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LONG-TERM RETENTION OF A SIMPLE MOTOR SKILL

by

Douglas Ammons

B.A., 1983, University of Montana

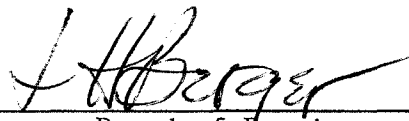
Presented in partial fulfillment of the requirements for the degree of

Master of Arts


UNIVERSITY OF MONTANA

1988

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Chairman, Board of Examiners


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ABSTRACT

Ammons, Douglas, Masters, 1988

Psychology

Long-term retention of a simple motor skill

Director: Laurence H. Berger

Historically in motor skills research, there has been an emphasis on acquisition and limited work on retention. Recent reviews by Adams (1987) and Schendel, Shields, and Katz (1978) summarize the empirical retention research as vague, qualitative "principles," which do not integrate retention results with acquisition phenomena. The present study describes pursuit rotor retention over a much longer period than any previous research. Thirteen subjects who had taken part in an earlier rotary pursuit acquisition study were retested an average of 15.5 years after original practice. Matched age control groups were given the same amount of acquisition practice and retested after a one-week retention interval, so that all subjects had the same amount of total practice but differed in length of retention interval. The results provided data for testing and revising two principles of retention: (i) forgetting increases as a positive function of the retention interval; (ii) relearning is more rapid than the original learning. It was found that subjects retested after a 15.5 year period of no practice perform much like naive subjects, with essentially a slow, linear increase in performance during initial continuous practice. After the first rest, performance jumps in one large increment up to the performance pattern and level of the control groups, but shows more rapid decrement in the later parts of the practice period. A reinterpretation of these and other retention phenomena as schedule-induced differences in performance was made, showing that forgetting is simply the decay in reminiscence over long periods of time and not the decay of learning. Apparent losses in performance upon initial retest measure merely the predictable changes in reminiscence as its reappearance is depressed by the continuous or highly massed retest conditions, and rapid "relearning" to previous acquisition levels is simply the predictable reappearance of reminiscence after the first postrest practice during retesting. Four principles of pursuit rotor performance are stated and used to describe retention phenomena in terms of acquisition phenomena. Finally, some preliminary suggestions are made for the extension of Kimble's theory of skill acquisition.

Preface

For the best and safest method of philosophizing seems to be, first diligently to investigate the properties of things and establish them by experiment, and then to seek hypotheses to explain them. For hypotheses ought to be fitted merely to explain the properties of things and not attempt to predetermine them except in so far as they can be an aid to experiments. If anyone offers conjectures about the truth of things from the mere possibility of hypotheses, I do not see how anything certain can be determined in any science; for it is always possible to contrive hypotheses, one after another, which are found rich in new tribulations. Wherefore I judged that one should abstain from considering hypotheses as from a fallacious argument, and that the force of their opposition must be removed, that one may arrive at a maturer and more general explanation.

Isaac Newton, Letter to Henry Oldenberg,
1672, quoted in Opticks, pg. xxiv

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Introduction

The field of perceptual-motor skills acquisition has historically included a huge number of empirical studies and several rigorous theoretical treatments. The same is not true for the study of perceptual-motor skills retention. Researchers and theoreticians of motor skills have been overwhelmingly concerned with relatively small amounts of practice and rest intervals of less than several hours (Bilodeau & Bilodeau, 1961, p. 259). For example, in the past 50 years there have been many hundreds of articles reporting systematic research on the acquisition of the rotary pursuit skill (for reviews: Adams, 1964; Ammons & Ammons, 1970; Bilodeau & Bilodeau, 1961; Irion, 1969) but only four scattered studies of retention over periods greater than six months using this apparatus (Bell, 1950; Eysenck, 1960; Koonce, et al., 1964; Smith, 1971). This pattern holds generally for the entire field of perceptual-motor skills research; among the thousands of articles published on various aspects of skill acquisition since 1920, there are only eleven empirical studies of retention over no-practice periods longer than three months and up to a maximum of two years (Ammons, et al., 1958; Battig & Nagel, 1957; Fleishman & Parker, 1962; Jones & Bilodeau, 1953; Mengelbach, Adams, & Gainer, 1971; Meyers, 1967; Roehrig, 1964, plus the four cited above; See Appendix 1 for a brief review of the major studies; See also Adams, 1987, Schendel, Shields, & Katz, 1978; Stelmach, 1974, for more extensive reviews).

Although at least five fairly systematic theoretical developments dealing with skill acquisition exist (Adams, 1971; Ammons, 1947a, 1947b, 1950; Eysenck & Frith, 1977; Kimble, 1948, 1949a, 1949b; Schmidt, 1975), the rigorous treatment of skill retention as a theoretical issue remains unattempted within these or any other framework. There has not as yet been

any thorough discussion of or even relatively systematic speculation concerning these long-term retention studies' findings in terms of existing theoretical concepts.

Reviewers have attributed the few studies and lack of significant theoretical development to (1) the technical difficulties of such long-term experiments (Bilodeau & Bilodeau, 1961); (2) an emphasis on applied research directed toward the solution of specific problems to the exclusion of theory, e.g., the military's interest in and funding of research on the retention of flying skills (Adams, 1964); (3) the historical treatment of retention under separated headings of "trace decay" and "interference" forgetting, and not as an issue related to skills acquisition (despite the close relationship between acquisition and retention); (4) the fairly consistent large retention demonstrated by continuous tracking skills (such as rotary pursuit) over retention periods up to two years (Bilodeau & Bilodeau, 1961). It is claimed that this last characteristic has made theoretical development of little interest (Stelmach, 1974). Adams (1987) gives the current assessment: "(recent) reviews of the retention of motor skills underscore the impression that long-term motor retention is a domain empty of productive ideas and in which only a little research is being done" (pp. 64-65).

Such statements give the impression that Adams and the other reviewers think that retention is either well understood and precisely described or is a trivial phenomenon. This is a peculiar point of view. Consider the statement by Adams, following his above dismissal of the field of retention, of two "established principles" of retention:

- (1) Forgetting increases as a positive function of the retention interval.
- (2) Relearning is more rapid than the original learning (Adams, 1987, p. 65).

Vague, qualitative statements such as these may commonly pass for "principles" in psychology, but in rigorous science they are not normally considered an adequate account and are unsatisfactory if one is interested in predictive precision. They are especially unsatisfactory if they are wrong.

The preceding discussion points to several problems, the few existing retention studies seem only to have led to imprecise, qualitative "principles" of retention phenomena, and these principles have not been related to acquisition phenomena in any way. As one of the major objectives in science is the precise theoretical description of a group of related phenomena, it seems only logical that the existing empirical findings in the retention of motor skills should not be left as separated results, unrelated to each other, or theoretically unassimilated into theories of acquisition. But given the imprecise state of the findings to date, an essential step preceding these developments should be a more systematic study of the empirical characteristics of the phenomena, providing more accurate descriptions and assessing the accuracy of previously accepted "principles" or developing new principles. Once these steps are accomplished, it will be possible to sketch an extension of one or more of the existing theories of acquisition mentioned above to accommodate retention phenomena. This paper

- (1) Describes the specific pattern of the reacquisition of a continuously practiced motor skill after an extremely long period of no practice;
- (2) Evaluates the above "general principles" with respect to this long retention period:
 - (i) Forgetting increases as a positive function of the retention interval,

- (ii) Relearning is more rapid than the original learning;
- (3) Describes consistencies between acquisition and retention phenomena, which may later be used to extend existing theories of skill acquisition to include long-term retention;
- (4) States the postulates of Kimble's (1948, 1949a, 1949b) theory of pursuit rotor acquisition and sketches some preliminary changes in them required by the retention findings.

METHOD

Subjects

These were three groups of subjects, an "older" control, a "younger" control, and a "retention" group.

"Younger" control subjects were 13 naive, right-handed males aged 18 to 22 years ($\underline{M} = 20.4$ years, $\underline{S} = 1.6$). All were enrolled in an introductory psychology class at the University of Montana and received course credit for participation.

"Older" control subjects were 13 naive, right-handed males aged 32 to 39 years ($\underline{M} = 35.2$, $\underline{S} = 2.5$). Three were enrolled in an introductory psychology class at the University of Montana and received course credit for participation. Ten other subjects were acquaintances of the experimenter, recruited by asking them to participate as a favor. No subject approached refused to participate.

"Retention" subjects were 13 right-handed males aged 33 to 39 years ($\underline{M} = 35.3$, $\underline{S} = 2.1$) formerly enrolled at the University of Montana. All had participated as naive subjects aged 18 to 22 years ($\underline{M} = 19.8$, $\underline{S} = 1.5$) in a rotary pursuit study 14 to 18 years previously. They were recruited by telephone call after first matching names of former subjects with names in the Missoula telephone directory. (See Appendix 2 for exact wording.)

Of 20 potential subjects called, three refused to participate and four more expressed interest in participating but could not arrange a meeting time. Mean retention interval was 15.5 years.

Apparatus

The apparatus was a single pursuit rotor with a black vinylite, 11-inch-diameter turntable, and a 3/4-inch brass target whose center was 3 $\frac{1}{4}$ -inches from the center of the turntable and flush with its surface. The stylus consisted of a wooden handle and a 6 $\frac{1}{2}$ -inch silver-tipped extension of 1/8-inch brass rod, hinged with approximately 100° free motion so that only the rod's weight (0.6 oz.) rested on the turntable. Stylus-target-circuit completion time was measured by two .001-minute Standard Electric timers used alternately to permit continuous recording of scores. Turntables were set to rotate at 60 rpm, and speeds were checked once before each subject was run and at least once during each practice period. There was never a change in rotation rate greater than one rpm. Stylus tips and targets were cleaned thoroughly with steel wool before each practice period.

Design

Two "age" control groups and one "retention" group were tested twice on the pursuit rotor task using the same practice conditions. The control groups were retested one week after acquisition, and the retention group was retested an average of 15 years after acquisition. The "younger" and "older" control groups were set up to assess possible age effects on rotary pursuit ability. The "younger" control group was matched in average age to that of the retention group at initial acquisition. The "older" controls were matched in average age to that of the retention group at retesting.

<u>Group</u>	<u>Acquisition Schedule (minutes)</u>	<u>Retention Interval</u>	<u>Retesting Schedule</u>
(1) Retention	8-5-8-5-8 *	15 years	8-5-8-5-8
(2) "Younger" age control	8-5-8-5-8	1 week **	8-5-8-5-8
(3) "Older" age control	8-5-8-5-8	1 week **	8-5-8-5-8

Procedure

Subjects were tested individually by the same experimenter. Each subject answered a 40-point laterality scale used for assessing handedness (See Appendix 3). "Right-handed" subjects gave eight or fewer "left-handed" answers. All acquisition and retest conditions were the same for all subjects and were those used in the original "Component Reliability Study" (See Appendix 3) from which retention subjects were drawn. In all conditions the 8-5-8-5-8 practice schedule was used, with practice being continuous at 60 rpm. Each eight-minute practice period was divided into 24 20-second timing intervals (trials), with cumulative time-on-target recorded for each interval.

RESULTS

Three methods of data analysis are used. Group mean performance scores are plotted by 20-second trial averages; i.e., trials one and two, trials three and four, trials five and six, and so on, are averaged and plotted, giving a curve formed by 12 points for each eight-minute (24-trial) practice period, for each group. (This averaging was done due to ANOVA considerations requiring the number of trials to be less than or equal to the number of subjects.)

* 8 minutes continuous practice, 5 minutes rest...

** The one-week retention interval was chosen to control immediate reminiscence gains which occur in the first five to 60 minutes after practice.

The heights and shapes of the group mean curves are visually compared and differences described. (The shape of the 12-point curves was not visually significantly different from the 24-point curves, in that the major phenomena of warm-up and decrement were still clearly present.)

The second method is a set of analyses of variance on raw scores assessing the level of statistical significance of the various differences and similarities between the group curves for each practice period, and for the initial practice (period one) and the first retest period (practice period four). Of specific interest are the comparisons between the control groups indicating the presence of age-related differences in performance between the controls' and retention group's performance levels and patterns as introduced by the retention interval and between the performance levels and patterns for each group on practice period four as compared to its initial period one naive performance.

The third method is the calculation of several "savings scores" from the curves of performance means, giving measures of "percent savings" over the retention interval. Several are used to compare the present study's results with those of two earlier studies.

As mentioned above, because there were only 13 subjects per group, an ANOVA could not be done on the complete 24-trial-per-practice-period raw data or on the overall raw data for all three groups and six practice periods. Instead, data were averaged by every two successive 20-second scores, giving 12 scores per practice period per subject. ANOVAS were done on each of these averaged data sets, comparing two groups at a time for each practice period.

Visual Characteristics of the Performance Curves (See Figure 1)

(1) The mean time-on-target curve shapes for practice periods one, two, and three are similar for each group. There is a slightly negatively

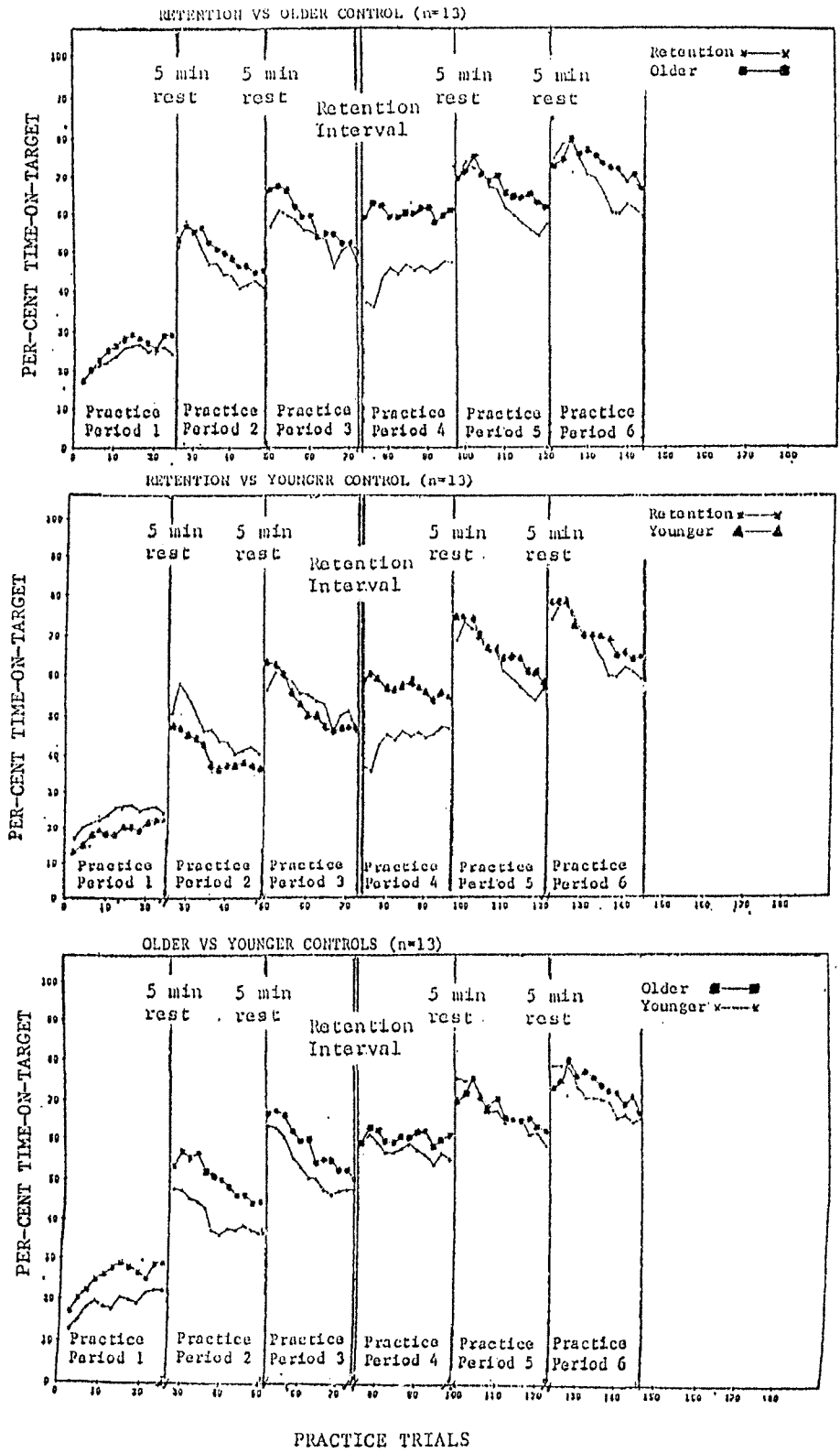


Figure 1. Comparisons of performance curves

accelerated increase in performance during practice period one and "standard" postrest performance during practice periods two and three, with a brief "warm-up" section, followed by a decremental section extending to the end of practice (See Appendix 4 for definitions).

