will learn enough about the pattern to permit you to anticipate the extent and the direction of the next position as well as the moment at which the target will jump to its next position. Let's look at a typical pattern and see what happens to your error score when you are able to anticipate correctly. (E shows S a pattern from viscorder record and explains how error is affected by a correct anticipation.) I think you can see that correct anticipation can greatly improve your score. The degree to which you can make correct anticipations depends a great deal on the type of pattern that you have been assigned. Some subjects are given patterns that have all predictable elements within it. Others have some targets which vary randomly on each repetition. You can see that the sooner you learn these predictable elements the sooner you will make an increasing number of correct anticipations. Your pattern will consist of a repeated sequence of targets. Your cue for the beginning of the sequence will be the middle target. This target will appear only at the beginning of a sequence.

A second important factor is the rate with which you move the arm control. You can see on this record (E shows S a record of slow response) that when your response is slow, much more error is built up than when your response is fast. As was true with anticipation, however, a fast rate of movement can also hurt your score if not used properly. For example if you use such a fast rate of movement that you overshoot the target by a great deal, your score will not be helped.

> Let's look at some more records which will show you a number of instances in which error is increased (E shows S examples of anticipation too soon, anticipation in the wrong direction, overshoot, slow rate, lag, failure to correct for overshoots and undershoots). These are the types of things which if avoided will greatly improve your score. Note that rapid arm movement and corrections for overshoots is more beneficial than slow movements with no overshoots.
>
> You will be given 20 trials, 48 sec. long with a 12 sec. rest period. A buzzer will sound 2 sec. before the beginning of the next trial. You will be given your error score every other trial. Do you have any questions?

One subject remained in the first booth while the second subject was led to the adjoining subject booth and reminded that all conditions in the two booths were identical. When both subjects were seated and a verbal confirmation was received over the intercom that they were ready, the experimenter started the testing.

Knowledge of results was provided to subjects after alternate trials, over the intercom system. These results consisted of the total integrated error accumulated on the preceding trial and read from the meter (to the nearest .10 volt) by the experimenter.

The subjects with an equal practice criterion received five days of practice. The subjects with an equal repetitions criterion received 20 trials per day until they had tracked 360 repetitions of their sequence. This required three sessions for the 8 target sequences, four and one-half sessions for 12 target sequences, six for 16 target sequences and nine days for 24 target sequences. The 48 target sequence groups received

10 days of practice for 180 repetitions of the sequence.

Retention. When the subjects returned for their assigned retention period they were given a brief review of the task and the tracking errors. The following set of instructions were read to them:

> We are interested in determining how much you remember about the pattern you tracked during your original training, so today we are asking you to track the same problem as before. Remembering that predictability and length of sequence are variables.
>
> Do you recall the types of errors that we talked about the first day? (E shows S the examples and points out errors of anticipation too soon, anticipation in the wrong direction, excessive lag, too slow of a rate, overshoot, and undershoot). Keep all these errors in mind avoiding them as much as possible.
>
> Remember we are interested in determining how much you remember about the task, so do your very best on every trial. As before, the buzzer will sound 2 sec. before the trial starts. The trials will be 48 sec. as before and a 12 sec. rest period between trials.
>
> We are also interested in how rapidly you relearn; thus, we will give you 20 trials as we did during training. We will then give you a 5 min. break during which time you may stand up, walk around and generally relax. We will then have you track an additional 20 trials following the same procedure.

Each subject entered the subject booth to which he had been assigned for training. The retention session consisted of 20 trials, a five minute rest period, and 20 additional trials. All conditions in retention were identical with those in training.

Performance Measures

Integrated error scores. The principle performance criterion was absolute integrated error score for each subject. These scores were recorded after each trial from the voltmeters. The scores consisted of the momentary absolute differences between the target and the cursor in voltage units integrated throughout the entire 48 seconds of the trial.

Analytical measures. The hand-scoring of the oscillograph records provided additional indicants of spatial-temporal patterning of responses. Average lead and lag times were scored to the nearest 50 milliseconds of the interval between the target displacement and the initiation of the primary pursuit movement. An overall temporal index consisted of the algerbic sum of the leads and lags divided by the total number of targets in a trial (48) and indicated the average timing per response.

The spatial errors were scored as overshoots and undershoots of the target, to the nearest .10 cm between, the actual target position and the termination of the initial pursuit movement. The average scores consisted of the sum of the magnitudes of the spatial errors divided by the frequency of each, providing an average overshoot and undershoot error per trial.

RESULTS

Acquisition

Integrated Error Scores-Equal Practice Criterion

The integrated error scores presented in Figure 1 are based on the mean performance of six subjects in each of the 10 groups which received the equal practice training criterion. The group means for the five sequence lengths and the two degrees of pattern predictability are plotted in ten 10-trial blocks for a total of 100 acquisition trials.

