FACTORS INFLUENCING THE RELATIVE ECONOMY OF MASSED AND DISTRIBUTED PRACTICE IN LEARNING

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The purpose of this paper is to review the literature on the optimal distribution of work and rest periods in view of determining how and to what extent the various conditions of learning affect the relative economy of different degrees of distribution. The various factors which have been shown in the literature to affect the margin of superiority of spaced over unspaced learning will be enumerated, and a rough approximation of their individual importances and inter-relations will be attempted. The following factors have received experimental consideration and are of major importance: first, the general characteristics of the distribution of practice (number and length of periods, intervals between periods, degree of learning being considered, etc.); second, the type of material being learned; third, the age of the subjects; fourth criterion or aim of the learning (immediate or delayed recall, speed, accuracy, and amount of recall, improvement, etc.); fifth, the order of repetitions within a practice period (whole vs. part order); sixth, manner of studying; seventh, the stage of learning (whether the distribution is equally effective at the initial and final stages of learning and in the exercise of a well learned habit). Certain other factors or conditions have been indicated but have not received special treatment, such as individual differences, affective value of the learning, motivation, etc. If a thesis is permissible, it is that any statement of the value of distributing or massing learning must be qualified carefully in terms of the conditions listed above in view of

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the instability of the margin of superiority between these two methods of learning.

Since most of the conditions enumerated above enter in some fashion into any investigation of the general problem of the economy of distributing work and rest periods, it has been possible to tabulate most of the investigations in a chart arranged on the bases of these conditions. In this chart the studies, or parts of studies, are listed roughly according to the main variable factor rather than in chronological order. Whenever the significant data permit numerical presentation in a brief compass they are entered under 'Results' in the chart. Certain investigations cannot be forced into the chart at all. They are summarized in the body of the review along with a further consideration of the studies found in the table.

Type of Material to be Learned in Relation to the Characteristics of the Distribution

To avoid unnecessary repetition, the general characteristics of the distribution are treated in connection with the type of material used in the experiment. The type of learning material has been varied for the same distribution in only one experiment, but the comparison of distributions of different extents (distribution will be used as a general term and includes absolute massing) has been the central feature of numerous investigations. The learning schedules differ in the amount of time to be spent or amount and difficulty of the material, the number and length of separate practice periods and whether the periods are decreasing or increasing in length, the length of interval between the periods of practice and whether diminishing or increasing in length, and the period of time over which the learning extends. Investigations intended for school room application usually keep the time interval invariable, and seek to determine the optimal length of period for a 24-hour interval. The interval between periods of learning is of importance in other than its quantitative aspects. The same interval spent in rest, in different types of mental work, physical work, play, etc., may approach the

Experimenter (Date)	No.	Subjects Age	Learning Activity	Length of the Practice Period	Time Interval between Periods	Criteria of Learning	Results
Perkins (1914)	4	Adult	Nonsense syllables, 16 repetitions of lists of 7 pairs	1 reading of list 2 readings of list 4 readings of list 8 readings of list	1, 2, 3, and 4 days Same Same Same	Per cent correctly recalled after a two week interval	1 2 3 4 days' interval 1. 79 72 82 68% 2. 43 78 65 45% 4. 25 33 29 41% 8. 9 16 11 17%
Robinson (1920)	12	Adults	12 presentations of 10 3-place numbers	12 presentations 6 presentations	None 1 day	Recall after 5 min., 20 min., and 24 hours, as measured by 1. Total digits 2. Correct digits 3. Time per digit	After 5 min. After 20 sec. After 24 hrs. 6–6 12 6–6 12 6-6 12 1. 25.4 24.6 24.8 25.0 21.6 20.3 2. 23.1 20.8 21.3 20.2 15.4 9.6 3. 1.85 2.55 2.15 2.65 2.8 3.4 3–3 6 3–3 6 3–3 6 1. 19.3 20.4 19.1 19.7 14.5 14.0 2. 14.6 16.9 13.8 14.6 8.8 6.8 3. 2.6 2.2 2.2 2.8 3.92 3.95
			6 presentations	6 presentations 3 presentations	None 1 day	Same	
Pieron (1913)	1		Numbers, lists of 20	1 reading of list	30 seconds 2 minutes 5 minutes 10 minutes Varying intervals up to 48 hours	'Perfect mastery'	11 readings required for learning 7.5 readings required for learning 6 readings required for learning 5 readings required for learning . . . about 5 for various intervals 5 between 10 min. and 48 hours