(2) For each group there are substantial but diminishing overall increases in performance from practice periods one to two and periods two to three.

(3) There is a difference in amount of time-on-target between the curves for the control groups during the second and third practice periods and, to a lesser extent, between the control groups and the long-term retention group.

(4) The "younger" control group shows less warm-up than either the "older" control or the long-term retention group on practice periods two, three, five, and six.

(5) There is a large difference in shape and height of the performance curves between the control groups and the long-term retention group during practice period four, the first practice period after the retention interval. Both control groups have similar, almost flat performance curves upon retest after one week of no-practice, while the long-term retention group shows a linear increase in performance.

(6) On practice period four the long-term retention group's performance is very similar in shape to its performance during practice period one, but is higher.

(7) On practice period four both control groups' performance is very different in shape from their performance during practice period one. During period four they show warm-up and a slightly decremental section, while during period one there is a continually increasing, somewhat negatively accelerating pattern.

(8) The retention group shows a substantial overall decrease in average performance level on practice period four compared to practice period three, while the control groups' overall performance is approximately the same or slightly higher during period four as compared to period three.

(9) All groups have similar performance on practice periods five and six, with the long-term retention group's performance equal to that of the controls during warm-up but decreasing somewhat more rapidly during the later parts of practice.

Statistical Analyses

Two kinds of comparisons were made using a split-plot factorial design with repeated measures.

(1) ANOVAS for each pair of groups for each practice period separately, using data averaged in blocks of two successive 20-second scoring trials for each subject (12 points for each practice period), to evaluate differences in performance at various levels of practice due to age-related effects and between the retention and control groups due to the retention interval.

(2) ANOVAS for practice period one and four for each group, using data averaged as in (1) above, to evaluate the differences between performance level and pattern during initial, naive practice and during initial retest practice after the retention interval.

Results for ANOVAS done on pairs of groups
for each time period (See Figures 2-8, Tables 1-7)

(1) There are no main effects or interactions among any of the groups on practice period one.

(2) There is a significant main effect between the control groups on practice period two but no significant interactions.

TABLE 1

ANOVAs on Averaged Time-on-Target Scores:
Comparisons for Practice Period One

<u>Groups</u>	<u>Source</u>	<u>MS</u>	<u>df</u>	<u>F</u>	<u>p</u>
Retention vs Older (<u>n</u> = 13)	Between Groups	2898.7	1	.21	.65
	Trials	3190.4	11	8.16	<.01*
	Interaction	147.8	11	.37	.96
Retention vs Younger (<u>n</u> = 13)	Between Groups	20321.6	1	2.17	.15
	Trials	2289.4	11	5.22	<.01*
	Interaction	215.8	11	.49	.91
Older vs Younger (<u>n</u> = 13)	Between Groups	38570.4	1	2.56	.12
	Trials	2981.3	11	8.35	<.01*
	Interaction	281.7	11	.79	.65

* $p \leq .05$

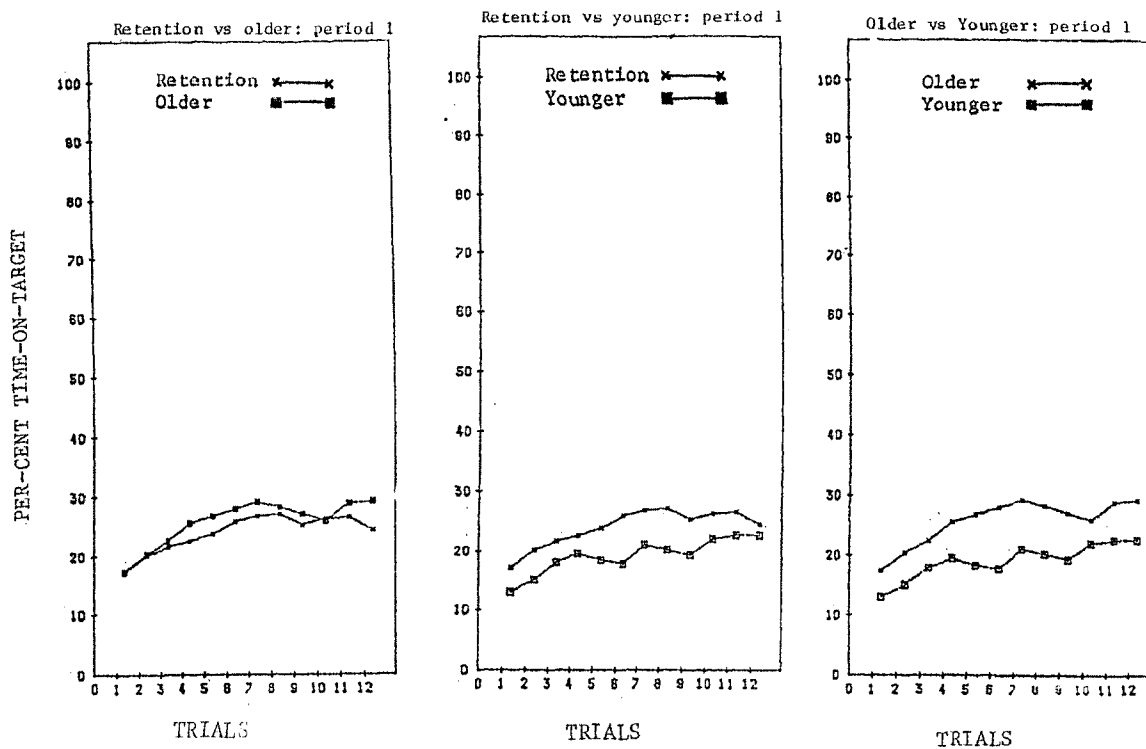


FIGURE 2. Group comparisons for practice period one.

TABLE 2

ANOVAa on Averaged Time-on-Target Scores:
Comparisons for Practice Period Two

<u>Groups</u>	<u>Source</u>	<u>MS</u>	<u>df</u>	<u>F</u>	<u>p</u>
Retention vs Older (<u>n</u> = 13)	Between Groups	12312.8	1	.97	.66
	Trials	6949.0	11	16.00	<.01*
	Interaction	270.0	11	.62	.81
Retention vs Younger (<u>n</u> = 13)	Between Groups	30188.3	1	3.20	.08
	Trials	6683.9	11	14.23	<.01*
	Interaction	421.8	11	.90	.54
Older vs Younger (<u>n</u> = 13)	Between Groups	81060.4	1	6.20	.02*
	Trials	5564.0	11	10.83	<.01*
	Interaction	465.9	11	.91	.53

* $p \leq .05$

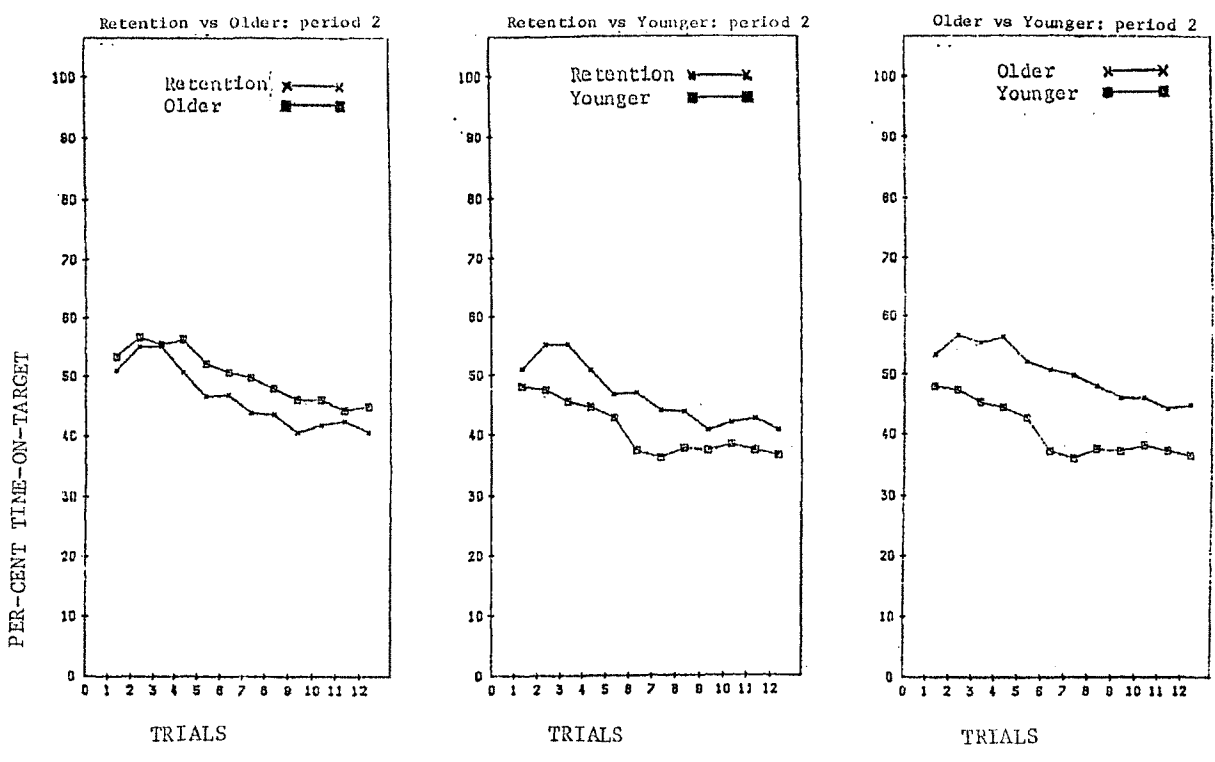


Figure 3. Group comparisons for practice period two.

TABLE 3

ANOVAs on Averaged Time-on-Target Scores:
Comparisons for Practice Period Three

<u>Groups</u>	<u>Source</u>	<u>MS</u>	<u>df</u>	<u>F</u>	<u>p</u>
Retention vs Older (<u>n</u> = 13)	Between Groups	15512.8	1	1.12	.30
	Trials	8190.6	11	17.79	<.01*
	Interaction	650.7	11	1.41	.17
Retention vs Younger (<u>n</u> = 13)	Between Groups	2139.4	1	.20	.67
	Trials	8378.0	11	20.85	<.01*
	Interaction	906.3	11	2.25	.01*
Older vs Younger (<u>n</u> = 13)	Between Groups	29174.0	1	2.94	.10
	Trials	11173.6	11	27.90	<.01*
	Interaction	286.5	11	.71	.73

* $p \leq .05$

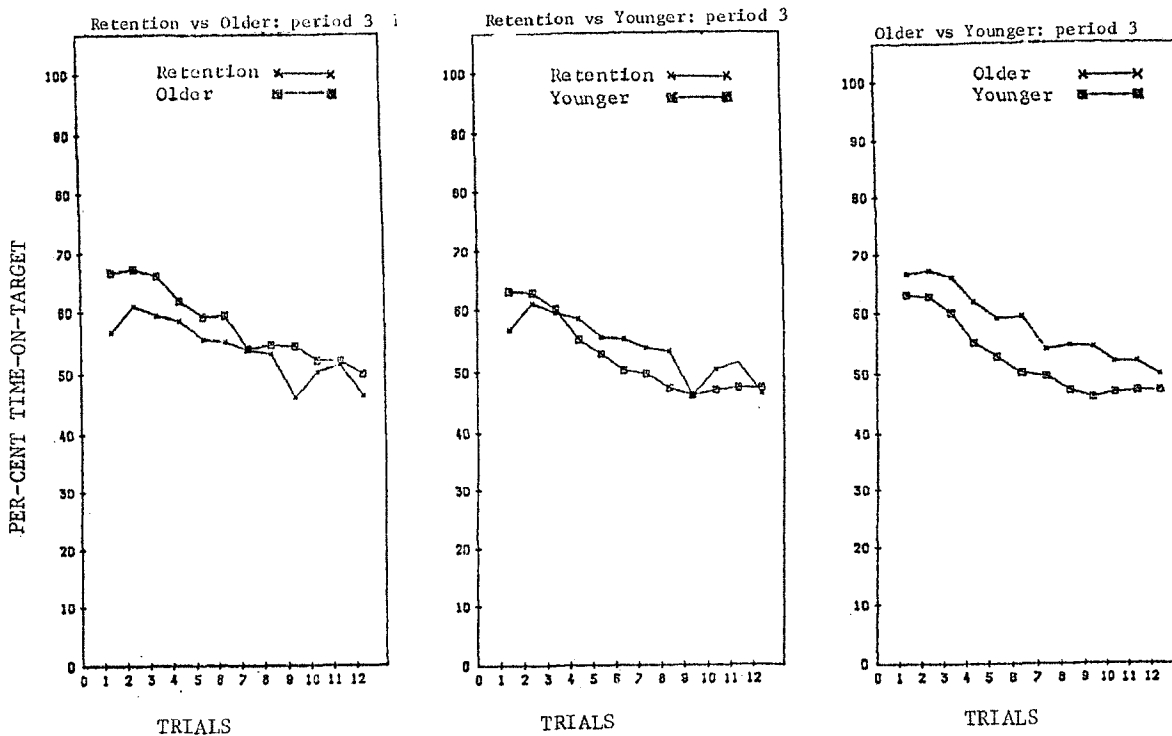


Figure 4. Group comparisons for practice period three.

TABLE 4
 ANOVAs on Averaged Time-on-Target Scores:
 Comparisons for Practice Period Four

Groups	Source	MS	df	F	p
Retention vs Older (n = 13)	Between Groups	230654.0	1	20.34	<.01*
	Trials	918.6	11	1.54	.12
	Interaction	1381.6	11	2.31	.01*
Retention vs Younger (n = 13)	Between Groups	144566.0	1	14.27	<.01*
	Trials	529.3	11	.77	.67
	Interaction	1991.1	11	2.91	<.01*
Older vs Younger (n = 13)	Between Groups	10007.3	1	.84	.63
	Trials	689.1	11	1.37	.19
	Interaction	200.4	11	.40	.96

* p ≤ .05

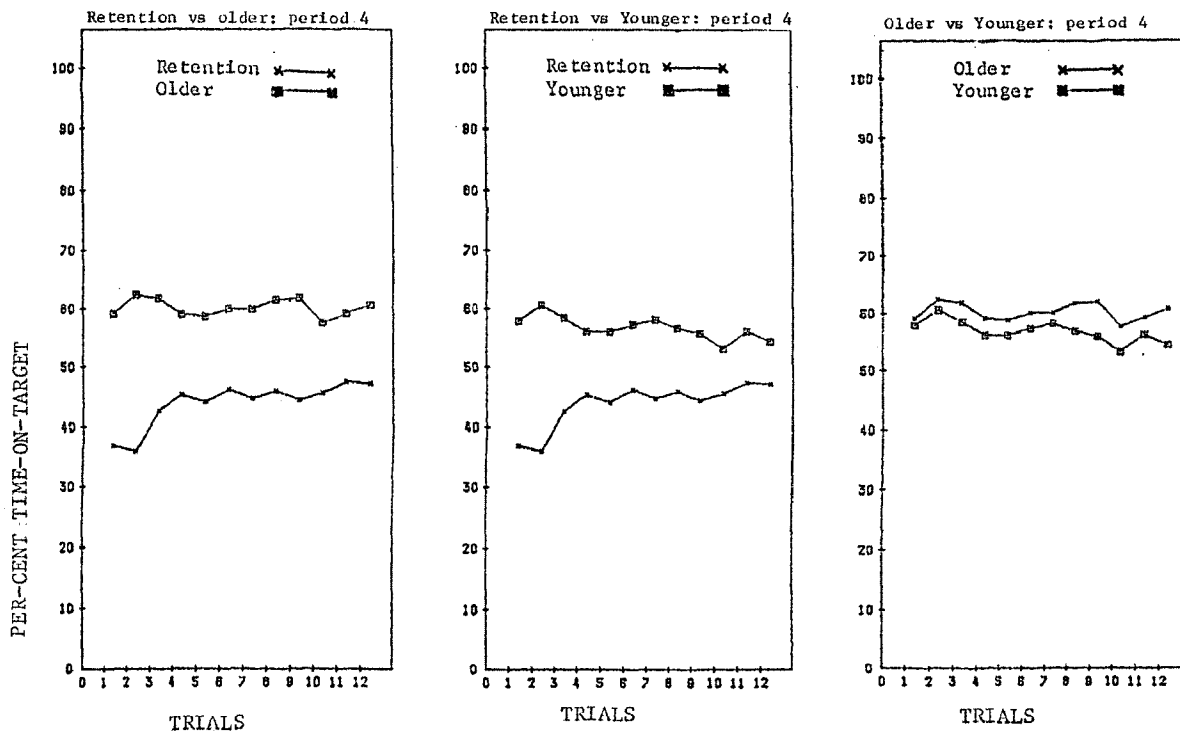


Figure 5. Group comparisons for practice period four.