Predictable pattern. The data of the five predictable sequences length groups, shows that the sequences of 8 and 12 targets yield initially high rates of acquisition which appear to asymptote after about 60 trials. The sequence lengths of 16 and 24 result in more constant and moderate acquisition rates throughout training, but achieve approximately the same terminal performance as the shorter sequences. The sequence of 48 targets results in a relatively slow rate of acquisition until the fifth day when a rapid acceleration occurs. The level of performance for the subjects with the 48-target sequence, however, remains substantially less than those of the four shorter sequence lengths throughout the entire training phase.

In order to determine whether the terminal performance levels for the five sequence lengths were significantly different at the end of the five days of practice, a simple

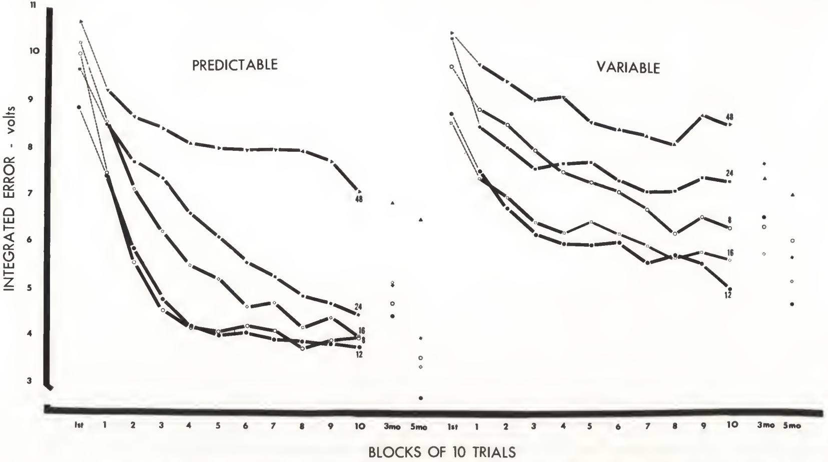

Fig. 1. Integrated error scores for all equal practice groups. Data points represent the average scores over 10 trials.

analysis of variance was performed on the error scores for the last block of ten trials. As indicated in Table 2, there was a significant difference ($p < .01$) in the scores between sequence of different lengths. To locate these performance differences a Fisher's least significant difference (lsd) test of multiple comparisons (Federer, 1955) was computed for the means of the various sequence lengths on the last ten trials. The results indicated no significant differences between the terminal performance of the 8, 12, 16 and 24-target sequences, but all four differed significantly ($P < .05$) from the sequence length of 48.

Variable pattern. The data for the five sequence-length groups with variable patterns, indicate that the rates of acquisition for all five groups were approximately comparable, but that the terminal performances differed. After five days of training, the level of performance appeared to be related to sequence length, with the exception of the eight-target sequence. A test of the performance differences at the end of training was performed by a simple analysis of variance on the last block of ten trials for the five groups. As Table 3 indicates, the differences between variances attributable to sequence length was highly significant ($P < .01$). A Fisher's lsd test indicated that the differences in performance were significant ($P < .01$) between all sequences except for adjacent pairs of means.

Combined equal practice analysis. A repeated measures analysis of variance was performed on the total acquisition

Table 2

Summary of Analysis of Variance for
Predictable Patterns-Equal Practice
at Last Block of 10 Acquisition Trials

Source of Variance	df	SS	MS	F
Between Sequence Lengths	4	54.8176	13.7044	6.79**
Within	25	50.4465	2.0179	
Total	29	105.2641		

** Significant at .01 level

Ordered Sequence Length Group Means	12	8	16	24	48	
	3.80	3.92	4.18	4.58	7.54	$\text{lsd}_{.05} > 1.69$

Table 3

Summary of Analysis of Variance for
Variable Patterns-Equal Practice at
Last Block of 10 Acquisition Trials

Source of Variance	df	SS	MS	F
Between Sequence Length	4	49.2076	12.3019	13.15**
Within	25	23.3928	.9357	
Total	29	72.6004		

** Significant at .01 level

Ordered Sequence Length Group Means	12	8	16	24	48	
	4.98	5.62	6.38	7.31	8.62	$\text{lsd}_{.05} > 1.15$

data for both degrees of pattern predictability. The results, as presented in Table 4, indicated that both independent variables, predictability and sequence length, had a significant ($P < .01$) effect on acquisition. These results are supported by data presented in Fig. 1 and by the independent statistical analyses for these groups. There was no significant interaction between the predictability and sequence length variables. The practice effects, analyzed as blocks of 10 trials, were found to be highly significant ($P < .01$). The significant interactions of Blocks by Predictability and Blocks by Sequence Length indicated a differential change in the acquisition rates across trials for both of the independent variables and is supported by inspection of Fig. 1. The significant ($P < .01$) second-order interactions of Blocks by Predictability by Sequence Length indicated a similar differential in the first-order interactions across the second independent variable.