Experimenter (Date)	No.	Subjects Age	Learning Activity	Length of the Practice Period	Time Interval between Periods	Criteria of Learning	Results
Lyons (1914)	1	Adult	Nonsense syllables	8, 12, 16, 24, 32, 48, and 72 syllables	1 day	Time in minutes for complete learning	8 12 16 24 32 48 72 104 200 300 .12 1.5 3.6 5 6 14 25 37 93 195
				Same number of syllables learned continuously	None		.25 6 9 16 28 43 138 .. .. ..
Jost (1897)	2		Nonsense syllables, 24 readings	8 readings 6 readings 2 readings	1 day 1 day 1 day	Recall after 24 hours	18 Score for 7 Score for 39 subject 31 subject 53 B. 55 M.
Culler (1912)		22–28 years old	Hampton Court Maze, 12 trials			1. Av. time—last 3 trials 2. Av. errors—last 3 trials 3. Improvement in time 4. Improvement in errors	Time Errors Time Gain Accuracy Gain
	5			12 trials	None		48 3.0 368.7% 147.9%
	5			6 trials	1 day		Invalidated through indifference of subject
	5			4 trials	1 day		39 .9 341.0% 218.5%
	5			3 trials	1 day		59 3.2 195.0% 302.0%
	5			2 trials	1 day		61 5.2 253.5% 161.5%
	3			1 trial	1 day		50 4.8 210.0% 147.9%
Pyle (1914)	5	College seniors	Typewriting, 45 hours practice	10 half hour periods	Half hr. between period 1 day every 10th period	1. Per cent superiority of distribution 2. Per cent superiority in accuracy (By successive 5 hours of practice)	1 2 3 4 5 6 7 8 9 (1) 23 28 27 39 27 21 23 23 22%
	5			2 half hour periods per day	About 7 and 17 hours alternately		(2) 25 12 44 121 161 .. .. .. 223%

Experimenter (Date)	No.	Subjects Age	Learning Activity	Length of the Practice Period	Time Interval between Periods	Criteria of Learning	Results
Lashley (1915)	26	14–36 years old	Archery, 360 shots	5 shots 12 shots 20 shots 40 shots 60 shots	1 day 1 day 1 day 1 day 1 day	1. Gain of final 5 shots over initial 5 2. Gain of final 40 shots over initial 40 3. Gain of final 180 shots over initial 180	1 2 3 34.2 19.3 10.9 average inches from the bull's-eye 47.6 26.0 11.4 19.6 12.3 5.4 26.8 15.5 5.2 29.1 15.7 6.6
Leuba and Hyde (1905)	5 5 4 3	21 years av. age	Writing German script 16 20-minute practices	20 minutes	Twice a day 1 day 2 days 3 days	Av. no. of letters written in 20 minutes after 5, 10, and 16 practices	5 10 15 practices 625 865 1,015 825 1,115 1,540 780 1,175 ** 750 985 **
Starch (1912)	12 14 9 7	College students	Substitution code translation 120 minutes	10 minutes 20 minutes 40 minutes 120 minutes	Twice a day 1 day 2 days None	Average amount done in 5 minutes based on last 15 minutes of practice approximated from graph	262 letters in 5 minutes 250 letters in 5 minutes 195 letters in 5 minutes 130 letters in 5 minutes
Pyle (1913)	6		Substitution 8 hours	30 minutes	1 day 2 days	Each subject compared with a check experi ment	Day interval subj. 2 day interval subj. 17.2% loss against 22.6% loss 15.4% loss against 32.3% loss 12.0% gain against 2.1% gain
			Substitution	15 minutes 30 minutes 45 minutes 60 minutes	1 day	†Relative improvement to check experiment (1) Average speed (2) Gain in speed	(1) (2) 22.3% better, 4.9% less than check exp. 36.1% better, 18.1% more than check exp. 25.0% better, 5.4% more than check exp. 14.8% better, 45.5% more than check exp.

Experimenter (Date)	No.	Subjects Age	Learning Activity	Length of the Practice Period	Time Interval between Periods	Criteria of Learning	Results
Cummins (A) (1919)	5	Adults	French vocabularies 120 minutes	Equal 20–20–20–20–20–20 Reducing 40–30–20–15–10–5	Equal—about 3 days Increasing—1 to 4 days	Recall after 1 day and after 1 week combined	110 words correct $\frac{\text{reducing}}{\text{equal}}$ 1.02 111.7 words correct 1.7 favor of reducing schedule 3.56 P.E. of obt. diff.
(B)	42	Normal school students	Addition	Equal A 10–10–10–10–10–10	2 days	(1) Av. gross gain in no. of correct problems	(1) 9.74 (2) 5.00
	41		60 minutes	Equal B 10–5–5–5–5–5–5–5–5–10	1 day	(2) Av. gain in per cent correct of problems attempted (accuracy)	9.36 3.13
	36			Reducing A 10–15–10–7½–5–2½–10	1 day		10.62 5.56
	38			Reducing B 10–2½–5–7½–10–15–10	1 day		9.92 6.32
(C)	114	7th grade	Geog. 120 min.	15–15–10–10–15–10–10–7½–7½–5–15	Increasing	(1) Av. gross gain in no. of correct problems	(1) 1.12 (2) 6.19 Av. of all groups tested: gives a ratio for amount (1) 1.125 with P.E. of obt. av. of 0.033 and for accuracy 2.64 with P.E. of obt. av. of .371
	69	6th grade	Geog. 120 min.	15–15–55–15–15–15–15–55	Equal	(2) Av. gain in accuracy presented by the ratio	1.50 3.28
	328	3–4th grade	Add. 115 min.	Equal in	Equal		1.04 5.46
	127	5th grade	Div. 115 min.	Reducing	Increasing		1.03 1.20
	116	8th grade	Geog. 115 min.	Reducing–15–15–15–12½	Variable, less than 2 days		.93 .88
	111	7th grade	Hist. 115 min.	10–10–7½–7½–5–2½–15		Gain on reduc. schedule / Gain on equal schedule	.95 2.60
	141	6th grade	Hist. 115 min.				1.23 1.35