TABLE 5

ANOVAs on Averaged Time-on-Target Scores:
Comparisons for Practice Period Five

Groups	Source	MS	df	F	p
Retention vs Older ($\underline{n} = 13$)	Between Groups	12250.1	1	1.88	.18
	Trials	8657.9	11	18.63	<.01*
	Interaction	1002.2	11	2.16	.02*
Retention vs Younger ($\underline{n} = 13$)	Between Groups	8442.7	1	1.39	.25
	Trials	11423.8	11	26.56	<.01*
	Interaction	701.0	11	1.63	.09
Older vs Younger ($\underline{n} = 13$)	Between Groups	353.3	1	.06	.81
	Trials	6670.2	11	16.07	<.01*
	Interaction	639.1	11	1.54	.12

* $p \leq .05$

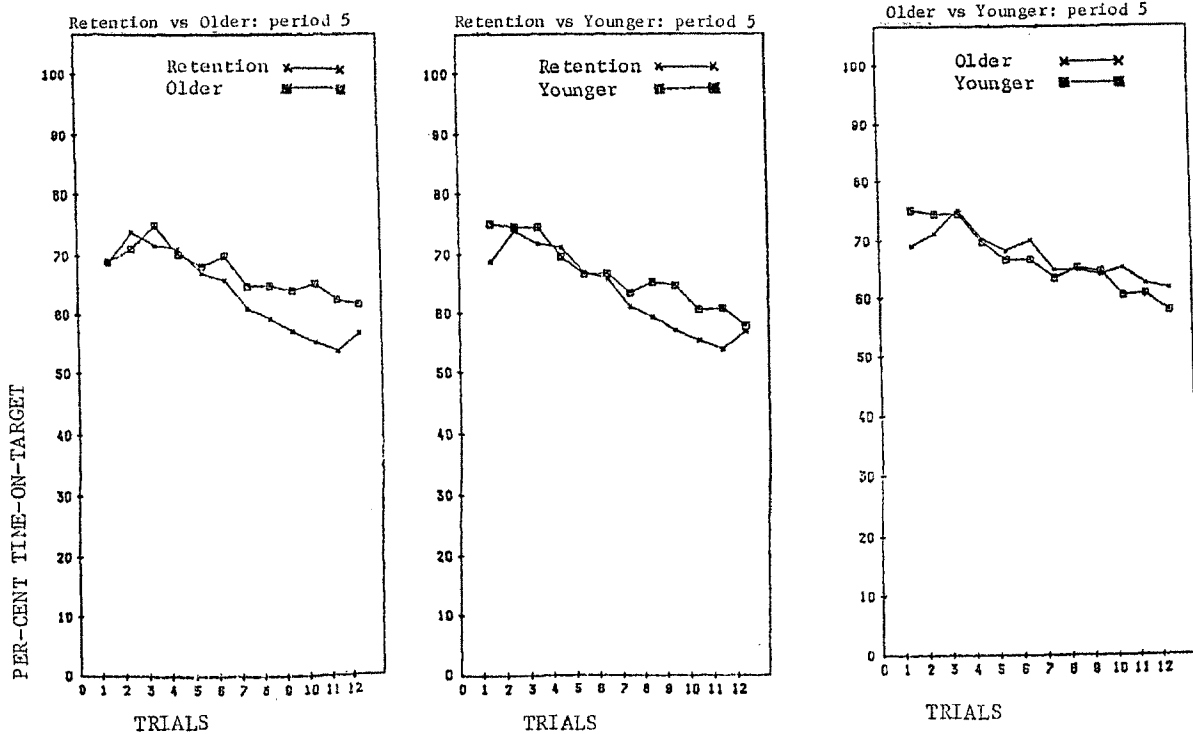


Figure 6. Group comparisons for practice period five.

TABLE 6

ANOVAs on Averaged Time-on-Target Scores:
Comparisons for Practice Period Six

<u>Groups</u>	<u>Source</u>	<u>MS</u>	<u>df</u>	<u>F</u>	<u>p</u>
Retention vs Older (<u>n</u> = 13)	Between Groups	25110.3	1	4.84	.04*
	Trials	8081.3	11	17.29	<.01*
	Interaction	1902.5	11	4.07	<.01*
Retention vs Younger (<u>n</u> = 13)	Between Groups	6878.9	1	1.10	.31
	Trials	11398.0	11	30.29	<.01*
	Interaction	729.6	11	1.94	.04*
Older vs Younger (<u>n</u> = 13)	Between Groups	5703.7	1	.78	.61
	Trials	4973.7	11	12.32	<.01*
	Interaction	1117.3	11	2.77	<.01*

* $p \leq .05$

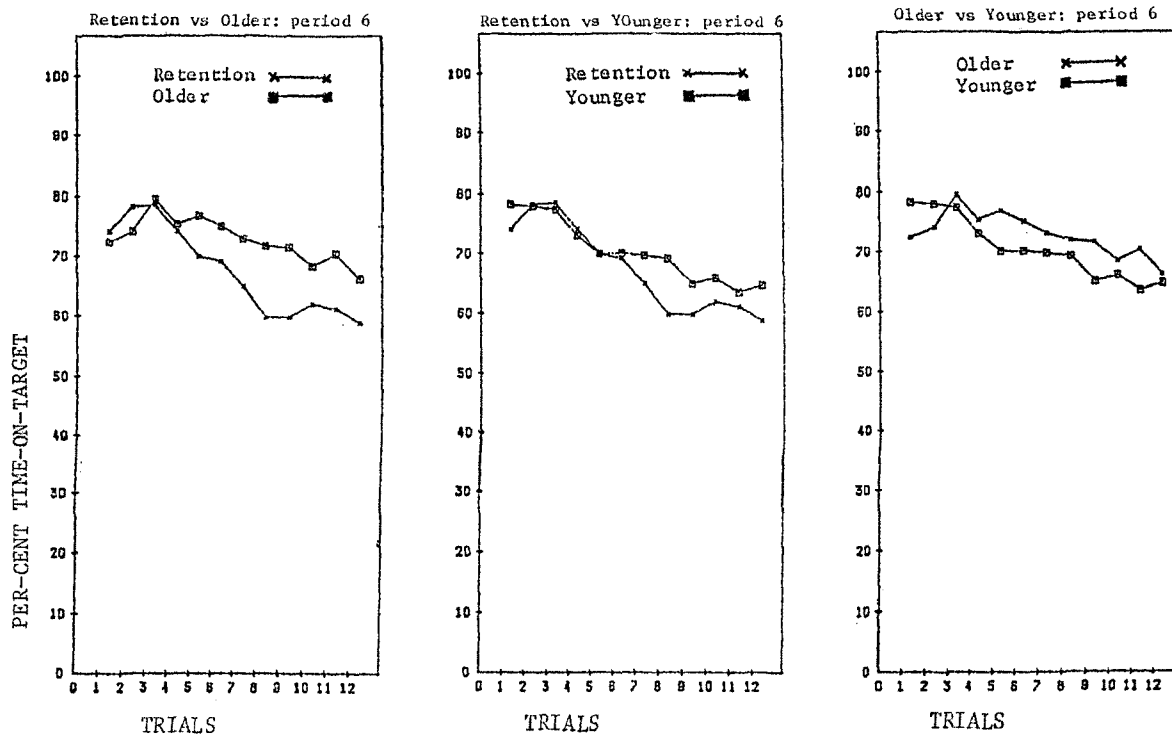


Figure 7. Group comparisons for practice period six.

TABLE 7

ANOVAs on Averaged Time-on-Target Scores:
 Comparisons for Practice Periods One vs Four

Groups	Source	MS	df	F	p
Retention: Period 1 vs 4 (\bar{n} = 13)	Between Periods	344869.0	1	39.45	<.01*
	Trials	2992.0	11	4.78	<.01*
	Interaction	263.8	11	.42	.95
Older: Period 1 vs 4 (\bar{n} = 13)	Between Periods	1027530.0	1	62.82	<.01*
	Trials	1108.6	11	3.06	<.01*
	Interaction	1274.1	11	3.51	<.01*
Younger: Period 1 vs 4 (\bar{n} = 13)	Between Periods	1232160.0	1	114.90	<.01*
	Trials	320.2	11	.64	.79
	Interaction	1449.7	11	2.92	<.01*

* $p \leq .05$

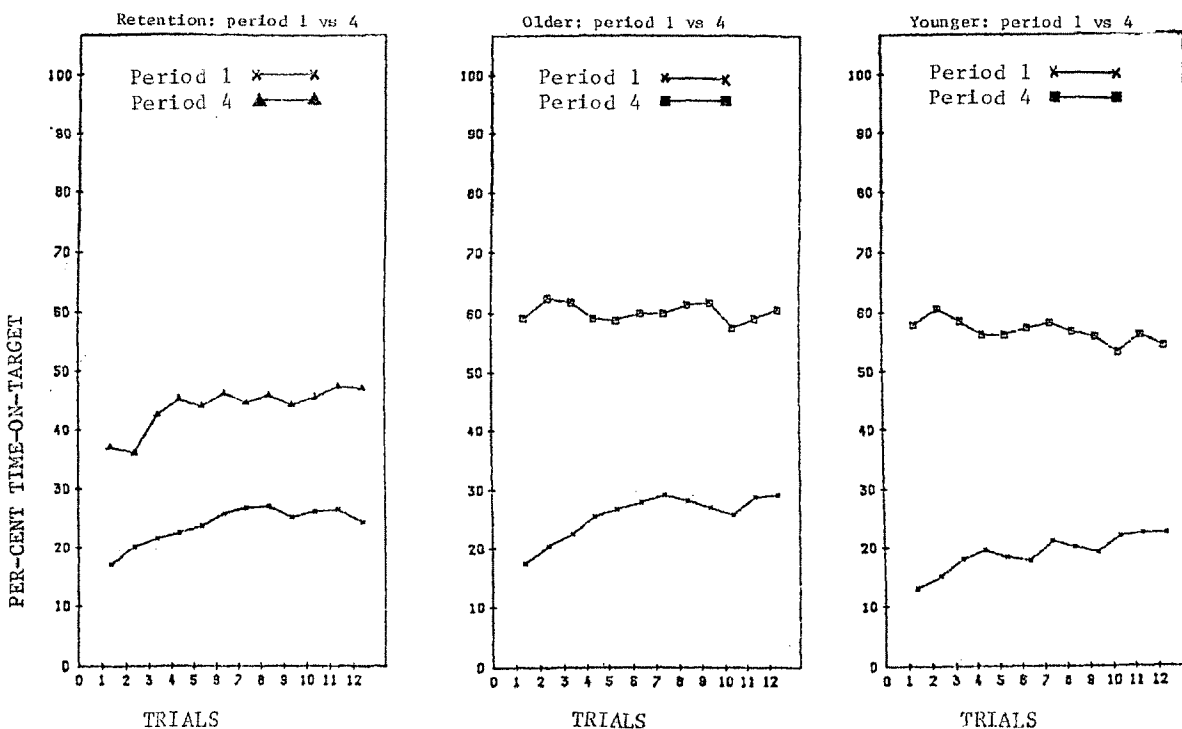


Figure 8. Comparison of practice periods one and four.

(3) There is no significant main effect among performances of any groups on practice period three, but there is a significant interaction between the performances of the retention group and the younger control group.

(4) The difference in warm-up during the first two minutes of practice between the younger control group and the other groups specifically produces two significant interactions--for retention group X younger control during practice period three, and for the older control X younger control during practice period six.

(5) There are significant main effects during practice period four between the performance of the retention group and each of the controls and a significant interaction for the retention group X older control, and the retention group X younger control.

(6) There is no significant main effect ($p = .627$) and no interaction ($p = .956$) between the two control groups during practice period four.

(7) Comparison of the retention group's performance during practice periods one and four shows a main effect and no interaction ($p = .945$).

(8) There are no main effects during practice period five, but there is one significant interaction for the retention group X older control.

(9) There is one significant main effect between the retention group and the older control during practice period six. (This arises from the retention group's increased decrement late in the practice period. That performance is greater than or equal to that of the older control for the first half of the practice period.)

(10) All the interactions for practice period six are significant.

Savings Measures

"Savings" retention measures give a simple ratio index of the amount of retention. The calculated ratios are normally multiplied by 100 to give "percent savings". There are a variety of savings measures used below, each emphasizing a different aspect of retention performance.

Longitudinal savings scores are calculated from the differences between the retention group's acquisition performance and initial re-test performance.

$$\begin{aligned}
 \text{(a)} \quad \text{savings} &= \frac{\text{Total practice time to reach maximum performance in acquisition} - \text{Total practice time during retest to reach acquisition maximum}}{\text{Total practice time to reach maximum performance in acquisition}} \\
 &= \frac{(8 + 8 + 1.3) - 8}{8 + 8 + 1.3} \\
 &= \frac{9.3}{17.3} = .54 \\
 \text{percent savings} &= (.54) \times 100 = 54\% \quad (\text{see Figure 9})
 \end{aligned}$$

$$\begin{aligned}
 \text{(b)} \quad \text{savings} &= \frac{\text{Total performance score for the first one-minute of the first retest practice period (Period 4)}}{\text{Total performance score for the first one-minute of the last acquisition practice period (Period 3)}} \\
 &= \frac{364.5}{576.0} \quad \begin{matrix} \text{(raw scores-)} \\ \text{.001 min.} \end{matrix} \\
 &= .63 \\
 \text{percent savings} &= (.63) \times 100 = 63\% \quad (\text{see Figure 10})
 \end{aligned}$$

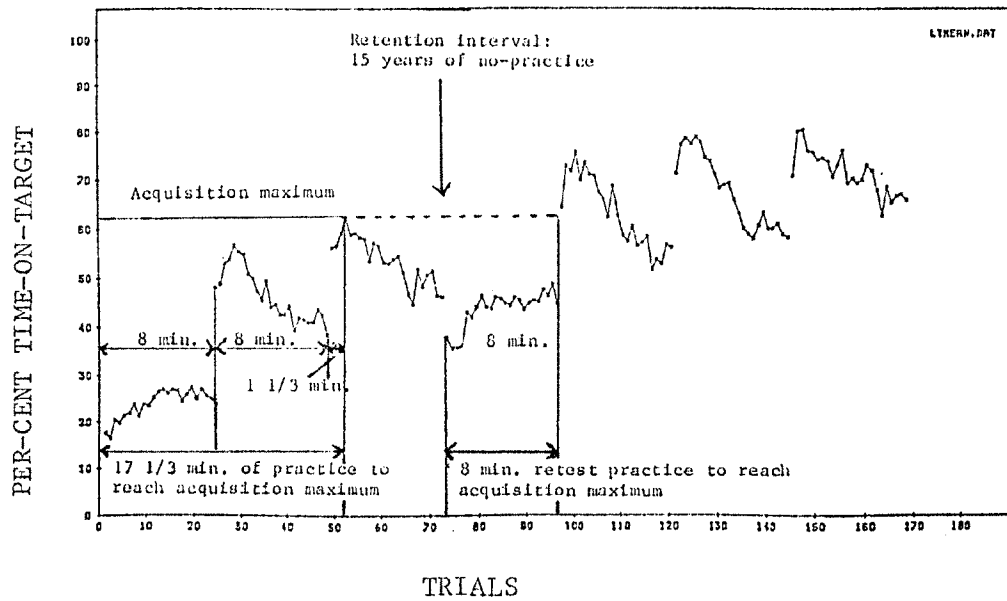


Figure 9. Retention group performance, calculation of savings score a.