Integrated Error Scores-Equal Repetitions Criterion

The integrated error scores presented in Fig. 2 are based on performance means of six subjects in each of five sequence-length groups for the two degrees of pattern predictability. The data of the 10 groups receiving the equal repetitions are plotted in ten, 36 repetition blocks for a total of 360 sequence repetitions. The data for the 48-target sequence is presented for only 180 repetitions of the sequence over a 9 day period.

Table 4

Summary of Analysis of Variance for Equal Practice Groups for the Five Blocks of 20 Acquisition Trials

Source of variance	df	SS	MS	F
Predictability (P)	1	138.3803	138.3803	22.74**
Sequence Length (S)	4	374.0684	93.5171	15.37**
P x S	4	38.9089	9.7272	1.60^{ns}
Between Subjects	50	304.2289	6.0846	
Blocks (B)	4	184.0959	46.0240	146.34**
B x P	4	15.7751	3.9438	12.54**
B x S	16	11.2743	.7046	2.24**
B x P x S	16	16.6987	1.0437	3.32**
Blocks x Subjects	200	62.8965	.3145	
Total	299	1146.3271		

** Significant at .01 level

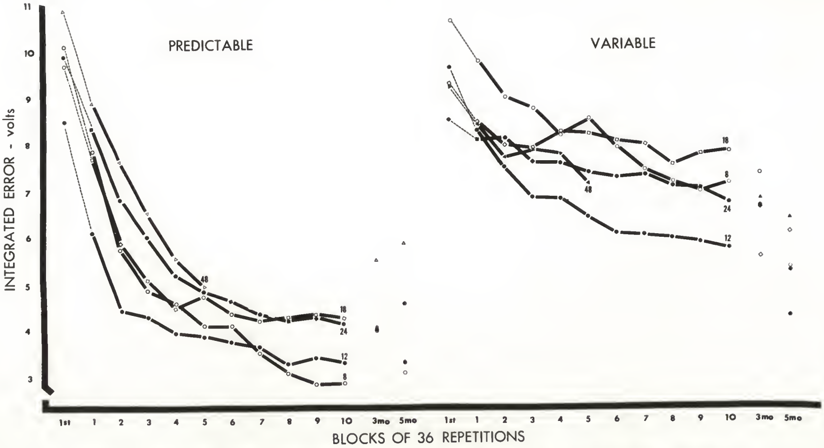

Fig. 2. Integrated error scores for all equal repetition groups. Data points represent the average score per 36 repetitions.

Predictable pattern. The data for the five predictable sequences showed acquisition rates to be approximately equal for all five sequence lengths, with all groups achieving comparable levels of performance throughout training. A simple analysis of variance was performed on the acquisition data of the predictable sequences at two points in training. The first was computed for the scores after 180 sequence repetitions (fifth block in Fig. 2). The second was computed on scores for the final training block for the four sequence lengths which received a total of 360 repetitions. As indicated in Table 5, there were no significant differences in the performance among any of the sequences length conditions at either stage in training.

Variable pattern. The data for the five variable patterns with equal repetition also indicates similar acquisition rates for all sequence lengths, except the 16-target sequence. As indicated in Table 2, two simple analyses of variance on the error scores at two stages of training, one at 180 and a second at 360 equal repetitions, both failed to detect any significant performance differences attributable to sequence length.

Combined Equal Repetition Analysis. Two repeated-measures analyses of variance were performed on the complete acquisition data of both the predictable and variable patterns. The first analysis was on performance scores after 180 repetitions and included all five sequence lengths. The second was on scores

Table 5

Summary of Analysis of Variance for
Predictable Patterns-Equal Repetitions
at 180 and 360 Repetitions

Source of Variance	180 repetitions				360 repetitions			
	df	SS	MS	F	df	SS	MS	F
Between Sequence Length	4	5.4275	1.3569	.55^{ns}	3	6.5618	2.1873	1.44^{ns}
Within	25	61.2353	2.4494		20	30.4082	1.5204	
Total	29	66.6628			23	36.9700		

Table 6

Summary of Analysis of Variance for
Variable Patterns-Equal Repetitions
at 180 and 360 Repetitions

Source of Variance	180 repetitions				360 repetitions			
	df	SS	MS	F	df	SS	MS	F
Between Sequence Length	4	16.8169	4.2042	2.60^{ns}	3	13.6716	4.5572	2.64^{ns}
Within	25	40.3569	1.6123		20	34.4666	1.7233	
Total	29	57.1738			23	48.1382		

after 360 repetitions and was for all sequences lengths except 48. The results, as indicated in Tables 7(A) and (B), were virtually the same in both analyses, indicating no differences as a function of the stage of training. It was found that under conditions of equal repetitions of the sequences only the predictability variable significantly ($P < .01$) influenced acquisition performance and that sequence length was not a significant factor. These findings substantiate the statistical analyses made independently for the predictable and variable conditions and are supported by the data presented in Fig. 2. The practice effects, analyzed as blocks of 36 sequence repetitions, were highly significant ($P < .01$) as were all the interactions involving Blocks. The Blocks by Predictability and Blocks by Sequence Length interactions indicated differential effects of the independent variables on the acquisition rates. These interactions, as indicated by the significant Blocks by Predictability by Sequence Length two-way interaction, operated differentially over the second independent variable.