Experimenter (Date)	No.	Subjects Age	Learning Activity	Length of the Practice Period	Time Interval between Periods	Criteria of Learning	Results
Cummins (C) (1919)	122	5th grade	Geog. 115 min.	Equal–10–15–15–15–15–15–15–10–15	2 days		1.34 2.46
	201	3–4th grade	Add. 115 min.				1.11 1.52
Austin (A) (1913)	1	Adult	Logical	5 readings	None	(1) Recall after 1 day	(1) (2) (3) 66.00% 13.13% 11.49% retained
			5 readings			(2) Recall after 2 weeks	
				1 reading	24 hours	(3) Recall after 1 month	64.40 37.26% 30.59%
(B)	32–53	College students	Logical 3 readings	3 readings	None	Immediate recall	No. 1 No. 2 No. 3 No. 4 group 34.0 45.7 49.0 40.2% retained
				1 reading	24 hours		46.0 45.6 52.4 39.3% retained
							Immediate Delayed recall
Gordon (1925)	101	College students	Logical	6 readings	None	Correct word in correct position (possible 115 points)	80 points 37 points after 1 month
				3 readings	3 days		76 points 48 points after 1 month
				3 readings	None		54 points 26 points after 3 weeks
				1 readings	7 days		45 points 32 points after 3 weeks
Pechstein (1921)		Rats and adult humans	Maze consisting of 4 sections	2 trials per day by sections	1 day	(1) Trials (2) Time in seconds	Rats: Trials Time Errors; Humans: Trials Time Errors 30 1907 199 23 1220 237
				One section practiced continuously until mastered	1 day	(3) Errors before making 4 out of 5 perfect trials	10 829 135 10 538 108
				2 trials per day on the whole maze	1 day		27 4174 217 12 641 126
				Learned as a whole on one day	None		Rats incapable of so much continuous work 30 1250 260

Experimenter (Date)	No.	Subjects Age	Learning Activity	Length of the Practice Period	Time Interval between Periods	Criteria of Learning	Results		
							Whole star	Half star	Quarter star
Gopalaswami (1924–25)	10		Mirror star Tracing—star divisible into quarters (a–b–c–d)	Whole star	3 times per day	No. of trials before completion of 2 circuits of the whole star within 28 strokes and 4 errors of each other	747 whole massed		
	10			One quarter of star	12 times per day (3 in coordinating quarters)		735 part massed	375 part massed	222 massed whole
	10			Varied—a–b–ab–c–abc–d–abcd	3 times per day regardless of length of run		694 progressive part distributed 739 two part (massed)	401 part distributed 468 whole massed	296 whole distributed
	10			One half of star	6 runs per day (3 in coördinating halves)				
							1st 10 trials	2d 10 trials	(3)
Carr (1919)	20	College students	Pencil maze 20 trials	10 trials first day 1 trial a day for 10 days	None for first 10 trials 1 day for 2d 10 trials	1. Errors per 10 trials 2. Time per 10 trials 3–4 perfect trials out of 5	1126 (1.43) (massed)	319 (0.98) (distributed)	2 subjects
				1 trial a day for 10 days and 10 trials on the 11th day	1 day for 1st 10 trials None for 2d 10 trials		784 (1.00) (distributed) Two methods equal by the time criterion	327 (1.00) (massed)	6 subjects

Experimenter (Date)	No.	Subjects Age	Learning Activity	Length of the Practice Period	Time Interval between Periods	Criteria of Learning	Results
Mould, Treadwell, & Washburn (1915)	144	College students	4 presentations of a list of 10 nonsense syllables	1 syllable	4 secs.	No. of syllables correctly recalled by all subjects after 4 presentations of the list	1,001.0 7.3% advantage for 1 min. rest
					1 min. (syllable articulated)		1,075.4
					4 secs.		847.9 3.7% advantage for 1 min. rest
					1 min. (articulation suppressed)		879.9
					4 secs.		902.0 1.9% advantage for 1 min. rest
					1 min. ("deb" articulated)		920.0
McClatchy (1925)	24	College students	Pencil maze Mastery of maze	Continuous	48 hour rest interval occurring after trial indicated in previous column	(1) Av. no. of trials (2) Av. amount of time (3) Av. no. of errors before mastering the maze	Trials Time Errors
	39			1st trial			20 751 96.4
	24			3d trial			27 1,136 103.7
	24			5th trial			26 1,133 108.4
	39			7th trial			24 1,111 207.0
	24			9th trial			17 721 82.0
	24			11th trial			20 970 148.0
	15			3d trial	24 hour interval inserted		22 1,029 90.0
	15			5th trial			17 632 96.4
	15			9th trial			19 685 105.8
							24 879 113.0

optimal interval for a period of a given length to entirely different extents. The same amount of work, the same number of periods, and the same number of days included within a distribution leaves the lengths of the periods and the lengths of the intervals undefined, since they may be either equal, increasing, or decreasing in length throughout the course of the practice.