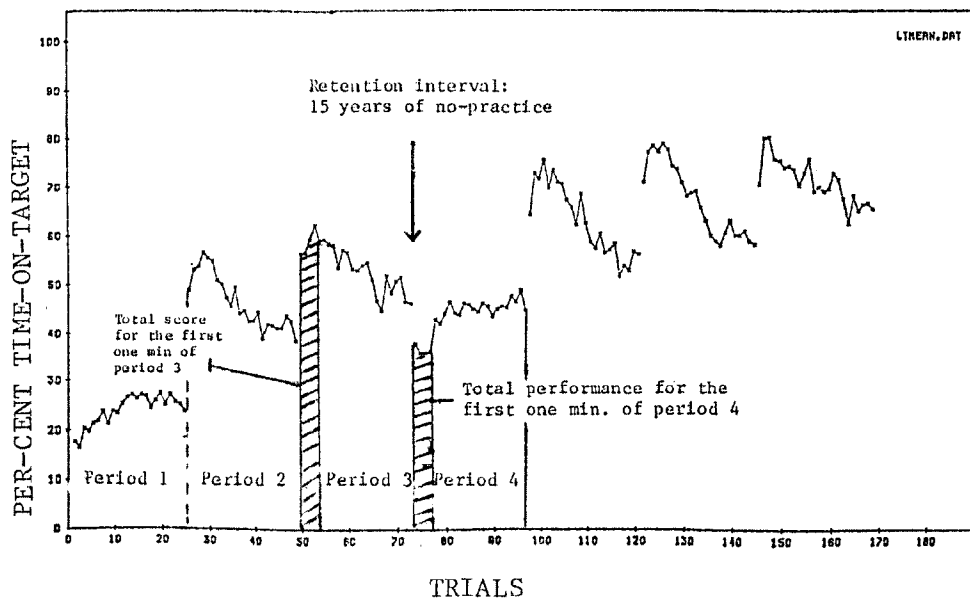


Figure 10. Retention group performance, calculation of savings score b.

(c)

$$\text{savings} = \frac{\text{Total performance score for the entire first eight-minute retest practice period (period 4)}}{\text{Total performance score for the entire last eight-minute acquisition period (period 3)}}$$

$$= \frac{3500.0}{4302.5} \text{ (raw scores- } \cdot 100 \text{ min.)}$$

$$= .81$$

$$\text{percent savings} = (.81) \times 100 = 81\% \quad (\text{see Figure 11})$$

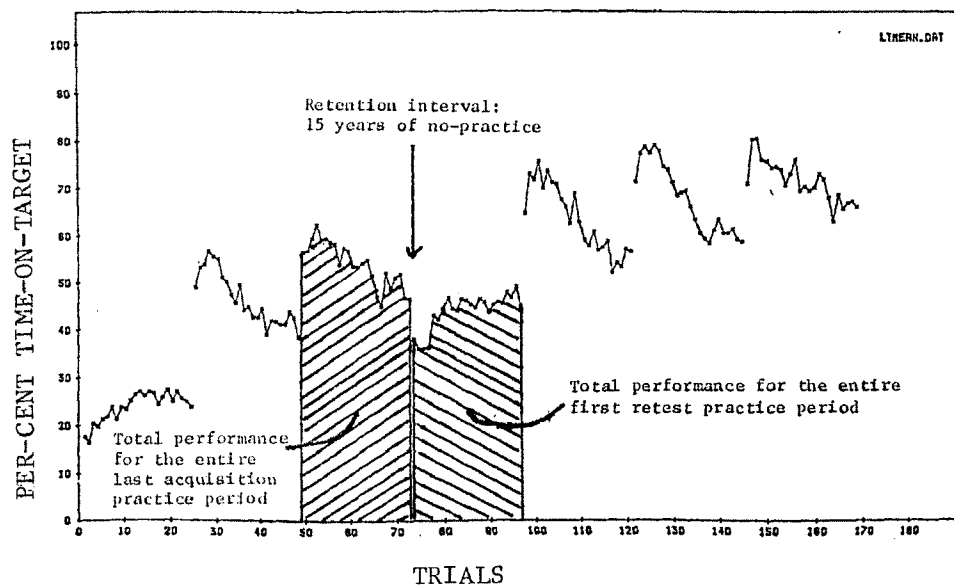


Figure 11. Retention group performance, calculation of savings score c.

Cross-sectional savings scores are calculated from the difference between the retention group's and the control groups' retest performance on practice periods four and five.

(a')

$$\text{savings} = \frac{\text{Total performance score for the retention group's first one-minute of retest performance (Period 4)}}{\text{Total performance score for the control group's first one-minute of retest performance (Period 4)}}$$

Retention vs Older Control:

$$\begin{aligned} \text{savings} &= \frac{364.5}{615.4} \text{ (raw scores)} \\ &\quad \text{.001 min.} \\ &= .59 \end{aligned}$$

$$\text{percent savings} = (.59) \times 100 = 59\%$$

Retention vs Younger Control:

$$\begin{aligned} \text{savings} &= \frac{364.5}{586.6} \text{ (raw scores)} \\ &\quad \text{.001 min.} \\ &= .62 \end{aligned}$$

$$\text{percent savings} = (.62) \times 100 = 62\% \quad (\text{see Figure 12})$$

(b')

$$\text{savings} = \frac{\text{Total performance score for the retention group's entire first eight-minute retest practice period (Period 4)}}{\text{Total performance score for the control groups' entire first eight-minute retest practice period (Period 4)}}$$

Retention Group vs Older Control:

$$\begin{aligned} \text{savings} &= \frac{3499.9}{4603.1} \text{ (raw scores)} \\ &\quad \text{.001 min.} \\ &= .76 \end{aligned}$$

$$\text{percent savings} = (.76) \times 100 = 76\%$$

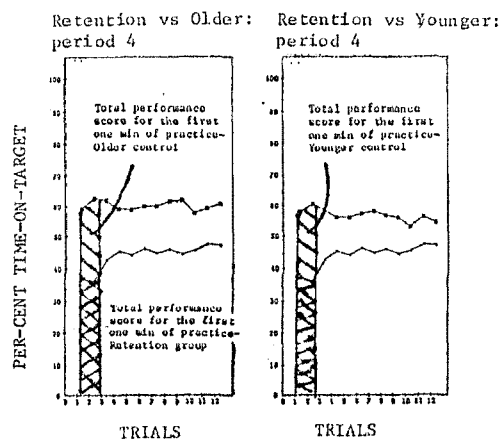


Figure 12. Comparisons of control group performance to retention group performance for period 4, calculation of savings score a'.

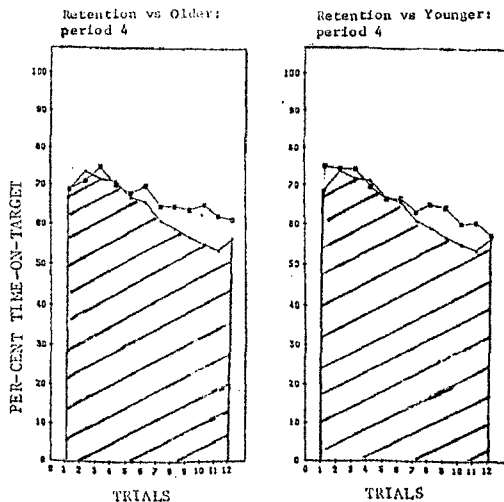


Figure 13. Comparisons of control group performance to retention group performance for period 5, calculation of savings score c'.

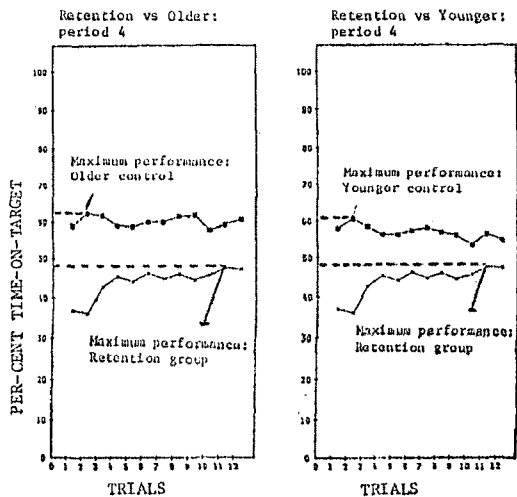


Figure 14. Comparisons of control group performance to retention group performance for period 4, calculation of savings score d'.

Retention Group vs Younger Control''

$$\begin{aligned} \text{savings} &= \frac{3499.9}{4533.3} \quad \begin{array}{l} \text{(raw scores)} \\ \text{.001 min.} \end{array} \\ &= .77 \end{aligned}$$

$$\text{percent savings} = (.77) \times 100 = 77\%$$

(c')

$$\text{savings} = \frac{\text{Total score for retention group over practice period 5}}{\text{Total score for control groups over practice period 5}}$$

Retention vs Older Control:

$$\begin{aligned} \text{savings} &= \frac{5063.7}{5365.3} \quad \begin{array}{l} \text{(raw scores)} \\ \text{.001 min.} \end{array} \\ &= .94 \end{aligned}$$

$$\text{percent savings} = (.94) \times 100 = 94\%$$

Retention vs Younger Control:

$$\begin{aligned} \text{savings} &= \frac{5063.7}{5314.0} \quad \begin{array}{l} \text{(raw scores)} \\ \text{.001 min.} \end{array} \\ &= .95 \end{aligned}$$

$$\text{percent savings} = (.95) \times 100 = 95\% \quad (\text{see Figure 13})$$

(d')

$$\text{savings} = \frac{\text{Maximum performance of the retention group on period 4}}{\text{Maximum performance of the control groups on period 4}}$$

Retention Group vs Older Control:

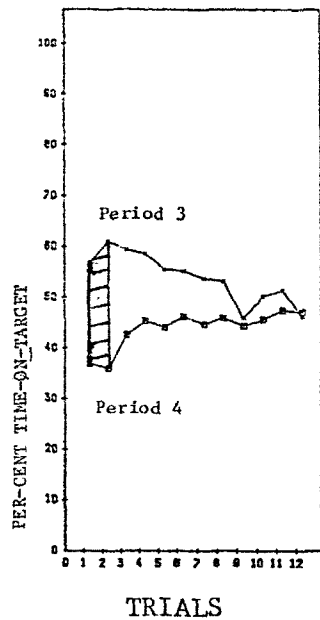
$$\begin{aligned} \text{savings} &= \frac{163.5}{222.6} \quad \begin{array}{l} \text{(raw scores)} \\ \text{.001 min.} \end{array} \\ &= .73 \end{aligned}$$

$$\text{percent savings} = (.73) \times 100 = 73\%$$

Retention vs Younger Control:

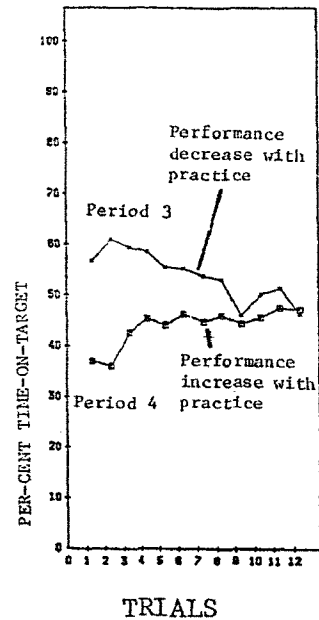
$$\begin{aligned} \text{savings} &= \frac{163.5}{203.0} \quad \begin{array}{l} \text{(raw scores)} \\ \text{.001 min.} \end{array} \\ &= .81 \end{aligned}$$

$$\text{percent savings} = (.81) \times 100 = 81\% \quad (\text{see Figure 14})$$



Retention measure (a) based on the difference in performance due to warm-up (period 3) and lack of warm-up (period 4) in the first one-minute of practice: accentuation of maximum difference between curves, resulting in decreased savings measure.

(a)



Retention measure (c) based on overall performance difference over the entire eight-minute practice: difference between curves decreasing over practice, resulting in increased savings measure.

(b)

Figure 15 a,b. Effect of performance curve shape on retention measures.

(e')

$$\text{savings} = \frac{\text{Maximum performance for retention group on practice period 5}}{\text{Maximum performance for controls on practice period 5}}$$

Retention Group vs Older Control:

$$\begin{aligned} \text{savings} &= \frac{252.3 \text{ (raw scores)}}{252.2 \text{ (.001 min.)}} \\ &= 1.00 \end{aligned}$$

$$\text{percent savings} = (1.00) \times 100 = 100\%$$

Retention Group vs Younger Control:

$$\begin{aligned} \text{savings} &= \frac{252.3 \text{ (raw scores)}}{255.7 \text{ (.001 min.)}} \\ &= .99 \end{aligned}$$

$$\text{percent savings} = (.99) \times 100 = 99\%$$

See Table 8 for a summary of the savings score results.

TABLE 8
Summary of Savings Score Results

	Savings Score	Per-cent Savings
Longitudinal	a	54
	b	63
	c	81
Cross-sectional	a'	62
	b'	76
	c'	95
	d'	81
	e'	99

Summary of Results

(1) The younger and older control groups are similar in performance level and pattern, although there are several differences. (a) On period two the younger control has significantly lower performance, though there is no interaction effect. (b) The younger control has noticeably less warm-up on every practice period, resulting in an interaction effect on period six, even though the performance levels throughout the period are virtually identical. Overall, these results indicate there are no systematic significant performance differences related to the age differences between the groups.

(2) The retention group's performance is similar to that of the controls for the first three practice periods, with no main effects on any period and one interaction (on period three), indicating no systematic significant differences between the groups prior to the retention interval.

(3) There are interaction effects for the retention group vs both controls for five of the six retest practice period comparisons, indicating a different retest performance pattern associated with the difference in length of retention interval.

(4) The source of the interaction effects on the retest practice periods is different from period four to periods five and six. (a) For period four the retention group has an almost linearly increasing performance curve after the first minute of practice vs a decremental section for each of the controls. (b) During periods five and six the retention group has a very similarly shaped curve to those of the controls, but the interaction effect arises from its more rapidly decreasing decremental section.

(5) The small interaction sum of squares for the retention group's period one vs period four performance indicates the curves are virtually identically shaped, whereas both controls have large sums of squares for this interaction, resulting in a statistically significant difference and indicating a large orthogonal component for their period one vs period

four performance.

(6) Points 4(b) and 5 suggest that the long retention interval results in the retention subjects performing on retest almost exactly like naive subjects, but after the first practice period and rest, catching up to and performing with a pattern almost like that of the controls during periods five and six, but with more rapid decrement.

(7) The savings measures vary from a low of 54% to a high of 99% and follow the pattern described in point six. Those measures that contrast the maximum differences between the shapes of the retention and control groups' performance curves for period four (measures a', b'), or for the retention group's performance on period three vs period four (measures a, b) show the least savings, indicating the differences in performance pattern. Those measures that contrast the retention vs control groups' performance curves for period five show essentially 100% savings (measures c', e'), indicating the retention group's regaining of a performance level and pattern similar to that of the controls during period five.

DISCUSSION

This section contains a discussion of the study's findings, their interpretation as the time-dependent characteristics of reminiscence arising from schedule effects and as shifts in practice schedule conditions, and a summary of four "new" principles of rotary pursuit performance and their application to the retention study results. Finally, a brief discussion is given of Kimble's (1948, 1949a, 1949b) theory of skill acquisition, and preliminary suggestions are made as to how its postulates might have to be changed in light of the retention findings.