Analytical Measures

The hand-scoring of visicorder record is costly and time consuming; therefore, both subjects and trials were sampled. Records were scored for three subjects in each of the twenty experimental groups, or one-half the original sample. The error scores of these subjects at the end of training were representative of their respective group means. The trials

Table 7A

Summary of Analysis of Variance for
Equal Repetition Groups after 180 Repetitions

Source of Variance	df	SS	MS	F
Predictability (P)	1	398.2003	398.2003	44.93**
Sequence Length (S)	4	73.4989	18.3747	2.07^{ns}
P x S	4	53.9139	13.4785	1.52^{ns}
Between Subjects	50	443.1376	8.8628	
Blocks (B)	4	176.0466	44.0116	155.74**
B x P	4	50.9249	12.7312	45.05**
B x S	16	9.9941	.6246	2.21**
B x P x S	16	13.1224	.8206	2.90**
Blocks x Subjects	200	56.5178	.2826	
Total	299	1275.3565		

** Significant at .01 level

Table 7B

Summary of Analysis of Variance for
Equal Repetition Groups after 360 Repetitions

Source of variance	df	SS	MS	F
Predictability (P)	1	1042.2655	1042.2655	68.58**
Sequence Length (S)	3	103.4117	34.4706	2.27^{ns}
P x S	3	40.9722	13.6574	.90^{ns}
Between Subjects	40	607.8732	15.1968	
Blocks (B)	9	318.0082	35.3342	95.09**
B x P	9	50.5242	5.6138	15.11**
B x S	27	25.7010	.9519	2.56**
B x P x S	27	19.1626	.7097	1.91**
Blocks x Subjects	360	133.7750	.3716	
Total	479	2341.6936		

** Significant at .01 level

scored were selected as representing three different stages of acquisition, depending on the training criterion. For the equal practice criterion, trials 20, 60 and 100 were selected. For the equal repetitions criterion, the trials selected varied depending upon sequence length. They were, however, those trials where 2, 180 and 360 sequence repetitions were presented. For both criteria the three trials represented early, middle and late stages of training. The analytical measure which appeared to be the most consistent and descriptive of the tracking performance was the algebraic mean lead-lag score. This score represents the average response per target throughout a 48-target trial with leads scored positive and lags scored negative. The data presented in Fig. 3 are means for the three subjects plotted as a function of the stage of training.

Equal Practice Criterion

Predictable pattern. The data for the five predictable patterns showed an early lagging shifting to leading by trial 60, except for the 48 target sequence which continued to lag throughout training. At trial 100, the groups with 8 and 12-target sequences had made a slight reduction in lead magnitude and the 16 and 24-target sequences have shown moderate increases in leading. All sequences except the 48 are leading by 100 milliseconds or more at the end of training.

Variable pattern. The variable-pattern sequences also showed early lagging, except for the sequence of 12-targets

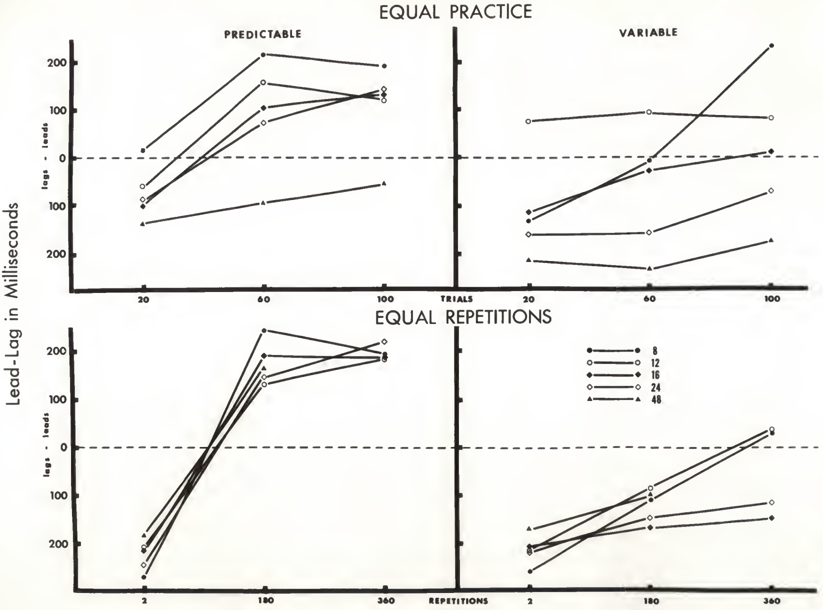

Fig. 3. Acquisition analytical measures of lead-lag for all groups at 3 stages of training.

which maintained a constant 75-100 millisecond lead throughout training. All of the sequence lengths have made reductions in the magnitude of lags by trial 100, but only the subjects on the 8-target sequence had obtained a substantial mean lead. The terminal levels differed greatly and were ordered as a function of sequence length.