Nonsense Materials.—Lyons (**20**) has made the only study of widely varying materials with the same distribution. He conducted an extensive and heroic series of experiments on the relation of the length of study periods to the advantage of distribution, in which he memorized varying amounts of nonsense syllables, digits, prose, and poetry at one sitting and at the rate of one repetition per day. There was only one subject and one determination for each length of period, but when several successive periods are considered together enough learning is involved to be significant. The data for the nonsense syllables are presented in the chart. For both nonsense syllables and digits, the shorter lists show a consistent saving in time by distributing the memorizing, and for the larger units of work spacing practice is overwhelmingly economical. There appears to be no consistent saving in time by distributing the memorizing of the logical materials, prose and poetry. Within the limits explored by Lyons, the factor of the amount of material influences the economy of distribution when the learning is rote, but not when it is logical.

Perkins (**28**) presents data which permit a comparison to be made between the relative influence of the length of the study period and the interval elapsing between study periods on the economy of distributing effort. Sixteen repetitions of lists of nonsense syllables are divided into periods consisting of 1, 2, 4, and 8 readings of the lists with 1, 2, 3, and 4 day intervals for each period length, making 16 different distributions of the learning involved. In general, less was recalled after a lapse of two weeks when the readings occurred every day than when separated by an interval of 2 to 4 days for all lengths of periods concerned except the period consisting of one repetition per day, which shows the least recall for study every other day.

The percentage of syllables correctly recalled was inversely proportional to the length of the study period regardless of the time interval between periods. Within the limits of the experiment, varying the length of the practice period has more influence on the amount recalled than does varying the interval between practices. Averaging the per cent of syllables correctly recalled for each period length regardless of interval, gives for periods of 1, 2, 4, and 8 repetitions 75, 58, 32, and 13 per cent correctly recalled respectively. The average of all lengths of periods for intervals of 1 to 4 days gives respectively 39, 45, 47, and 45 per cent correctly recalled. The length of period seems to be the more significant factor for the learning of nonsense materials for recall after two weeks. Piéron (29) finds an approximately equal superiority for different time intervals between practices varying between 10 minutes and 48 hours in length over a 30 second or a 5 minute interval. Here, again, beyond a certain point the interval between practices of equal length fails to be of importance.

The economy of two simple distributions (continuous work and equal division of the work between two successive days) has been investigated by Robinson (33) for small amounts of learning (12 and 6 presentations of lists of numbers) as judged by recall after 5 minutes, 20 minutes, and 24 hours, according to three criteria, total number of digits recalled irrespective of correctness, number correct as to content and position, and rapidity of recall. Nine criteria are afforded for the comparison of the two types of distribution. When 12 presentations constitute the degree of learning, 8 out of the 9 criteria show an advantage for the distributed study, but when 6 presentations or one half the amount of study is concerned the concentrated study is favored by 5 out of the 9 criteria. The advantage of this particular distribution of rote learning appears to vary with the total amount or degree of learning involved as judged by amount, accuracy, and rapidity of recall after varying periods of time.

Motor Habits.—Twelve trials on a Hampton Court Pencil

Maze are distributed by Culler (7) into different lengths of periods with a constant interval between practices, except, of course, for absolute massing. The lengths of period are 12 trials with no interval between and 6, 4, 3, 2 and 1 trials per day with one day elapsing between periods, necessarily making the time spanned by the learning unequal and the time length of periods variable for the different stages of the learning. Since there is a gradual decrease in the time required for one trial as the learning progresses, making a trial the unit of work amounts to using a decreasing length of period. Outside of the data for the 6 trials per day period (which were invalidated by the indifference of one subject) the one and two repetitions per day groups showed a lower absolute attainment and less improvement than did the 12 and 4 trials per day groups. For the maze used it seems that prolonged and persistent practice repeated for a few days is preferable to shorter practice periods distributed over a longer span of time.

The study of Pyle (32) on the relative economy of two distributions for learning to typewrite is adequately summarized in the chart. The group for which the practice was distributed maintained about a 25 per cent superiority in speed to the massed practice group throughout the whole course of the practice and was from 12 per cent up to 223 per cent more accurate. The group which worked under distributed conditions was, perhaps, a little higher in initial motor capacity. He does not mention whether the learning proceeded by the whole or part method but presumably the part method of some sort was used in view of the nature of the habit involved. Pechstein (25) found that rats were incapable of sufficient continuous work to learn the maze in question as a whole in one day, but learned it in 27 trials at the rate of two trials per day, also by the whole method. Thirty trials were required by humans to learn the maze as a whole at one continuous sitting, while it was learned in twelve trials when the trials were separated by one day intervals. He finds a different result, however, when the maze is attacked by the part method, in which case the distributed practice is found to be less economical. Leuba and Hyde (19) in an early study in which the subjects practiced the hand movements requisite to writing German script, found that 20 minutes of practice every day or every other day yields a better gain than either more highly concentrated or more highly distributed practice, *i.e.*, two 20-minute periods a day or 20 minutes of practice every third day. Lashley (18) practiced subjects on archery at the rate of 5, 12, 20, 40, and 60 shots per day for 360 shots at the target. During the first 180 shots there was little or no relation between the extent of distribution and improvement in accuracy of shooting, but during the last half of the practice the extent of distribution is associated with greater proficiency. Murphy (24) found that practice at throwing a javelin at a target is best distributed to the extent of one or three practices a week rather than practice 5 times a week.