Major Findings of the Study and Their Interpretation
as Practice Schedule Effects: Amount of Retention as
Determined by the Appearance or Absence of Reminiscence

This study has two major findings. First, retention subjects after an extremely long period of no-practice do not rapidly relearn the rotary pursuit skill during the first retest practice period, but improve slowly at the same linear rate as naive subjects during initial acquisition practice (See Figures 8 and 9). Second, the retention subjects have a very large performance gain during the first postrest practice period of retesting (period five), catching up to the control subjects' performance in one large increment over the first rest. These two phenomena are different from those found for shorter no-practice intervals; there subjects regain nearly all their former level of acquisition performance during the first retest practice period (Battig & Nagel, 1957; Eysenck, 1960; Fleishman & Parker, 1962). These phenomena also contradict or highly qualify the vague "general principle" quoted from Adams (1987) in the introduction: "Relearning is more rapid than original learning." The results suggest that the retention subjects' initial low, nearly linearly-increasing per-

formance is not a true difference due to forgetting, but is due to a "schedule effect" on performance, where a "schedule effect" is a specific, identifiable pattern of performance associated with specific practice schedule conditions (See Appendix 4b).

The savings measure results bear on this last point. The low longitudinal measure (measure (a), p. 19) of 63% savings accentuates the differences in shape between pre- and postrest performance curves. That is, we see the presence of the postrest phenomena "warm-up" and reminiscence during practice period three, (See Appendix 4a for definitions and examples) and their absence in practice period four (See Figure 15a, b). The high longitudinal savings measure (81%, See measure (c), p. 23) shows greater apparent retention by contrasting the continuous linear increase in performance over practice period four against the constant performance decrease during practice period three (See Figure 11, p. 22).

For the cross-sectional savings scores, the large increase in savings occurring on practice period five (94% to 100% savings) is due to the appearance of reminiscence during postrest practice; the comparisons (measures (c') and (e'), p. 25, 27) now being made between two postrest curves. This suggests that the entire difference between the retention group's performance and that of the controls may be due to the schedule-dependent appearance of postrest reminiscence.

The savings measures are used here instead of statistical analyses in order to point out the effects of differences in performance curve shape on the measurement of retention. Savings scores have been used historically to measure the amount of learning retained over a retention interval, but the present study demonstrates that such measures give extremely different results depending on what the experimenter chooses as a basis of comparison, and they mislead one into talking about "forgetting" and "retention of learning" rather than reminiscence.

The longitudinal savings measure (measure (b), p.21) can be used to directly compare the present results to those of Eysenck (1960) and Bell (1950), but we must convert the 63% savings score into forgetting, i.e.,

$$100\% - (\% \text{ savings}) = \% \text{ forgetting}$$

or

$$100 - 63 = 37\% \text{ forgetting}$$

This amount is equal to the 37% "forgetting" measured by Eysenck and slightly greater than the 29% "forgetting" measured by Bell over one-year retention periods. One implication is that there is little or no additional first-retest practice performance loss over 15 years than there is over one year. A savings measure (measure (e'), p.29) comparing the first one minute of practice during the second retest period with final acquisition performance yields 102% savings for Eysenck's data (group mean performance increases above the previous maximum), and approximately 99.5% for the retention group in this study. Since Eysenck's subjects were extremely well-practiced and performing at asymptotic levels before the one-year retention interval, these results suggest that low-to-moderate levels of skill may be retained equally well over a 15-year period as are asymptotically high levels of skill over a one-year period, given one continuous practice and one rest period for reacquisition. This contradicts, or highly qualifies, Adams's (1987) second "general principle": "forgetting increases as a positive function of the retention interval." There may be 100 percent retention of any amount of prior practice over any retention interval, but the full expression of learning resulting from the earlier practice requires the reappearance of reminiscence during postrest practice.

A reexamination of reminiscence data from Koonce, et al. (1964), provides a partial test of whether amount of retention depends solely on the

appearance of reminiscence during acquisition and retention testing. Koonce, et al. had nine groups of subjects practice continuously for a single five-minute period, then measured reminiscence with a second five-minute continuous practice at different rest intervals: 0 min., 10 min., and 1, 7, 35, 70, 175, 365, and 730 days. All groups with non-zero rest had higher retest performance than the no-rest control (See Figure 16 below).

Calculating savings score (b) (p. 21) for Koonce, et al.'s data, we find 71% savings (29% forgetting) for the two-year rest group compared to the ten-minute rest group. This is very close to the amounts of forgetting in Bell's, Eysenck's, and the present study, and is further evidence that such retention savings measure the temporary loss of reminiscence in postrest performance after extremely long rests, not the decay in learning. Unfortunately, it is not possible to fully test this hypothesis since Koonce, et al. employed only one retest period. Results of the present study suggest equal final performance by all of the Koonce, et al. groups, had they been given one further five-minute practice following a ten-minute rest. Final postrest performance would have been equated with respect to total amount of practice and practice schedule, hence would have had equal reminiscence.

Reminiscence seems to be a temporary phenomena central to performance but not to learning. Over very long no-practice intervals reminiscence decreases, producing an apparent decrease in learning when initial retest performance lacking warm-up and reminiscence phenomena is compared to a postrest pattern which shows these phenomena. The apparent differences in retention are eliminated if retesting includes practice schedule conditions which allow the reappearance of reminiscence. The differences in retention are accentuated if the retest practice is continuous or highly "massed"

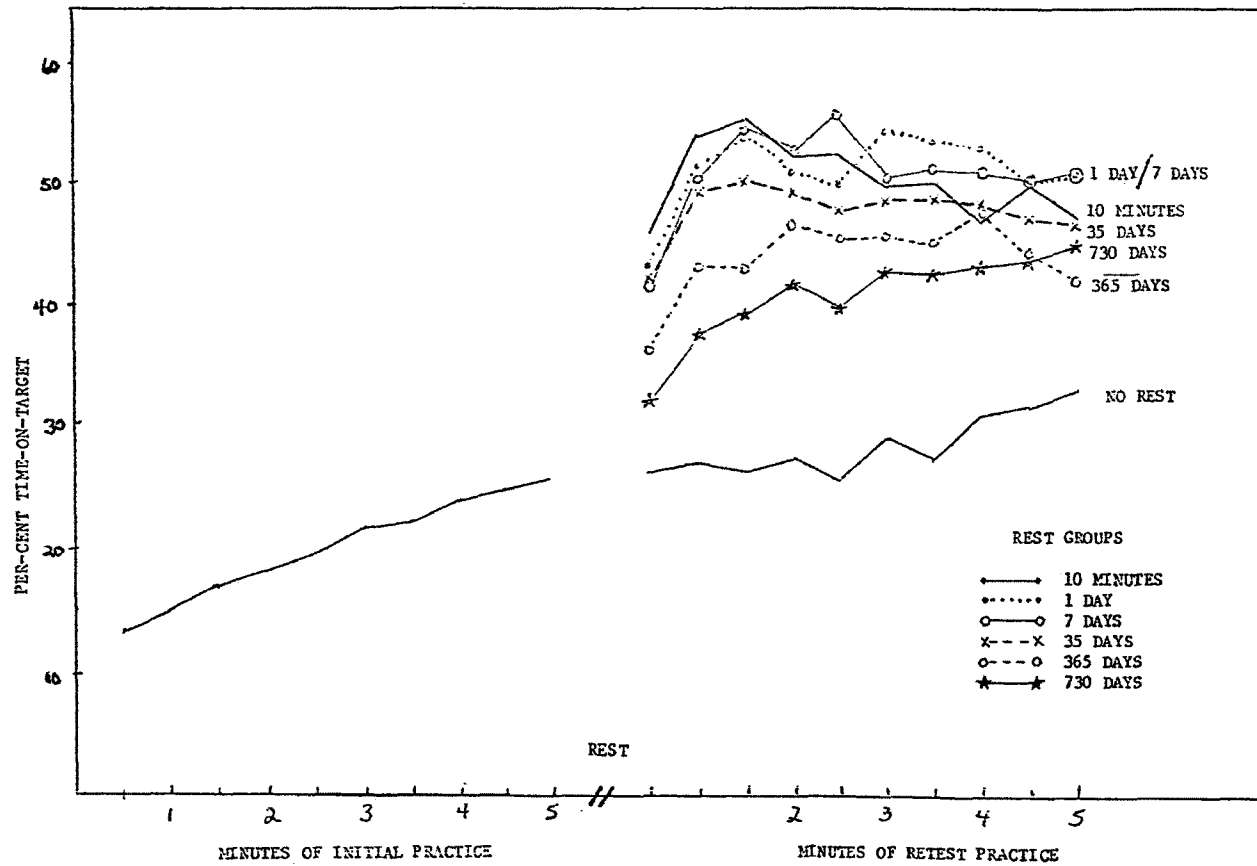


Figure 16. Functional dependence of reminiscence on amount of rest (redrawn from Koonce, Chambliss, and Irion, 1964).

("massing" means relatively more practice and less rest per unit time). "Rapid relearning of skill" is a misnomer. Instead, we are observing the effects of decay in reminiscence over long periods of no-practice and the failure of continuous practice (or a highly massed schedule of practice) to enable it to fully reappear until the first rest of five to ten minutes duration.

Adams (1987) makes a similar point with respect to differences in distributed versus massed acquisition schedules: "massed practice influences how well you perform, not how well you learn" (p. 50). Ammons and Willig's (1956) results three decades earlier also demonstrate this by showing eventual performance level convergence between highly distributed and relatively more massed practice. They concluded that there is no "permanent work decrement," i.e., a permanent difference in performance due to the different practice schedules (See also Reynolds & Adams, 1954; Ball & Payne, 1987). However, the results have never been applied to differences in performance arising from the interpolation of long rest intervals. Adams (1987) and others seem to assume it is a finding which applies only to immediate, short-term acquisition practice and that forgetting does take place over longer no-practice intervals: "...habit was permanent in Hull's theory (forgetting notwithstanding)" (Adams, 1987, p. 49). Adams's "general principles" of retention also reflect this belief.

Contrary to this assumption, the present study suggests these results should be generalized to all practice schedules, including those containing multi-year, no-practice rests.

To summarize: "forgetting" in a continuous tracking skill is not a gradual decay in learning, but results from schedule-based performance differences which can be completely and quickly reversed by reintroducing

a schedule which allows the appearance of reminiscence. Apparent decay in learning occurs because the retention measures in effect mistakenly compare the different phenomena of prerest and postrest performance. One must use comparable phenomena to measure real differences in performance and from them infer real differences in learning and retention.

The results of past retention studies showing apparent forgetting and "fast relearning" during retest (Fleishman & Parker, 1962; Ammons, et al., 1958; Battig & Nagel, 1957) can now be readily understood. All had no-practice intervals long enough to decrease reminiscence substantially and used highly massed or continuous practice conditions on the first retest period. All therefore had subjects who started retest with performance depressed by the decay of reminiscence and practiced under conditions not allowing full reappearance of reminiscence, hence found relatively rapid but incomplete reacquisition. These retention of learning results are examples of reacquisition slowed by continuous or highly massed practice schedules, not of any decay in learning. Prior acquisition performance levels would have quickly and completely reappeared had the subjects been given a five- to ten-minute rest after even a small amount of continuous retest practice.

The Retention Group's Rapid Rate of Decrement as Induced
by Shifts in the Distribution of Practice During Retesting

A difference not yet discussed is the retention group's more rapid performance decrement during practice periods five and six as compared to the control groups' performance. The rapid decrement can be interpreted as a schedule effect arising due to the shift from a highly distributed to a more massed practice schedule with long continuous practice periods. First, let us note that this effect appears in at least two other studies, one a short-term acquisition study by Ammons, Willig, & Ammons (1952) and

the other a long-term retention study by Eysenck (1960).

In the experiment by Ammons and Willig (1956), greatly increased performance decrement was associated with the shift from a relatively distributed schedule (one minute practice, two minutes rest) to an effectively more massed schedule with long, continuous practice periods (ten minutes practice, twenty minutes rest). The shifted groups' performance curves during periods ten and eleven (See Figure 17a, b) look highly similar to the retention group's performance on periods five and six in the present study when compared to the unshifted control groups. Both the shifted, highly distributed group and the retention group have greater decrement during practice as compared to the massed schedule controls.

The schedule-shift interpretation of the retention studies' results depends upon considering the long retention interval as increasing the degree of practice distribution, i.e., practice is "distributed" over 15 years, rather than merely the time spent in the original testing, and treating the retention group's change to retest conditions as a shift to a more massed practice schedule with long, continuous practice periods.

Greater decrement during continuous retest practice also appears in Eysenck's (1960) retention study, and the schedule-shift interpretation fits the data nicely. Prior acquisition practice was 50 15-minute practice periods distributed over approximately 60 days, with single practices on successive days whenever possible. The retention interval was one year, and there were three 15-minute retest periods on successive days. As above, the retention period can be treated as a long rest during acquisition, effectively increasing the distribution of acquisition practice, and the retest conditions considered as a shift from this highly distributed schedule (50 15-minute practices distributed over approximately 420 days) to a more massed one (three 15-minute practices distributed over three

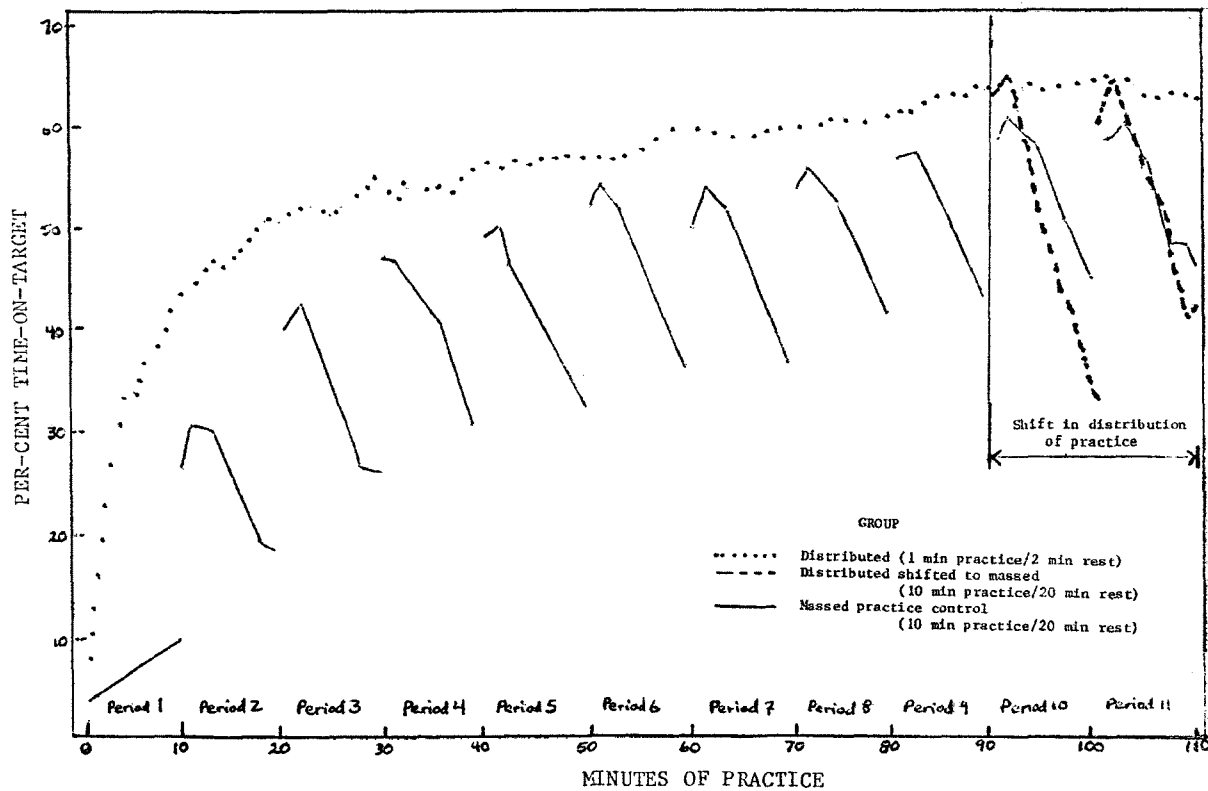


Figure 17a. More rapid decrement during practice as a result of practice schedule shifts, from relatively distributed schedules to relatively massed schedules with a long continuous practice period (redrawn from Ammons and Willig, 1956).