Equal Repetitions Criterion

Predictable patterns. The sequences with predictable patterns all began with about a 200 millisecond lag. At the 180th repetition, subjects on all sequence lengths were leading by at least 100 milliseconds. After 360 repetitions they were all leading equally at about 200 milliseconds per target.

Variable patterns. The subjects on variable patterns all started with the same 200 millisecond lag and as training progressed tended to reduce magnitude. At 180 repetitions, lagging had been reduced by 50-100 milliseconds by all groups. After 360 repetitions, however, only the subjects on the 8 and 12-target sequences had eliminated lagging completely while the groups with 16 and 24-targets continued to lag by more than 100 milliseconds.

The analytical measures are based on small and unequal samples, subject to several sources of measurement error and involving large variance differences. Statistical analysis under these conditions would not enhance the descriptive function served by Fig. 3. The primary purpose in presenting the measures is to supplement the integrated error data with what appears to be a direct reciprocal correlate. This secondary source of information may aid in the interpretation of the other data.

Retention

An initial inspection of the error data at retention (Fig. 1 and Fig. 2) revealed that the scores for the five month interval were substantially lower than those for the three month interval. An analysis of variance performed on the mean scores for the first five retention trials, as shown in Table 8, confirmed this observation and indicated that the scores were significant ($P < .01$) lower for the longer retention period. Due to the peculiarity of this finding, with respect to previous empirical evidence and theory, a thorough examination of the data was made. It was discovered that not only did the five month group have lower retention scores; but also that 67 per cent of the subjects actually had scores lower than those obtained at the end of training. The anomaly of these results strongly suggested some source of unknown experimental error. The uniform nature of the lower scores hinted that all the groups in the second interval had been non-differentially affected. A recheck of the matching procedure, a sample analysis of the analytical scores for retention trials, and a review of experimental procedures all

Table 8

Summary of Analysis of Variance for All Groups on First 5 Retention Trials

Source of Variance	df	SS	MS	F	$F\cdot(\frac{ho}{n})$
Predictability (P)	1	77.8929	77.8929	59.858	54.47**
Sequence Length (S)	1	43.5356	10.8839	8.364	7.61**
Training Criterion (T)	1	4.4636	4.4636	3.430	3.12^{ns}
Retention Interval (R)	1	19.4013	19.4013	14.909	13.57**
P x S	4	8.7438	2.1860	1.608	1.53^{ns}
P x T	1	1.4018	1.4018		
P x R	1	.3619	.3619		ho=2.73
S x T	4	3.9247	.9812		$\frac{ho}{n}$=.91
S x R	4	6.5566	1.6392		
T x R	1	.1621	.1621		
P x S x T	4	2.0426	.5106		
P x S x R	4	6.1432	1.5358		
P x T x R	1	.5393	.5393		
S x T x R	4	3.6546	.9136		
P x S x T x R	4	1.9107	.4777		
Error	72	93.6911	1.3013		
Total	111	274.4258			

** Significant at .01 level

Ordered Sequence Length	12	16	8	24	48	
Group Means	4.74	4.97	5.32	5.39	6.55	$\text{lsd}_{.05}$ > .658

failed to reveal any systematic source of bias.

A failure to substantiate or reject the data as a true retention phenomena lead to the assumption that the most probable explanation was that some form of system error had been introduced which had distorted error scores for the five-month interval. A check indicated that various equipment modifications and adjustments were made during the period separating the two retention intervals which could have changed the gain on the error integration process. Such changes between the two periods could result in a systematic and proportional reduction in the integrated error scores for the second interval.

The result of such a system error would amount to subtracting a constant from each score in the five month interval. Such an operation would preclude any direct comparisons between retention intervals in terms of absolute losses, but would not interfer with valid statistical tests of the other experimental variables across the two intervals. The retention analyses were performed with these restrictions and reservations considered.

Integrated error data. The error scores for retention are based on the mean performance of three subjects for each of the 20 acquisition groups and are presented in Fig. 1 and Fig. 2, for both the three month and five month intervals. The subsamples for the two retention intervals were matched on the basis of mean integrated error scores for the last block of acquisition trials and each received 40 retention trials. The retention data are plotted as group means for the first ten retention trials.

An analysis of variance was performed on the mean error scores for the first five retention trials of all subjects in the two retention intervals. These scores are a more stable and reliable measure than the initial recall score and should provide a more adequate evaluation of the effects of the experimental variable upon retention. All F ratios in this analysis were corrected for unequal samples sizes resulting from missing observations (Li, 1957).

As indicated in Table 8, the experimental variables of predictability and sequence length were highly significant ($p < .01$) factors in retention. The training criterion, however, had no significant influence on retention performance. The significance ($p < .01$) F ratio for retention intervals, as previously indicated, is viewed as a system error artifact. The analysis of variance indicated that there was no significant interactions between the independent variables. A Fisher's lsd was calculated to test the differences among the means of the five sequences lengths. No differences were found among the mean retention scores of the 8, 12, 16 and 24-target sequence groups but all four differed significantly (Table 8) from the sequence of 48 targets.