Code Translation.—The much quoted experiment of Starch (35) involving the distribution of 120 minutes of practice time into periods of 10, 20, 40, and 120 minutes with different time intervals for each length of period, favors the shorter periods. Graphical presentation alone is supplied so that the data used in the chart are approximations from a graph. Both the length of period and the time interval between are varied, and there is no mention of equating the groups, which varied from 7 to 14 subjects. The group working in 10-minute periods translated an average of 10 letters per 5 minute period more than did the group working 20 minute periods, which group in turn translated an average of 21 letters more per each 5 minute period than did the 40 minute group. Similar code substitution material was used by Pyle (31) to determine whether 30 minutes of practice every day is more efficient per unit of time than the same amount of practice on alternate days. The two methods of distribution are used by a pair of subjects and their results are compared with a check experiment which is the same for each pair of subjects. The three comparisons thus afforded all favor daily practice. Another such determination favors daily practice for a 20 minute period, and another indicates that practice daily and on alternate days are equally efficient when the length of the period is 11 minutes. Dearborn (9) in a brief experiment reports that 10 minutes of working on substitution once a day yields better results per unit of time than 10 minutes of practice twice a day, and Munn (23) in an experiment on the same learning activity favors distribution of effort into very short periods of practice, less than one minute. The studies indicate that for code translation distributed practice favors learning more than massing does.

Logical Materials and School Subjects.—Under this heading will be summarized investigations in which the material is logical with recall tested for a verbatim reproduction, in which the material is logical and the recall tested for ideas contained, and in which the learning consists in drill on some arithmetic function. Lyons (20) parallelled his experiments with digits and nonsense syllables by using prose and poetry as learning materials, and found that for various lengths of material there was no consistent advantage or disadvantage in studying at the rate of one repetition per day instead of entirely learning the passage in one sitting. One determination was made for 20 passages of poetry in graded lengths between 25 and 2,500 word passages, and for 20 passages of prose varying in length between 15 and 1,200 words. Gordon (13) recently has carried on some class experiments in which the learning of a meaningful passage was tested by the ability of the subjects to recall it word for word. Six repetitions of the passage on one day proved about equal to two periods of 3 presentations separated by a 3 day interval for immediate recall, but was considerably inferior when the criterion was recall after the lapse of one month. Three presentations with a week interval between each one was less economical for immediate recall than the same amount of time spent continuously, but was more economical for delayed recall (3 weeks). Austin (1) finds that with logical materials, repetitions lose in effectiveness if too close together or too widely separated. (See below under Criterion of Learning.)

Kirby (17) attacks the problem of the most favorable length of period when there is an interval of one day between periods of addition and division. 2 minutes per day is superior to longer periods. The results have been criticized by the investigator, inasmuch as the students studying 2 minutes per day would be studying over a greater period of time, giving more opportunity for outside practice and learning through the regular school work. Hahn and Thorndike (14) have investigated the identical problem, using addition as the learning material. A 22½ minute period is superior to a 11¼ minute period for 7th grade students and a 10 minute period is about equally superior to a 5 minute period for the 4th grade, while for the 6th grade 20 minutes is just slightly superior to 10 minutes and 7½ and 15 minutes are equally efficient for children in the fifth grade.

Thorndike (39), using multiplication drill, finds a case in which a given amount of work per day is done more advantageously at one continuous sitting than if distributed into 4 sittings on the same day. Also he finds that whether practice is spread over 24 days or is consolidated into 6 makes little difference, provided the long day's work is made at one sitting. With 2 units of work per sitting and 4 sittings per day, and with 8 units to a sitting and one sitting a day, there is little difference between practice daily or on alternate days. It proved more advantageous to introduce a rest period of 10 minutes between two series of five mental multiplication problems than a 20 minute interval or no interval at all. Edwards (11) compared groups who studied various school materials, geography, history, and others, 6½ minutes continuously or with the same amount of time divided into a study period of 4 minutes followed some days later by a review of 2½ minutes. Time intervals, difficulty of the subject matter, age of the subjects were so variable that it is difficult to interpret the results, which tended to favor the spaced study.