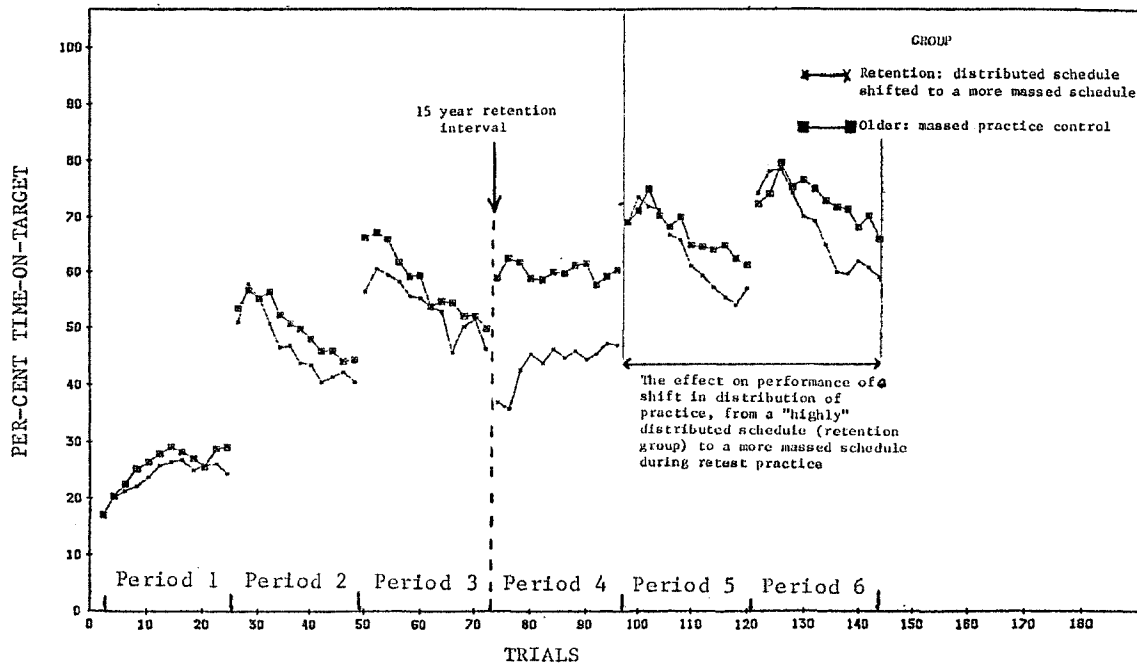


Figure 17b. More rapid decrement during practice as a result of practice schedule shifts, Retention group vs Older control.

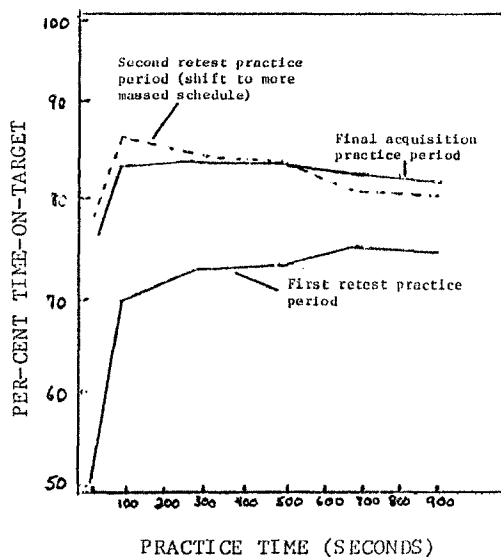


Figure 17c. More rapid decrement during practice as a result of practice schedule shifts, resumption of practice after a one-year rest (redrawn from Eysenck, 1960).

days). Retest performance during the first retest period's 15-minute continuous practice increases rapidly but does not reach final acquisition levels, indicating the relatively depressing effect of continuous practice on reminiscence as discussed in the previous section. The performance curve for the second retest period shows reinstatement of reminiscence and the effect of the schedule shift: a decremental rate twice that of the curve for preshift performance, similar to the Ammons and Willig (1956) data (See Figure 17c). The third retest period (not shown in Figure 17c) also has a greater rate of decrement, as expected. A comparison of the graphs for Ammons and Willig, Eysenck, and the present study illustrates the consistency in the results (See Figures 17a, b, c).

The preceding discussion can be summarized in four principles of rotary pursuit performance as it depends on practice schedules.

Summary Principles of Rotary Pursuit Performance

(1) Base performance is a linearly increasing function of the total practice time (number of repetitions of the task) and is given by the performance curve for continuous (infinitely massed) practice (See Figure 18).

(2) Reminiscence (gain in performance over rest) is dependent on the amount of rest between practices. The fundamental functional dependence of reminiscence on rest, for a single practice-rest-practice cycle, is given by the data from Koonce, et al. (1964) (See Figure 16, p. 35).

As logical extensions of Koonce, et al. and the control groups in the present study:

(a) For no-practice intervals longer than two years, reminiscence converges toward zero, and the retest performance curve converges to the base, linearly increasing continuous-practice performance curve for the corresponding total amount of practice.

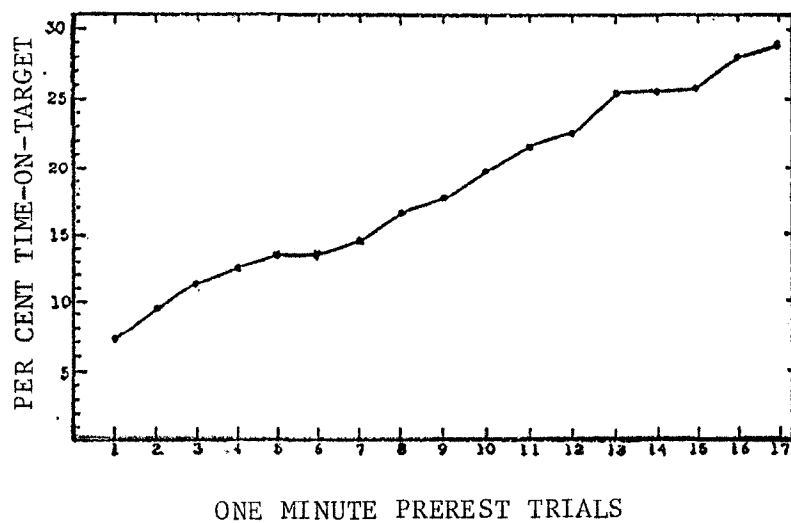


Figure 18. Linear increase in performance with continuous pretest practice (n=60), redrawn from Ammons (1947b).

(b) The amount of reminiscence on the second retest after any long (greater than one year) no-practice interval interrupting the acquisition schedule, is given by the level the performance would have reached had the schedule not been interrupted by the long rest.

(3) All differences in performance between groups with the same amount of total practice are due to temporary practice-rest distribution, i.e., schedule-effects. Schedule-effects on performance depend on the degree to which they allow or depress the appearance of reminiscence and warm-up and produce decrement.

(a) To each schedule there corresponds a unique performance pattern and level depending on the ratio of practice to rest, and the absolute lengths of practice and rest.

(i) The ratio determines the asymptotic performance level toward which all schedules of that ratio converge.

(ii) The absolute lengths of continuous practice and rest determine the appearance, specific pattern, and degree of warm-up, reminiscence, and decrement.

(iii) For two groups with the same ratio of continuous practice to rest, but different absolute lengths of continuous practice and rest, the one with the greater absolute lengths of practice and rest will be depressed below the other, but (by (i)) will eventually converge to the common asymptote.

(4) A shift from a more distributed to a more massed schedule results in

(a) greater rate of decrement after warm-up during the first two or three continuous-practice periods, and

(b) rapid reappearance of reminiscence effects, hence perfor-

mance levels, corresponding to that of the degree of distribution or massing of the final schedule (within one or two practice rest cycles if the rest is greater than or equal to five minutes). (See 2(b) above.)

Application to Retention Studies: Performance Phenomena
 After Extremely Long No-practice Intervals
 Interpreted as Practice-schedule Effects

To apply the above principles, no-practice periods of any length should be interpreted as part of the overall practice schedule, so that all retention studies can be treated as schedule shifts toward more distributed practice as the no-practice interval gets longer and as a shift toward a more massed practice as retest practice is begun.

(a) These schedule-shift effects in retention studies (4 above) will be most pronounced with long no-practice retention intervals (greater than one year) and long continuous practice retesting periods (greater than five minutes), because these are the conditions most strongly determining the appearance of warm-up, reminiscence and decrement (See 2).

(i) If the second retest period uses continuous practice of greater than four minutes duration (so that it continues past the warm-up peak occurring at around two minutes), performance decrement will be greater than that of a control group practicing on an uninterrupted schedule. In the present study, with a 15-year no-practice period, and an eight-minute continuous practice - five-minute rest schedule, the second retest period has a decremental rate approximately half again as large as that of the control (4(a) above).

(b) Initial retest performance in retention studies is determined

by decrease in reminiscence over long rest periods. The longer the retention interval, the greater the loss of reminiscence and the more similar the initial retest performance will be in shape to that of continuously practicing subjects, i.e., it will converge toward the base, linearly increasing, continuous-practice performance curve (See 2(a) above).

(i) The present study has an extremely long, 15-year no-practice interval. The retention subjects' performance during the initial eight-minute continuous retest practice increases with an almost identical shape to that of the first acquisition practice period (See Figure 8, p. 17). The level of this retest performance curve, and its shape, are very close to a direct linear extension of the performance curve for practice period one.

(c) Reappearance of reminiscence takes as little as a single practice-rest-practice cycle during retention testing, depending on the absolute lengths of continuous practice and rest. There is a shift after the first retest practice to the performance pattern corresponding to the retest practice conditions (See 2(b), 4(b)).

(i) In the present study, during the second retest practice after the 15-year no-practice interval, performance increases to match that of the control almost identically in level, for approximately the first half of the practice period.

(c) If initial practice during retention testing is continuous, then the performance of the retention subjects cannot show maximum reminiscence and will always have longitudinal savings measures of less than 100% (See 2).

(i) In the present study, with its long no-practice interval and eight-minute continuous retest practice, retention measures ranged from 54% to 81%.

We have interpreted the major rotary pursuit retention phenomena in terms of the practice-schedule dependent properties of reminiscence. This should make it possible in the future to link the historically separated areas of motor skill acquisition and retention, allowing the extension of skill acquisition theories to describe retention phenomena readily as special cases of acquisition interrupted by long rests. For now, as a start in this direction, we can state several preliminary suggestions and considerations for possible changes in one of the main skill acquisition theories - that developed by Kimble.

Postulates of Kimble's Theory of Rotary Pursuit Acquisition

Kimble's (1948, 1949a, 1949b) theoretical development of motor skills acquisition was strongly influenced by Hullian concepts. Kimble's assumptions and operational definitions are not explicitly identified so that some interpretation is required to state his ideas as postulates.

(1) The movements made by a subject learning a skill (the rotary pursuit task) are "effortful responses." Each response produces a tendency or "drive" (reactive inhibition, I_R) to avoid repeating the response. As applied to tracking movements, I_R inhibits practiced tracking movements by producing a "tendency to rest."

(2) I_R has two properties:

(a) I_R increases as a negatively accelerated function of practice with an asymptotic value reached after approximately eight minutes of continuous practice.

(b) I_R dissipates with rest after practice as a function of time:

$$I_R(t) = I_{R_0}(10^{-qt})$$

where

t = time allowed for rest

$I_R(t)$ = amount of I_R present at time t

I_{R_0} = amount of I_R present immediately after the original learning

q = an empirically determined constant.

(3) There is a threshold amount of I_R automatically producing a resting response, ${}_s I_R$, or "conditioned inhibition." ${}_s I_R$ is a "habit," a learned behavior.

(4) ${}_s I_R$ has two properties:

(a) It increases as a negatively accelerated function of practice.

(b) It is "relatively permanent," showing little tendency to diminish with passage of time.

Empirical estimates of the curves for I_R and ${}_S I_R$ were made from subsequent experimental data (e.g., Kimble, 1949b), and the theory was used to describe reminiscence (gains in performance over rest) by the dissipation of inhibition and "advantages of distributed over massed practice in learning" (Kimble, 1949b, p. 502), e.g., it was found that reminiscence increases as a negatively accelerated function of rest and reaches asymptote at approximately 600 seconds.

Some Preliminary Suggestions for the Revision of Kimble's Theory

Kimble's theory is phrased in terms of internal mechanisms, not directly measurable variables, hence some interpretation is necessary to evaluate it. Of the four postulates, the retention results bear directly only on number two, concerning the properties of I_R . However, data pertaining to the possible revision of two of the other three postulates will be noted.

Postulate one asserts the existence of a particular underlying mechanism and has thus far had no direct empirical test of its validity. We will not attempt to revise it.

Postulate three predicts the existence of a learned "resting response," I_{S^R} , which is assumed to result from the subject's reaching a threshold level of inhibition which prevents him from continuously responding. Investigators in several studies (Ammons, Ammons, & Morgan, 1958; Eysenck & Frith, 1977) explicitly looked for rest pauses during practice but found no such phenomenon. If this idea is to be used, it would have to take some different form, e.g., as describing the rate of change of irregularities in a subject's tracking speed and direction at various times during practice. These irregularities in tracking do increase during continuous practice periods longer than approximately three minutes (depending on prior practice), and perhaps could be used in place of the "resting response." Such a change would also imply other possibly different properties for how inhibition accrued and how it affected other aspects of performance.

Postulate four depends on number three, hence any revision of it depends on the specific interpretation given to I_{S^R} . Kimble originally intended that I_{S^R} describe the performance level differences between groups practicing with different schedules. However, Ammons, Willig, and Ammons

(1952), Ball and Payne (1988), and Reynolds and Adams (1954) all have demonstrated that the performance level differences associated with different practice schedules are not permanent but are reversible with even small amounts of additional practice after a group shifts schedules. Further, Hagen, Wilkerson, and Noble (1980) have shown these differences in performance seem to be predictable solely from the properties of I_R . Hence, at present, postulate 4(b) seems to be false, and the phenomena addressed by 4(a) seem to be predictable from postulate two.

Postulate 2(a) is in accord with empirical acquisition data and is actually a finding reported by Ammons (1947b). The second part of the postulate was proposed to fit performance data for interpolated rests up to approximately an hour. It is here that the retention data suggest additional properties of I_R for extended rest periods and give some insight into its feasibility as an assumed mechanism.

The exponential decay function assumed for I_R has the property, that as rest time increases to infinity, I_R decreases to zero. As fitted to Kimble's (1949a) data, a rest time of ten minutes resulted in complete and permanent dissipation of I_R , hence reminiscence increased and reached an asymptote after this or any greater length of rest. It is seen from Koonce, et al.'s and the present study's data, that reminiscence does indeed increase to an asymptote for rests of ten minutes to one day but then decreases to nearly zero given a long enough no-practice interval. This is clearly in conflict with the predicted permanent asymptotic reminiscence for any rest greater than ten minutes. Also, it leads to a somewhat peculiar description if the observed performance changes are described in terms of the increase and dissipation of inhibition: inhibition increases during practice, dissipates over short rests, then increases again over long rests. This is not a fatal problem, but it is awkward and

suggests that inhibitory processes might not be the most direct way to describe pursuit rotor performance phenomena.

Simple possibilities for revision could include the use of Kimble's original I_R for schedules using short rests and a new, long-term inhibitory process assumed to act over longer rests, or rather than using a simple exponential decay function, fitting I_R to Koonce, et al.'s and the present study's data and accepting the descriptive awkwardness.

There are further problems with the theory regarding the two main findings of this study. Kimble's I_R , as it stands, does not directly predict either the large single jump in performance level of the retention group up to that of the control group after one practice and one rest, or the retention group's increased rate of decrement during the re-test practice periods five and six. Both of these findings would probably have to be included as additional characteristics describing the dependence of I_R on extended rests or changes in the distribution of practice.

SUMMARY

Empirical studies and theory construction for short-term phenomena in motor skills acquisition have been plentiful historically. The same is not true for retention phenomena. An empirical study of retention over an extremely long (15.5-year) period of no practice using the pursuit rotor task provides data for the reassessment of the relationship between acquisition and retention performance phenomena in motor skills behavior. It is shown that (1) several new and different phenomena occur over this longer retention interval than occur over intervals previously studied, (2) two widely accepted, general principles of skills retention are highly incomplete and must be revised, (3) all major retention phenomena can be interpreted as the temporary effects of practice schedules on reminiscence, and not as decay in learning, and (4) the findings suggest several possible changes in the postulates of Kimble's theory of skill acquisition.