DISCUSSION

Acquisition. The major finding of the study was that during acquisition the length of a sequence had a significant effect on the terminal performance of a sequential tracking task when the training criterion was equal practice. However, the sequence length was not a significant factor when the training criterion equated the number of repetitions of the sequences regardless of lengths.

The equal practice training criterion (i.e., equal number of trials, targets track and time in training) provided the shorter sequences with more repetitions, per unit time, than the longer sequences and therefore the opportunities for learning were greater for the shorter sequences. In the predictable patterns, this sequence length difference was reflected primarily in the acquisition rates. The variable patterns, however, showed a marked effect of sequence length throughout training and after five days the performance levels varied greatly and appeared to be largely a function of sequence length (Fig. 1).

Since sequence length obviously affects the performance of both degrees of predictability and since there was no significant interaction between the two variables in the equal practice training condition (Table 4), it appears that sequence length may be a crucial tracking variable. The results are similar to those found by Trumbo, Noble and Ulrich (1965), using equal practice for three sequence lengths. However, because of the unequal repetitions it seems doubtful that these results indicate anything about the general relationship of sequence length to task difficulty.

When sequences of different lengths receive equal repetitions the performance differences diminish. When the predictable pattern data were plotted in equal repetition units the acquisition rates of different sequence lengths appeared more similar. There was no significant differences in performance (Table 5 and Table 6) between sequences, either after 180 repetitions or 360 repetitions; however, the Blocks by Sequence Length interactions were significant (Tables 7A and B) indicating that the various sequence lengths yield differential acquisition rates. Thus, it appears that when all sequence lengths receive equal repetitions terminal performance is not effected but the length of the sequence primarily effects the rate at which this performance level is obtained.

When the data is compared to that of verbal learning the results appear quite similar. It will be recalled that when Deese replotted Lyon's data as if the number of repetitions was proportional to time that the total number of repetitions increased with the longer lists but the number of repetitions per item actually decreased. Thus the number of repetitions per item required to reach a common criterion became less as the length of the list was increased. In Fig.4A the number of repetitions per target required to reach a common integrated error voltage was plotted for the sequences of varying lengths. The function is very similar to that obtained by Deese and tends to support his conclusion that, "the net result of these studies is to make it probable that the increase in amount of work (time or trials) to criterion is not disproportionate to an increase in amount of material, except possibly in the transition from the immediate memory span to longer lists" (Deese, 1958, p. 212). A second point of correspondence with verbal data is related to Thurstone's equation that number of repetitions increases as the square root of the number of items in the list above the attention span. The data presented in Fig. 48 represent the total number of repetitions required to reach a common error voltage score as a function of sequence length. As can be seen, the fit of the empirical data to Thurstone's theoretical equation is quite good with the exception of the 8-target sequence. Thurstone indicated that, "it is quite probable that our rationalization of the adaptation constant is only a rough approximation so that perfect agreement for the short lists near that of the attention span is not to be expected" (Thurstone, 1930, p. 50). Thus, the data obtained with a sequential tracking task seems to yield results similar to those obtained with serial verbal tasks.

The overall lower error scores of the predictable patterns as compared with the variable patterns in both training conditions was anticipated in view of previous work concerning task coherency, or predictability (Trumbo, Noble, Cross and Ulrich, 1965). Predictability facilitates the perceptual

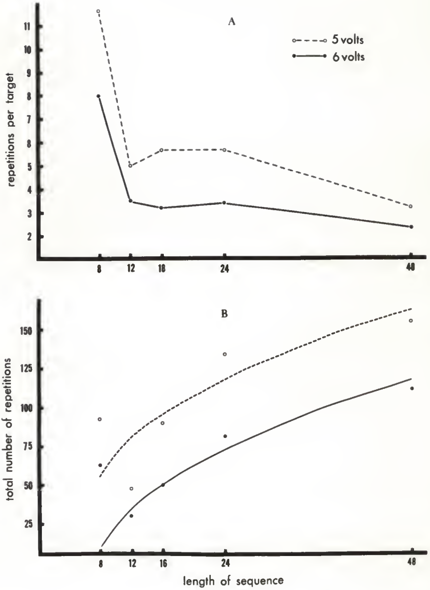

Fig. 4. Equal-repetitions-predictable pattern data for equal error score criteria. Data points represent mean values for 6 subjects in each sequence length group (A) Average number of repetitions per target required to reach successive error criteria. The data points are obtained by dividing the total number of repetitions of the sequence by the number of targets in the sequence. (B) Total number of repetitions required by the various sequence lengths to reach successive error criteria. The data points represent empirical values; the curves are derived from Thurstone's theoretical equations (see text).

anticipation which is necessary for optimal performance in this type of task. The predictable patterns are completely invariant from repetition to repetition of the sequence and therefore enable the subject to correctly anticipate each target change once the sequence is learned. Although the variable patterns consist of only 25 per cent random targets, performance often shows a disproportionately greater integrated error. The subjects are not only prevented from correctly anticipating the variable targets but the correct anticipation of subsequent predictable targets may be interfered with, since the response must originate from a different and randomly selected spatial location each time. Such variation in response amplitude, with temporal conditions remaining constant, has been suggested by Adams and Creamer (1962) as having a disrupting effect upon timing through what they refer to as changes in "anticipatory proprioceptive stimulation."