An extensive series of experiments in which an elaborate distribution schedule is compared with a schedule of periods of equal length, has been carried on by Cummins (8). A total of 120 minutes of study was distributed into periods of 40, 30, 20, 15, 10, and 5 minutes, with an increasing interval of time between, and into six 20-minute periods with equal intervals (3–4 days) between. These two distributions are comparable in that they both involve the same amount of time and the same number of periods, and substantially span the same number of days, and differ only in the length of the study periods and the intervals between periods. The ratio representing the superiority of the groups on the schedule of periods diminishing in length over the groups on the equal schedule, in terms of the average gross gain, gives for all ages and materials an average ratio of 1.125 with a P. E. of 0.033. The accuracy criterion gives the diminishing schedule a greater, statistically significant superiority, the diminishing of equal ratio being 2.64 with a P. E. of .371. These results will be considered in more detail under another heading. Cummins (B on the chart) gives data for comparing two 'equal' distributions of varying degree of massing. Sixty minutes of study divided into six 10-minute periods is just as economical as the same amount of time divided into an initial and final test period of 10 minutes separated by eight 5-minute periods when the criterion is average gross gain, and distribution of effort into smaller periods is slightly unfavorable if the gain in per cent of problems correct is the criterion. The subjects were about 20 years of age and were practicing addition, which must be taken into account in interpreting results.

Age of the Subjects

There is no direct attempt to ascertain the influence of the age of the subjects on the relative economy of distributions varying both in type and extent. Nevertheless age is in all probability a factor. The majority of the findings have been based on experiments in which the subjects have been at least of college age, with the exception of those in which school materials have been used, in which case the subjects are appropriately of school age. Edwards (11) used grade and normal school subjects, and suggests that distribution may be more important for children than adults. The results are not of much assistance because of the failure to control conditions carefully. Kirby's investigation (17) favors very short periods of work for young children, but the advantage is probably exaggerated by the operation of other causes. The experiments of Cummins (8) offer the only example of the same distribution being tested out with subjects of different age, but his results do not furnish the basis for adequate comparisons, since the lower grades worked largely at drill in arithmetic functions and the upper grades dealt with more logical material. Drawing an average from the third, fourth, and fifth grade ratios as shown in the chart and comparing them with the average of the three higher grades, reveals no very significant differentiating advantage in distributing practice for either age group. This holds for both criteria. Adults learned French vocabularies equally well under the two schedules described above. Further, for normal school subjects working on addition there was no great difference between two distributions of the same type but of different extents, and it seemed to make little difference whether the lengths of periods increased or decreased throughout the course of the practice. The greater fatigability of children, their lesser perseverence, etc., indicate that age is possibly an important factor here and that optimal conditions for studying various sorts of materials should be worked out for different ages.

Criterion of Learning

The object, aim, goal, or criterion of learning is a factor to be considered in deciding the superiority of massed and distributed practice. The various criteria which appear in the investigations are free and assisted recall, after periods of time varying from immediate recall to recall after a month interval, as measured by amount, accuracy, and rapidity. Where drill in arithmetic or any skill in which the subjects have previous training and varying abilities is concerned, learning is measured by a comparison of initial and final attainment. The formation of a muscular habit can be measured by final attainment or by gain over initial performance. On the whole the effects on retention of distributing practice in the latter learning activities have been neglected. However the recall is measured, the extent to which it is delayed is perhaps the most important factor in differentiating spaced and unspaced work in regard to economy.

A striking demonstration of the importance of the period separating the cessation of practice and the testing of the learning is found in the study of Austin (1). In terms of the percentage correctly recalled, one reading of the material per day for 5 successive days was 1.6 per cent inferior to 5 continuous readings for immediate recall, 24.13 per cent superior for recall after two weeks, and 19.10 per cent superior for recall delayed one month. This is the margin of superiority and not the difference in absolute per cent correctly recalled. The two distributions are about equal for immediate recall, but the distributed work yields results for recall after two weeks or a month about three times as great as the continuous study. The same scheme of distribution for 3 readings of a textbook assignment showed no significant advantage in distributing effort when immediate recall is the goal of learning. A recent study by Gordon (13) substantiates the findings of Austin. Six readings of a passage on one day was slightly superior for immediate recall to 3 readings a day separated by a three day interval, but the spaced readings were pronouncedly more advantageous for recall delayed one month. Likewise, three continuous readings were decidedly more profitable for immediate recall than three readings separated by a week interval, but the advantage was reversed when the recall was measured after the lapse of three weeks.

	Delay of Recall			
	5 min.	20 min.	24 hours	Total
No. of times 6 readings is superior	37	31	46	114
" " " 12 " " "	21	27	15	63
" " " neither is superior	14	14	11	39
" " " 3-3 readings is superior	21	33	36	90
" " " 6 " " "	45	29	26	100
" " " neither is superior	6	10	7	23

The most elaborate scheme of criteria is used by Robinson (33) in that he tested recall after 5 minutes, 20 minutes, and 24 hours by amount, accuracy, and speed of recall. Robinson has analyzed his data in order to bring to light the factor of delayed recall, by counting the number of times (by individuals) each distribution is superior on the basis of a composite of the three criteria. A division of 12 presentations into two equal periods 24 hours apart is advantageous for recall delayed 24 hours, but not to any great extent for recall as immediate as 5 or 20 minutes. When 6 presentations are used the continuous work is the more advantageous for immediate recall, but not so for delayed recall. The three studies on this phase of the question are univocal.