Appendix 1

Introduction

Phenomena in the acquisition and retention of perceptual-motor skills are important to many aspects of learning theory. While the study of acquisition of skill has historically generated a healthy number of systematic theoretical and empirical treatments, the same is not true for the study of retention. Virtually all studies deal with relatively small amounts of practice (hence low levels of learning and performance) and relatively short retention intervals, e.g., Bilodeau and Bilodeau (1961, p. 259) state, "99 percent of the literature is concerned with rests of no more than an hour or so and does at least as well without motor memory as with." Despite these limitations, the findings for continuously controlled perceptual-motor skills are remarkably consistent, showing high retention and even increases in performance over periods of no practice up to several weeks and quick recovery from the losses that do occur (Adams, 1964; Schmidt, 1982). With regard to the dozen or so studies which deal with no-practice intervals of more than two weeks, typical summary statements (from three of the five recent major reviews of the motor skills literature) are: "the data show relatively high upper temporal limits of retention" (McGeoch and Irion, 1952); "Recent research emphatically shows that motor skills performance is not sensitive to the mere lapse of time" (Bilodeau and Bilodeau, 1961, p. 260); and "Continuous motor tasks are extremely well retained over very long intervals" (Schmidt, 1982, p. 615). The last two researchers in particular are clearly not hesitant in

their conclusions. However, it is interesting to look at the empirical findings on which their comments are based. It turns out that in the literature on motor skills retention, there are only a very few formal long-term retention studies, in which "long term" means retention testing for retention after a one-year no-practice period. Indeed, the major studies of the past 40 years which form the empirical core of "long-term" retention research are only five in number (Ammons, et al., 1958; Battig, et al., 1957; Bell, 1950; Eysenck, 1960; Fleishman and Parker, 1962). There are several others which were done for the military but were only published as contract reports and are not available in the journal literature (Jones and Bilodeau, 1953; Mengelkoch, Adams, and Rainer, 1958). The longest no-practice period over which retention is tested is two years. As will be apparent in the brief summaries which now follow, the studies collectively contain somewhat of a jodge-podge of experimental conditions, using different practice levels, acquisition schedules, types and complexities of skill, numbers of subjects, retesting conditions, and data analyses.

The Ammons, et al. (1958) retention study used a continuous compensatory-tracking skill (a simplified airplane-control task), with 4 successive 1-minute cycles, training 500 Ss and retesting 450 of them up to two years later. There were 10 conditions representing two levels of training (a and 8 hours), combined with five durations of no practice (1 day, 1 month, 6 months, 1 year, 2 years); each interval was followed by 2 hours of retraining. In addition, 6 Ss were trained for 40 hours and retrained for 2 hours after one year of no-practice in order to examine possible effects of overlearning on retention. Learning, retention, and relearning were measured by the percent time on target per one-minute trial. Results include:

- (1) The longer the no-practice interval, the greater is the loss, i.e., the lower the performance at the start of retraining.

- (2) The absolute loss over the 2-year period is about the same for the groups receiving 1 hour and the groups receiving 8 hours of training.
- (3) The computed loss over the no-practice interval is greater when retraining scores are analyzed by 1-minute periods, rather than the combined 15-minute scores.
- (4) The loss, analyzed by 1-minute periods, amounts to more than 20% time on target for all retention groups compared with their controls.
- (5) Proficiency is regained very rapidly, as much as 50% to 75% of the loss being recouped during the first 5 minutes of retraining practice.
- (6) Retraining takes longer the greater the duration of the no-practice interval.
- (7) The absolute loss is greater but the relative loss is less in the case of the 8-hour Ss as compared with the 1-hour Ss.
- (8) As far as the time-on-target measure of proficiency is concerned, overlearning does not detectably increase retention.

Battig, et al. (1957) used a cathode ray tube tracking task with a 1-min. "course" and examined its retention over an 8-month no-practice period after acquisition to asymptotic performance. Their intention was to approximate the large amount of practice apparently necessary for learning "everyday" skills and to then study retention. The four authors served as the subjects, practicing ten 1-minute trials per day for 100 days, reaching asymptote by approximately the 80th day. They found a slow acquisition rate, indicating the relatively great difficulty of the task, while performance after 223 days of rest showed a "very high degree of retention." Initial 1-minute retention trials gave measurements of performance slightly poorer than performance late in the acquisition phase, but these differences were not significant at the .05 level. No other measures or analyses of retention were made.

Bell (1950) tested 457 Ss on a pursuit rotor, giving them 20 1-minute trials at 60 rpm, with successive trials separated by 1 minute of rest. After one year of no practice, the Ss were tested again under the same practice conditions (Trials 21 to 40). On the 21st trial, the average score dropped to the level of Trial 9 during acquisition, an absolute loss of 29% in the time-on-target score. There was rapid improvement, so that by the 28th trial, the Ss had equalled their previous maximum performance. Performance continued to improve slightly from Trial 29 to Trial 40.

Eysenck (1960) also used the pursuit rotor to study the amount of decrement, the speed of relearning, and the length of warmup after a 1-year retention interval. This study differed from Bell's in several ways; it used continuous rather than distributed practice, high levels of initial training, and a small number of subjects whose performances were compared individually over the intervals. Eight Ss were given 50 15-minute pursuit rotor trials at 60 rpm, with the trials on successive days (excluding weekends). They were retested for one additional 15-minute trial on each of three successive days, 1 year after completion of the 50th trial. It was noted that in acquisition there were large individual differences in the apparent final asymptotes toward which the subjects were working.

In the first retesting trial (Number 51), 7 of the 8 Ss showed a performance decrement in time-on-target scores from their Trial 50 scores. These decrements averaged 10% but varied from 3% to 25%, while one subject showed an increment of 6%. There was no apparent relationship between level of performance on Trial 50 and the amount of decrement over the 1-year retention interval. Further findings were:

- (1) The average decrement from Trial 50 to Trial 51 was significant at the .05 level.
- (2) This decrement was overcome by all Ss by the beginning of Trial 52.

- (3) Warmup on Trial 51 was much more prolonged than on Trials 50, 52 or 53.
- (4) By visual inspection, the overall shape of the curve for Trial 51 was clearly different from those for Trials 50, 52, and 53.
- (5) When the first 50-seconds performance on Trial 51 was compared to Trial 50 performance, there was a 37% average decrement -- obviously a much larger decrease than that calculated for the entire 15-minute period, and comparable to Bell's figure of 29%.
- (6) "Neither the massing of practice nor the much longer period of original learning appears to affect the decrement in the performance after 1 year" (p. 270).

Fleishman and Parker (1962) tested 130 Ss using a complex airplane tracking task with a 1-minute "course," and 17 sessions of 21 1-minute trials distributed over six weeks. Retention was tested over 1-, 5-, 9-, 14-, and 24-month periods of no practice, with four additional sessions of 21 1-minute trials in two conditions: one with sessions massed in one day, and one with sessions distributed over four successive days. One week following the retraining, all Ss were retested for one additional session to evaluate possible differences in performance due to different relearning schedules. Results included:

- (1) Retention is extremely high, with virtually no loss observed up to the 14-month period of no practice. The small losses are recovered in the first few minutes of relearning.
- (2) For the 24-month no-practice period, losses are only slightly greater, with rapid recovery over the first 20 minutes after practice was resumed.
- (3) There was no significant difference in retention performance for no-practice intervals from 1 to 14 months, even in the first 1 minute when

practice is resumed.

- (4) The most important predictor of retention seems to be the initial level of performance in acquisition.
- (5) Retention using distributed practice is superior to that using massed practice as measured by performance during the final retraining session. However, on retesting one week later, there is no difference in final performance between the two procedures.

SUMMARY TABLE OF LONG-TERM RETENTION STUDIES

Skill Used	Number Subjects/Retested	Number	"Length" of movement sequence practical	Initial practice conditions	Total Practice Time	Retention Period	Retention Testing Conditions and Total Time
Ammons, <i>et al.</i>	500/450		4 sequences of 1 min. each	30x1 min. w/10 sec. rest after each 1-min. practice. 5 min. rest after each 30 min.	1, 8, 40 hr.	1 day, 1, 6, 12, 24 mo.	2 hr: same
Battig, <i>et al.</i>	4/3		1 min.	10x1 min. w/20 sec. rest after each 1-min. practice for 100 consecutive days	1000 min.=16.5 hr.	8 mo.	40 min.: 4x10 w/each 10: 10x1
Bell	457/47		1 sec.	20x1 min. w/1 min. rests	20 min.	1 yr.	20 min.: same
Eysenck	8/8		1 sec.	15 min. massed w/1 to 3 days rest between practice	50x15=750 min.=12.5 hr.	1 yr.	45 min.: 3x15 w/1 day rest between each
Fleishman & Parker	120/70		1 min.	21 min. massed average of 2 days rest	17x21=357 min.=5 hr.	1, 5, 9, 14, 24 mo.	84 min.: 4x21 - massed in 1 day w/10- min. rests - dist. w/1 day rests

APPENDIX 2

Is _____ there?

Sorry for bothering you. My name is Doug Ammons. I'm a graduate student at the U of M, and I'm trying to locate a number of people who were students in the early 1970's at the University. Do you have a minute?

I am doing a research project on how well physical skills are retained over long periods of time. You may not remember, but as part of the class activities in the Introductory Psychology classes, students (including yourself) practiced on a simple movement skill called rotary pursuit. I am trying to find people who would be willing to come back for about an hour to go through another practice session. If it is possible, and if you wouldn't mind, we can set up a time at your convenience.

APPENDIX 3

A Study of Hand Preference*

RBA 11/68

All answers are to go on the IBM answer sheet. Please print your name, the date, your class and section number, and your quiz section leader's name on the sheet in appropriate places.

Answer all items the best you can. Leave none out. Answer by marking alternative 1 on your IBM answer sheet for L (left) and alternative 2 for R (right). Don't struggle or agonize, just answer according to your impression. You have only a little over five minutes to complete the questionnaire, so don't waste any time.

1	2
L	R

1. With which hand do you distribute cards when dealing?
2. When setting a snap mouse-trap, with which hand do you prefer to pull back the spring?
3. When shooting with a bow and arrow, with which hand do you prefer to pull back the string?
4. When firing a rifle, with which hand do you manipulate the trigger?
5. When golfing, which hand do you have nearer that end of the club which strikes the ball?
6. When batting a baseball, which hand do you have nearer that end of the bat which strikes the ball?
7. When sweeping, which hand do you prefer to have nearer the upper end of the broom?
8. When using two hands to raise a large window, which hand does the most work?
9. When rubbing clothes which you are washing, which hand does most of the work?
10. When you clasp your hands, which thumb is on top?
11. When applauding, which hand is uppermost?
12. When lifting meat to your mouth after cutting it with a knife, in which hand do you prefer to use the fork?
13. With which hand do you prefer to write?
14. If both hands are free, with which do you prefer to wave good-bye?
15. In which hand do you prefer to hold the needle when sewing?
16. In which hand do you prefer to hold a tennis racket when playing tennis?
17. If both hands are free, with which hand do you prefer to hold the spoon when eating soup?
18. With which hand do you prefer to throw a ball?
19. With which hand do you prefer to shoot marbles?
20. With which hand do you prefer to hold the knife when buttering bread?

*Adapted from: Koch, H. L. A study of the nature, measurement, and determination of hand preference. Genet. Psychol. Monogr., 1933, 13, 117-221.

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21. When cutting a piece of paper, in which hand do you prefer to hold the scissors?
22. When holding a book, with which hand do you prefer to turn the pages?.
23. When drinking water from a glass, with which hand do you prefer to hold the glass?
24. With which hand do you prefer to turn a faucet?
25. With which hand do you prefer to place the stamp on an envelope?
26. When driving a nail into a flat board that is directly in front of you, in which hand do you prefer to hold the hammer?
27. In which hand do you prefer the comb when you comb your hair?
28. In which hand do you prefer to hold the toothbrush when you brush your teeth?
29. With which hand do you prefer to hold the knife when you are peeling an apple?
30. When washing dishes, with which hand do you prefer to hold the dishrag?
31. With which hand do you prefer to pull a cork from a bottle?
32. When raising your hand in class, which hand do you tend to raise?
33. With which hand do you prefer to turn a key in a lock if both hands are free?
34. With which hand do you prefer to drop letters into a slot in a small mail box?
35. With which hand do you prefer to wind a watch?
36. If you have made a mistake while writing on the blackboard, with which hand do you prefer to erase it?
37. Over which shoulder do you hold the bat before striking?
38. On which foot can you balance your body's weight the better?
39. Against which shoulder do you prefer to hold a gun while firing?
40. If you were told to listen to the ticking of a watch which was held behind you at a distance that you could barely hear it, which ear would you prefer to turn toward the watch in order to hear more effectively?

STANDARD : Used Fall '69 - Fall '70
 except for Oct 21-26, 1970 blw 10/27/70
 + Handedness Cont. deleted for
 some Ss last year.

INSTRUCTIONS FOR COMPONENT RELIABILITY STUDY

1. Condition: 8 minute practice - 5 minute rest - 8 minute practice - 5 minute rest - 8 minute practice.
2. Ss will be run using their right hands for all practice periods.
3. When the subjects arrive, fill out the required information on the top of the recording sheets. Close the door no later than 15 minutes past the hour. (The subjects will have been alerted to be there on time). Put "Please Wait" sign on the door.

Ask each of the Ss if they have done this study before. If a S has done it the same quarter for the same experiment hour requirement, dismiss him from the experiment. If a S has done it previous to the quarter (say for another class or at another school) run him but note the information on the data sheet. Ask each S what hand he writes with. Ask him if he considers himself right-handed or left-handed. Note response on data sheet in the space titled HAND. If a S writes with his left hand or considers himself left-handed mark discard on data sheet but run him anyway. Ask each S if they have taken the Handedness Questionnaire. If they have not, arrange for them to take it as soon as possible, reschedule him for pursuit rotor, and dismiss him from the experiment. The sex of the S should be written above the word "Hand".

(If used, include laterality test score for each S beneath the line for Hand. (A list of all laterality test scores are provided to experimenter.)

4. Stand in front of the rotor and ask the subjects to watch closely.
5. Read the instructions for the experiment to the subjects, demonstrating, as you read, how to hold the stylus with a tennis type grip, execute a circular movement, how one can press down by bending the stylus away from the body, and how one can accidentally touch the metal part of the stylus.

"I'm going to read the instructions to you so they will be the same for everyone. This is a test of coordination. The task is to keep the tip of the stylus, which is hinged to make handling easier, on the metal disk. Please remember that you are to try to keep the stylus on the disk as much of the time as possible. Try not to become tense as you do this or you will tire soon. Also do not tilt the stylus, press down on it, or hold it in one place to catch the target as it comes around. All of these things will lower your score. The best way to do well is to make a smooth, circular movement following the target around."

6. Ask the subjects if there are any questions. Answer by paraphrasing instructions, or deferring until they have been run.
7. Sit down behind the recording clocks.
8. Read the following instructions, remembering to designate which hand they will use according to the condition of the session.

"Please stand in front of the rotors and take the stylus in your right hand." (Calm them at this point and let them talk a little, if they seem to need to.) "Place the tip of the stylus on the target. Now I am going to count to three, and when I reach three, the rotors will start."

(Be sure the right persons are standing in front of their rotors - according to the order listed on the recording sheets.)

Wired with stopwatch for 3 sec.

9. Count to three and switch the rotors on. Begin mentally counting to three ^A when you reach three, switch to the alternate bank of clocks and begin the timing period (start the stopwatch). Reset the bank of clocks to zero that recorded the first three seconds of practice.
10. Switch recording banks every twenty second period, record the subjects' scores, and reset the clocks to zero.
11. Observe the subjects to make sure they are following instructions and correct them (individually - see Possible Difficulties, no. 1) if they're not. Encourage them from time to time ("Chase the target.") but no more than every two or three minutes, ordinarily.
12. At the end of the first eight minute timing trials, turn off the rotors, Reset the stopwatch to zero, but let it continue to run. Tell the subjects, "You will now be given a short rest." Please fill out these experiment hour cards and give them back to me when you are finished." (Hand out experiment cards to subjects.)

When the subjects give the cards back to you, sign them, but do not give them back until after the last timing trial. *Check on the exp. cards each subject's class and write this information at the top of the data sheet*
As the stopwatch reaches 4 mins. 30 secs., say to the subjects, "We are ready to begin again." Now re-read the following instructions to the subjects.