The performance differences between the predictable and variable patterns resulting from the limitation on the extent of perceptual and proprioceptive anticipation was most evident in the lead-lag index (Fig. 3). In both training conditions the Ss on the predictable patterns showed a transition from lagging to leading about midway through the training phase. Ss on the variable patterns were still lagging half way through training and, in general, were not leading even by the end of training. The lead-lag index appeared to be closely related to integrated error scores.

The lead-lag index also showed the same effects of sequence length as were found in the error data. With equal practice, the differences in temporal responding for the various sequence lengths were quite marked, and, after five days, response timing appeared to be a function of the length of the sequence. The lead-lag index for the equal repetition condition showed considerable similarity in the response timing of the different sequences lengths throughout training.

The errors scores of the variable 8-target sequences, which appear to be unusually high show no aberrancy in the temporal data. There were also no differences found in spatial accuracy. A failure to find evidence of sampling error and the systematic nature of the performance in both training conditions seems to indicate a true phenomena. Apparently the variable elements in a shorter sequence have a peculiar interference effect which does not exist in the longer sequences. Further research is required to confirm and isolate this effect.

In summary, the acquisition data indicated that the decrement in tracking performance resulting from increasing sequence lengths is limited to a restricted set of conditions, viz., the training to an equal practice criterion. It is reasonable to assume that any task which is repeated more times should be learned better and that a shorter task will be learned faster. Since learning of the sequence is a prerequisite for perceptual anticipation, and hence optimal tracking proficiency, the shorter sequences have a distinct advantage under the equal practice criterion. Such conditions, however, do not indicate that the performance decrement is the result of increasing task difficulty.

When sequences of different lengths are given equal repetitions, the longer sequences have an equal opportunity for being learned. Under these conditions no significant terminal performance differences were found between the various sequences and only acquisition rates showed a sequence effect. This suggests that, in a sequential tracking task, an increase in the task length has a similar effect on repetitions required to learn as is found in verbal learning. The results offer support for Deese's (1958) finding that longer tasks actually require fewer repetitions per item to reach an equal learning criterion. In this task, sequences of different lengths obtained comparable tracking proficiency after receiving an equal number of repetitions. The relationship of length of sequence to number of repetitions required to learn was a close approximation to Thurstone's theoretical equation. Thus, it appears that the underlying processes and laws of verbal and motor learning are quite similar.

Retention. The experimental artifact which is presumed to have reduced the retention scores for the five-month retention interval precludes any discussion of retention differences between the two intervals of three and five months. However, since the analysis of variance (Table 8) performed on the mean retention scores for the first five retention trials indicated no significant interactions between the variables in retention, no serious restrictions are placed on the interpretation of the other experimental variables and their effects on retention in general.

One of the principle retention findings was that the training criterion was not a significant retention variable. The levels of performance during acquisition generally showed little difference between the two training criteria (Fig. 1 and 2) other than the variability between sequences. This finding suggests that the losses during periods of no practice were not differential and that mean retention performance was generally comparable under the two conditions.

Sequence length, which was only significant for the equal practice criterion in acquisition, was found to be a significant retention variable. However, a comparison of the sequence means indicated that the only significantly different sequence length was the 48-target sequence. This group had never reached comparable performance in acquisition because even under the equal repetitions criterion they received only 180 repetitions. The non-significance of the Sequence Length by Training Criterion interaction in retention suggests that the performance differences present in acquisition were either eliminated in retention or that changes in variability and sample size prevented their detection. The predictability variable remained significant in retention. The large acquisition performance differences between the predictable and variable patterns were apparently too great to be removed by no practice. Earlier work (Trumbo, Noble, Cross and Ulrich, 1965) had found differential retention losses corresponding to task predictability with the higher degree of coherency showing the greater losses. This was attributed primarily to the transient nature of temporal accuracy in which the predictable patterns excel. The tenous observation of the data indicated that such a differential loss may have occurred; however, the overall losses were smaller and not of sufficient magnitude to overcome the initial acquisition differences. It is obvious that even in retention, the difference between having 100 per cent as opposed to 75 per cent of the targets invariant may be sufficient to cause a significant performance difference; even with only a slight differential retention decrement.

In summary, the retention data seems to indicate that the primary training variable which influenced retention was task coherency or predictability and that training criterion and sequence length were not major factors in determining how well a sequential tracking task was retained.