In Robinson's study, distribution of learning appears to a better relative advantage when learning is measured by correct digits and speed of recall than when measured by amount of recall. The possibility that distribution makes a greater difference in accuracy than in amount, is indicated in several investigations. Hahn and Thorndike (14) weighted a wrong answer in two different ways and thereby altered the superiority of certain lengths of periods over others. Cummins' (8) accuracy criterion reveals a much greater advantage for the 'reducing' distribution (*i.e.* the more highly distributed practice) than does the amount criterion. In learning to typewrite, Pyle (32) found a considerable superiority in speed for the more highly distributed schedule (between 20 and 30 per cent for successive stages), but a considerably greater superiority in accuracy in the initial stages of learning and an overwhelming superiority in the final stages. Also, the error criterion and the meeting of 4 errorless trials out of five differentiate two sorts of distribution which are equally effective as judged by the time criterion in Carr's study (6). Two studies using logical learning, one using rote, and two involving motor learning, indicate that distribution is most economical in avoiding errors rather than in making for rapid learning. This fact offers a clue to the explanation of why distribution is or is not favorable to learning.

Order of Repetitions within the Periods

The intimate relation of the problem of the whole vs. part method of learning a motor act to the problem of the economy of interspersing work and rest periods has been demonstrated by Pechstein (25, 26, 27). Previous researches all concerned learning in which the unit was repeated as a whole. Pechstein found that when the maze was attacked as a whole it could be learned in fewer trials, less time, and with fewer errors by humans when the practice was distributed at the rate of two trials per day than when the practice was massed into one day. In the face of such a complex situation rats were incapable of sufficient continuous effort to learn the maze at all under massed conditions, but were able to do so when the learning was distributed at the rate of two trials per day. Massing effort seems unfavorable to the whole method of learning. The maze which he used for both rats and humans was divisible into four smaller and unitary sections to permit part learning. Each fourth of the whole maze was learned separately, and finally the parts were run serially until the subject was able to thread the maze as a whole. A combination of part method and massing effort was obtained when the four sections were learned separately on four successive days and were integrated on the fifth, and a combination of part and distributed practice was obtained when the parts were learned and joined at the rate of two trials per day. Under part conditions the massed practice proved the more efficient for both rats and humans. Of the four different ways in which the maze was learned, the union of massed practice with the part method proved the most efficient. When the units had been learned at the rate of 2 trials per day, the act of connecting them together proved difficult, but when the maze had been learned at the rate of one section per day the complex act of connecting them was comparatively simple. The rats were capable of exerting a surprising amount of continuous effort on the simple unit, making a high degree of massing possible. Pechstein interprets the superiority of massed effort combined with the part method in hard problems to lie in preventing confusion, hesitation, emotional conditions, and in being more suited to the organism's powers.

Gopalaswami (12) has investigated the same problem with mirror tracing, using a star which could be divided into smaller comparable units. For the whole method massed, 3 runs were made per day on the star as a whole; for the pure part method massed the star was divided into 4 similar and equally different parts which were learned successively at the rate of 12 trials per day and finally the whole star was practiced at the rate of 3 runs per day; the progressive part method with distributed practicing, in which the parts are learned separately but are immediately joined to those learned previously, involved 3 runs per day irrespective of the length of time required for each run. The two-part method divided the star into halves which were first learned separately at the rate of 6 trials a day and then joined. There is a considerable superiority for the progressive part method with distributed practice. The pure part method with massed practice is somewhat superior to the whole method with massed practice, which is in agreement with Pechstein's findings. By considering only the first half of the star, the comparisons afforded show that distributing effort is somewhat unfavorable to part learning, and that the part method, regardless of how the practice is distributed, is considerably superior to the whole method with massed practice. For just one quarter of the star continuous work is more advantageous than distributed work.

Manner of Studying

That the manner of studying or presenting memory material may affect the relative economy of continuous and spaced learning is suggested by one study, that of Mould, Treadwell, and Washburn (22). The advantage of allowing 4 seconds interval to elapse between presentations of nonsense syllables as compared with a one-minute interval was ascertained for three different methods of studying the list, one in which the syllable is articulated, another in which the articulation is suppressed, and a third in which 'deb' is pronounced instead of the syllable which is being presented. The longer interval between syllables was 7.3 per cent superior when articulation was permitted, 3.7 per cent superior when suppressed, and 1.9 per cent advantagous when 'deb' was pronounced. The economy of distribution to the extent that a single movement or a single presentation of a syllable or word is followed by a brief pause has been investigated. Bergstrom (4) in presenting lists of nonsense syllables found that employing longer intervals between presentations of single syllables makes for more efficient learning than where no interval or a very short one is allowed. The same holds for intervals between series that make up a study period. The opposite result is reported by Bean (3) who studied the advantage of different intervals between single throws at a target. He found an inverse proportion between the interval separating throws and improvement. Browning, Brown, and Washburn (5) compared motor learning in which the requisite movements were made continuously and in which they were separated by a pause of one minute. The one-minute period of inactivity was more favorable to learning than no interval, and was particularly so on the more difficult series of movements.