"Please stand in front of the rotors and take the stylus in your right hand." (Calm them at this point and let them talk if they seem to need to.)
"Place the tip of the stylus on the target. Now I am going to count to three, and when I reach three, the rotors will start."

(Practice reading this part so that as the second hand of the stopwatch reaches 60, the rotors are switched on. Be sure that the subjects are standing in front of their rotor and are using the correct hand for the condition.)

Start time with stopwatch for 3 sec.
As the rotors start, mentally count to three ^A When you reach three, simultaneously reset the stopwatch to zero and switch to the alternate bank of clocks. Reset to zero the bank of clocks that recorded the first three secs. of practice.

13. At the end of the second eight minute timing trials, turn off the rotors. Reset the stopwatch to zero, but let it continue to run. Tell the subjects, "You will now be given another short rest."

As the stopwatch reaches 4 mins. 30 secs., say to the subjects, "We are ready to begin again." Now re-read the following instructions to the subjects.

"Please stand in front of the rotors and take the stylus in your right hand." (Calm them at this point and let them talk if they seem to need to.)
"Place the tip of the stylus on the target. Now I am going to count to three, and when I reach three, the rotors will start."

(Practice reading this part so that as the second hand of the stopwatch reaches 60, the rotors are switched on. Be sure that the subjects are standing in front of their rotor and are using the correct hand for the condition.)

INSTRUCTIONS FOR COMPONENT RELIABILITY STUDY (PAGE 3)

blw 10/27/70

time with stopwatch for 3 sec.

As the rotors start, mentally count to three. When you reach three, simultaneously reset the stopwatch to zero and switch to the alternate bank of clocks. Reset to zero the bank of clocks that recorded the first three secs. of practice.

14. Switch recording banks every twenty sec. period, record the subjects' scores, and reset the clocks to zero.

- * 15. At the end of the last timing period, ask each subject to rate himself thoughtfully on a separate handedness continuum sheet. Give the following instructions:

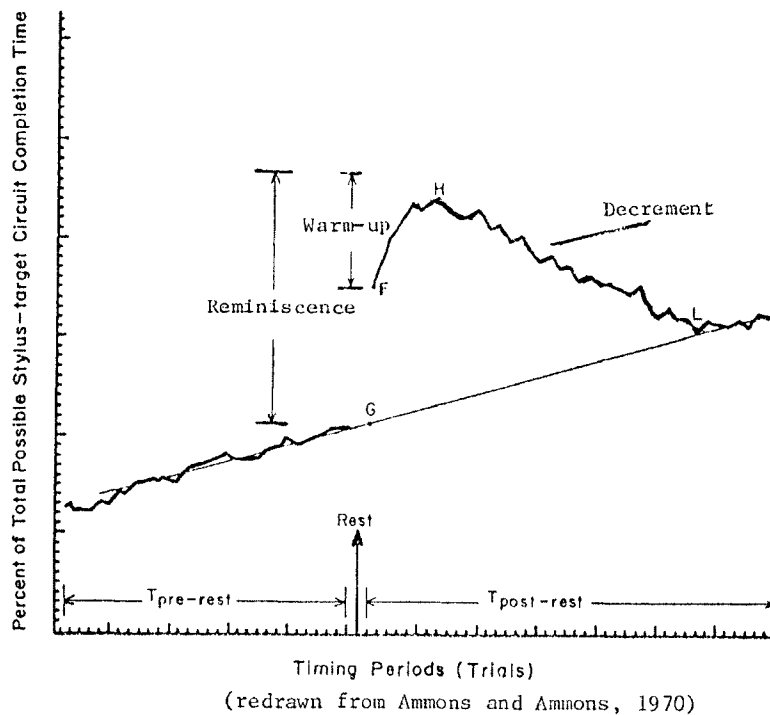
"Please rate your handedness ability on this form. You will note this is a scale ranging from 1, which represents Completely Left-Handed, to 9, which represents Completely Right-handed. Place a check or X-mark along this scale at any place which you feel best describes yourself."

Hold up the form and demonstrate as you are instructing them. Be sure they understand that it is a continuum scale.

16. Give each subject his "credit slip" and thank him for participating.

* N.B. When reading clocks - if hand falls between two marks, always write down the even number for that interval. For example, if the clock hand falls between 121 and 122, record 122 for that interval. In this way, weighting the scores consistently in one direction will be avoided.

Appendix 4a



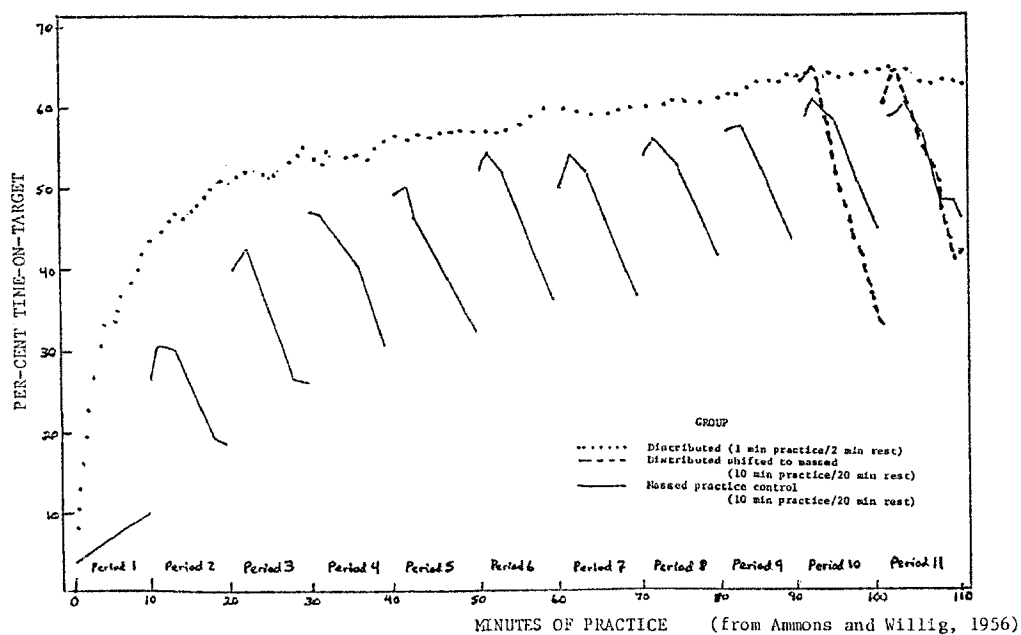
Reminiscence - Any gain in performance after a rest above the performance levels during prerest practice. In the graph above it refers to the performance gain during retest practice after the interpolated rest, above the performance curve for continuous practice (postrest curve from points F,H, to L).

Warm-up - The initial upswing in performance when continuous practice is resumed after a rest. Usually it refers to the performance gains during the first two to three minutes of postrest practice (postrest curve from points F to H).

Decrement - The decrease in performance during continuous postrest practice after the "warm-up" section of the performance curve. The decremental section usually begins after the first two to three minutes of continuous postrest practice (postrest curve from points H to L).

Appendix 4b

A "schedule effect" is a specific, identifiable pattern of performance associated with specific practice schedule conditions. Such a pattern is described by performance level, and the appearance and amount of warm-up, reminiscence and decrement. The graphs on the two following pages give examples of "schedule effects" for schedules of various amounts of practice and rest.



Notice that for the above graph comparing two practice schedules:

- A massed schedule with long (10 minute) continuous practice periods and long rests (20 minutes) induces warm-up, decrement, and reminiscence from period to period, and the performance level of the massed group is always below that of the distributed group.
- A distributed schedule with short (1 minute) continuous practice periods and short rests (2 minutes) induces reminiscence, but no warm-up or decrement, and the performance level of the distributed

group is always above that of the massed group.

-As soon as the distributed group is switched to the massed condition, its performance rapidly converges toward the pattern and level associated with the massed schedule.

The two schedules have an overall equivalence in practice/rest ratio (1/2), but the different absolute lengths in practice and rest periods induce different phenomena.

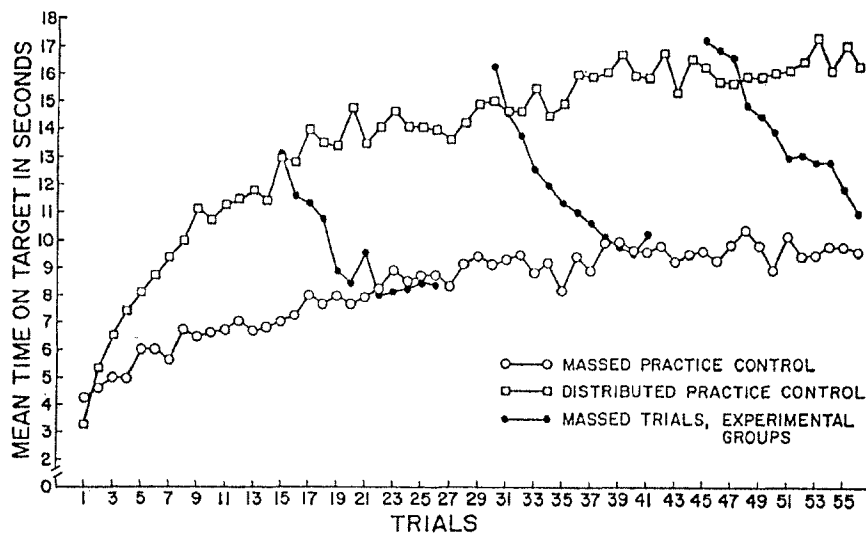


FIG. 1. Performance trends of distributed, massed, and distributed-massed groups. To keep the graph simple, the preshift curves of the distributed-massed groups are not shown. We note, however, that the initial points of the postshift curves were not significantly different from their corresponding distributed-control values and that the terminal points were not significantly different from their corresponding massed-control values.

(from Ball and Payne, 1988)

Notice that for the above graph comparing two practice schedules:

-The massed practice control (28 minutes of continuous practice) shows increasing performance which is close to linear for the first approximately 20 minutes, and then slightly negatively accelerated for the last 8 minutes. Its performance level is always below that of the distributed group.

-The distributed practice control with very short practice periods

(30 seconds) and very short rests (45 seconds) shows reminiscence, but no clear warm-up or decremental sections. Its performance level is always above that of massed group.

-As soon as the distributed group is switched to the massed schedule, its performance rapidly converges toward the pattern and level associated with the massed schedule.

REFERENCES

- Adams, J. A. (1964) Motor skills. Annu. Rev. Psychol., 15, 181-202.
- Adams, J. A. (1971) A closed-loop theory of motor learning. J. Motor Behav., 3, 111-149.
- Adams, J. A. (1987) Historical review and appraisal of research on the learning, retention, and transfer of human motor skills. Psychol. Rev., 101, 41-74.
- Ammons, D. (1984) Long-term retention of a simple motor skill. Paper presented at the 1984 meeting of the Montana Psychological Association.
- Ammons, R. B. (1947a) Acquisition of motor skill: I. Quantitative analysis and theoretical formulation. Psychol. Rev., 54, 263-281.
- Ammons, R. B. (1947b) Acquisition of motor skill: II. Rotary pursuit performance with continuous practice before and after a single rest. J. exp. Psychol., 37, 393-411.
- Ammons, R. B. (1950) Acquisition of motor skill: III. Effects of initially distributed practice on rotary pursuit performance. J. exp. Psychol., 40, 777-787.
- Ammons, R. B., and Ammons, C. H. Decremental and related processes in skilled performance. In L. E. Smith (Ed.) Psychology of motor learning, Proceedings of C.I.C. Symposium on Psychology of Motor Learning, Chicago: Athletic Institute, 1970. Pp. 205-238.
- Ammons, R. B., Ammons, C. H., and Morgan, R. L. (1958) Subskills in rotary pursuit as affected by rate and accuracy requirements and by distribution of practice. J. gen. Psychol., 58, 259-279.

- Ammons, R. B., and Carpenter, J. (1967) Montana State Prison rotary pursuit study. Unpublished laboratory paper.
- Ammons, R. B., and Willig, L. (1956) Acquisition of motor skill: IV. Effects of repeated periods of massed practice. J. exp. Psychol., 51, 427-436.
- Ammons, R. B., Farr, R. G., Bloch, E., Neumann, E., Dey, M., Marion, R., and Ammons, C. H. (1958) Long-term retention of perceptual-motor skills. J. exp. Psychol., 55, 318-328.
- Ball, L. J., and Payne, R. B. (1988) Comparison of inhibition and consolidation theories of spaced practice effects. Percep. & Motor Skills, 66, 219-225.
- Battig, W. F., Nagel, E. H., Voss, J. F., and Brogden, W. J. (1957) Transfer and retention of bidimensional compensatory tracking after extended practice. Amer. J. Psychol., 70, 75-80.
- Bell, H. M. (1950) Retention of pursuit rotor skill after one year. J. exp. Psychol., 40, 648-649.
- Bilodeau, E. A., and Bilodeau, I. McD. (1961) Motor skill learning. Annu. Rev. Psychol., 12, 243-280.
- Eysenck, S. B. G. (1960) Retention of a well developed motor skill after one year. J. gen. Psychol., 63, 267-273.
- Eysenck, H. J., and Frith, C. D. (1977) Reminiscence, motivation, and personality. New York: Plenum.
- Fleishman, E. A., and Parker, J. F. (1962) Factors in the retention and relearning of perceptual-motor skill. J. exp. Psychol., 64, 215-226.
- Hagen, S. J., Wilkerson, H. R., and Nobel, C. E. (1980) Pursuit tracking skill as a joint function of work and rest variables. Percep. & Motor Skills, 50, 683-697.

- Irion, A. L. (1949) Reminiscence in pursuit rotor learning as a function of length of rest and amount of pre-rest practice. J. exp. Psychol., 39, 492-499.
- Irion, A. L. Historical introduction. In E. A. Bilodeau and I. M. Bilodeau (Eds.), Principles of skill acquisition. New York: Academic Press, 1969, Pp. 1-31.
- Jahnke, J. C., and Duncan, C. P. (1956) Reminiscence and forgetting in motor learning after extended rest intervals. J. exp. Psychol., 52, 273-282.
- Jones, E. I., and Bilodeau, E. A. (1953) Retention and relearning of a complex perceptual-motor skill after ten months of no practice. HumRRO res. Bull., No. 53-15.
- Kimble, G. A. (1949) An experimental test of a two-factor theory of inhibition. J. exp. Psychol., 39, 15-23.
- Kimble, G. A. (1949) Performance and reminiscence in motor learning as a function of the degree of distribution of practice. J. exp. Psychol., 39, 500-510.
- Kimble, G. A., and Horenstein, B. R. (1948) Reminiscence in motor learning as a function of length of interpolated rest. J. exp. Psychol., 38, 239-244.
- Koonce, J. M., Chambliss, D. J., and Irion, A. L. (1964) Long-term reminiscence in the pursuit rotor habit. J. exp. Psychol., 67, 498-500.
- McGeoch, J. A., and Irion, A. L. (1952) The psychology of human learning. (2nd ed.) New York: Longmans.
- Meyers, J. (1967) Retention of balance coordination learning as influenced by extended lay-offs. Res. Quart., 38, 72-78.

- Mengelkoch, R. G., Adams, J. A., and Gainer, C. A. (1958) The forgetting of instrument flying skills as a function of the level of initial proficiency. USN Training Dev. Cent., tech. Rep., No. 17-16-18.
- Roehrig, H. C. (1964) Psychomotor task with perfect recall after fifty weeks of no practice. Percep. & Motor Skills, 19, 547-550.
- Reynolds, B., & Adams, J. A. (1953) Effect of distribution and shift in distribution of practice within a single training period. J. exp. Psychol., 46, 137-145.
- Schendel, J. D., Shields, J. L., & Katz, M. S. (1978) Retention of motor skills: Review (Tech. Paper No. 313). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences.
- Schmidt, R. A. (1975) A schema theory of discrete motor skill learning. Psychol. Rev., 82, 225-260.
- Schmidt, R. A. (1982) Motor control and learning: A behavioral emphasis. Champaign, IL: Human Kinetics.
- Smith, N. C., Jr. (1971) Long-term retention of a pursuit motor skill. Percep. & Motor Skills, 32, 773-774.
- Stelmach, G. E. Retention of Motor Skills. In J. Whilmore (Ed.), Exercise and sport sciences review. New York: Academic Press, 1974, Pp. 1-31.