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APPENDIX

Appendix A

One Example from the Three Patterns Constructed for Each of the Five Sequence Lengths and Two Degrees of Predictability

Target No.	8		12		16		24		48	
	F	V	F	V	F	V	F	V	F	V
	Position		Position		Position		Position		Position	
1	7	7	7	7	7	7	7	7	7	7
2	6	6	3	3	5	5	10	10	13	13
3	12	12	11	11	3	3	12	12	1	1
4	10	(r)	4	(r)	14	(r)	4	(r)	2	(r)
5	1	1	12	12	2	2	1	1	3	3
6	11	11	13	13	8	8	11	11	1	1
7	2	2	0	0	12	12	9	9	10	10
8	0	(r)	6	(r)	11	(r)	12	(r)	2	(r)
9			8	8	3	3	5	5	4	4
10	repeated		5	5	13	13	11	11	10	10
11	6		1	1	4	4	14	14	4	4
12	times		9	(r)	1	(r)	0	(r)	12	(r)
13					0	0	6	6	0	0
14			repeated		6	6	8	8	14	14
15			4		10	10	14	14	6	6
16			times		9	(r)	6	(r)	13	(r)
17	$\bar{x}$ 5.6						0	0	9	9
18					repeated		9	9	2	2
19					3		13	13	13	13
20					times		8	(r)	8	(r)
21			$\bar{x}$ 5.5				3	3	3	3
22							5	5	12	12
23							2	2	4	4
24							13	(r)	12	(r)
25					$\bar{x}$ 5.2				0	0
26							repeated		5	5
27							2		11	11
28							times		0	(r)
29									9	9
30									10	10
31									14	14
32									3	(r)
33							$\bar{x}$ 5.5		11	11
34									5	5
35									8	8
36									6	(r)
37									11	11
38									5	5
39									14	14
40									1	(r)
41									8	8
42									9	9
43									6	6
44									1	(r)
45									6	6
46									13	13
47									14	14
48									9	(r)
									$\bar{x}$ 6.1	

$\bar{x}$ is average number of positions traveled per target

AN ANALYSIS OF THE EFFECT OF SEQUENCE LENGTH ON THE ACQUISITION AND RETENTION OF A SEQUENTIAL TRACKING SKILL

by

JAY RUXFORD SWINK

B.A., University of Wichita, 1963

AN ABSTRACT OF A MASTER'S THESIS

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The primary purpose of this study was to determine the effect of the sequence length variable on the acquisition and retention of a one-dimensional sequential pursuit tracking task. The interactions of the sequence length variable with the variables, task predictability, training criteria, and retention interval were also assessed in a 5 x 2 x 2 x 2 complete factorial design.

The length of a sequence of targets in a tracking task was used to investigate the relationship between amount to be learned and task difficulty. A review of the literature indicated that an increase in the length of a task has generally been found (i.e., particularly in verbal learning) to disproportionally increase task difficulty, hence total learning time. However, there was evidence which suggested that increasing length may not involve an increase in the number of repetitions required to learn.

In this study 120 male college students were trained in the tracking of a sequential pattern of targets either 8, 12, 16, 24 or 48 targets long. One-half of the 24 subjects assigned to the five sequence lengths received an equal practice training criterion for 5 days, while the other half received equal repetitions training (360 repetition of the sequence regardless of length). The subjects were further divided with half (n=6) tracking a pattern which was 100 per cent predictable (i.e., the target sequence was invariant from repetition to repetition of the sequence) while the remaining half received patterns with only 75 per cent repeating targets and 25 per cent randomly selected on each repetition. At the end of training the six subjects in each group were divided into two matched groups for tests of retention after three and five months of no practice, respectively.

The results indicated that sequence length had a significant effect on tracking performance only under training conditions of equal practice. Tracking proficiency appeared to be a function of the length of the sequence with better performance on the shorter sequences. However, when subjects received an equal number of repetitions, regardless of sequence length, there were no significant terminal performance differences attributable to sequence length and only acquisition rates were effected. Task predictability was a significant variable in both training conditions with the 100 per cent predictable patterns achieving higher levels of performance. There was no evidence of an interaction between Task Predictability and Sequence Length under either training criterion, indicating that sequence length effects are non-differential across conditions of task predictability. The overall performance levels were comparable for both training conditions.

An experimental artifact prevented a comparison of the two retention intervals. However, analysis of the effects of other variables on retention in general indicated that task predictability was the principle factor affecting retention scores. The analysis indicated the completely predictable pattern continued to yield better performance after three and five months of no practice than the patterns containing variable elements. Sequence length was found to be significant, but the performance differences were restricted to the longest sequence (48) which did not receive equivalent training even under the equal repetitions criteria. The training criterion was not found to be a significant retention variable. There was no evidence of any significant interactions among the experimental variables during retention.

The major finding of this study was that in a sequential tracking task there was no evidence that increasing sequence length increases task difficulty when all sequences received equal repetitions. These findings are similar to various results in the verbal learning literature which cast doubt on the commonly accepted principle that increasing amounts of material causes a disproportionate increase in task difficulty.