Period in the Learning Curve

That the various criteria of learning for a given material, type of distribution, etc. show a superiority for either distribution or massing effort in learning some material or habit completely, does not permit the conclusion that one or the other type of distribution represents the optimal efficiency. The possibility exists that distribution may be more effective during the initial stages of habit formation or learning of any sort and massing more efficient in the final stages, or vice versa, in which case a combination of a greater degree of distribution at one period and a lesser degree at others would produce the optimal arrangement of work and rest periods. Carr (6) has studied this problem specifically by using two distributions, one in which the first ten trials are continuous and the second ten trials separated by day intervals, and one in which the arrangement is reversed. When the first ten trials of one schedule (massed) is compared with the first ten trials of the second schedule (distributed) the errors of the two series of ten trials are to each other as 1.43 is to 1; the errors of the last ten trials of the first schedule (distributed) are to the last ten trials of the second schedule (massed) as 0.98 is to 1. In regard to errors (which are probably most affected by distribution), the initial practices should be spread over a long period of time, and it seems to make little difference whether the practice is spaced or not in the final stages of the learning. The time criterion shows equality for the two schedules, but a criterion of 4 perfect trials out of 5 was met three times as often by the subjects who practiced under distributed conditions in the initial stages. Lashley (18) in his investigation of the relation between the degree of distribution and improvement in archery, finds about the same improvement regardless of the degree of distribution in the first half of the total practice, but in the last half greater distribution means greater improvement. During the first periods in acquiring a new motor skill without instruction, there are many sudden improvements through 'insight' which are unrelated to distribution, which accounts possibly for the failure of the relation between the spacing of practice and improvement to appear. Pechstein (25) believes with Carr that distributing effort is of value for the exploratory and eliminative stages, and massing advantageous for the mechanizing stage. Pyle (32) analyzes his data on typewriting to bring out any relation between the period of the learning curve and the superiority of distribution, by making his comparisons on the basis of successive 5 hours of practice. The spaced learning maintains a fairly consistent margin of superiority over the unspaced in speed, but for accuracy the spaced practice is increasingly superior period by period. The accuracy criterion favors distribution in the later stages of habit formation more than in the initial stages. Pyle (30), working with a substitution test, reports some evidence that in the early stages of habituation the second practice on the same day gives good returns, while in later stages alternate days may be the best distribution.

Recently McClatchy (21) has explored the stages of learning a pencil maze for the optimal position for introducing a rest period. She interpolated a 48-hour rest period after the first, third, fifth, seventh, ninth, and eleventh trials for corresponding different groups, and compared them on the basis of trials, time, and errors for learning. The criterion indicates that the optimal locus for a 48-hour period of rest is after the seventh trial, and that the insertion of the rest at any other point is detrimental. Inserting a 24-hour rest is beneficial if it is located between the first and fourth trials and detrimental only after the ninth trial. The proper position of the rest period depends on its length, that is, no general statement as to the benefits of massing at any point in the learning curve can be made.

Jost (16) found that the optimal distribution is obtained by massing the early learning, which conflicts with the view of Steffens (36) who found that learning is facilitated by distribution in the first stages. Cummins (8) gets at the same problem by comparing a distribution consisting of periods and intervals of equal length with one in which the periods decrease in length and the intervals increase. The practice is more highly massed at first in regard to both the length of periods and the frequency with which they occur. A large number of determinations show massing in the initial stages to be somewhat advantageous if the criterion is amount, and much more so if the criterion is accuracy. In another phase of the experiment, Cummins compared 60 minutes of time distributed so that the periods diminished in length with a schedule in which the periods increased in length, all other conditions being equal. The subjects were adults and practiced addition. It seemed to make little difference here if the concentrated practice came first or last. The inconsistency of this phase of the experiment with results obtained by comparing the equal and diminishing schedule may possibly be due to the age of the subjects and to the material used, which was an arithmetical function previously practiced considerably by them, so that the complete learning process was not represented. It is difficult to see why the diminishing schedule should be superior to an 'equal' schedule but not correspondingly superior to an 'increasing' schedule.

The investigators who present data on this point are far from being agreed. Robinson (33) offers data obtained by comparing the relative advantage of massing and distributing effort when the material is to be learned with different degrees of thoroughness. When a list of numbers to be memorized was presented 12 times, 8 out of the 9 criteria indicated that the best results were obtainable by having 6 presentations on two successive days rather than all 12 at the same sitting. Only 4 out of the 9 criteria favor a distribution of 6 presentations in the same fashion. The difference may be due to the difference in work-period lengths necessarily involved, or to the different degree of learning involved, in which case distribution is favored in the final periods.

Robinson (34) raises the question as to the advantage of spaced exercise of a well learned habit. He refers to an example of an industrial situation reported by Jones (15) in which the normal rate of a group of workmen, the production of 16 pieces per hour by continuous work, was increased by interspersing rest periods as follows:

Work Period	Rest Period	No. of Pieces per Hr.
All day	None	16
25 min.	5 min.	18
17 min.	3 min.	22
10 min.	2 min.	25

In a similar case, previously continuous work at driving rivets was divided into one-and-three-quarter minute periods separated by 2 minutes of rest, with the result that the total amount accomplished was raised from 600 to 1600 rivets per day. That resting 5 hours and 20 minutes out of a 10 hour work day increased the output 266 per cent illustrates the importance of this whole question in industrial situations.

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