Lintern, Gavan (2009). The Mystery of Distributed Learning. Proceedings of the Fifteenth International Symposium on Aviation Psychology, (pp. xxx-xxx). April 27-30, 2009, Dayton, OH [CD ROM]

THE MYSTERY OF DISTRIBUTED LEARNING

Gavan Lintern
Cognitive Systems Design
Dayton OH 45439

There are contrasting opinions about the value of distributed learning. Several textbooks on general training issues promote it as an effective training strategy while many researchers who have focused specifically on this topic argue that distributed practice is no more effective than non-distributed practice. It is noteworthy that most who promote distributed learning base their opinion on belief rather than on experimental research while most who argue that it is of no value base their opinions on empirical data restricted primarily to the learning of simple motor skills. Additionally, much of the distributed learning research has employed the experimentally convenient manipulation of distributing learning trials whereas, from a practical perspective, the distribution of sessions would offer a more relevant experimental manipulation. In this paper, I explore the insights that can be gleaned from research that has focused on operationally relevant tasks and in which learning sessions have been distributed.

Anderson (1985, p. 240) observes that distributed practice has profound effects on skill acquisition and Schultz and Schultz (1986, p. 213) claim that it is usually the better training approach. Hopkins, Snyder, Price, Hornick, Mackie, Smillie, and Sugarman (1982) take it for granted that distributed practice will benefit the training of nuclear power station operators. In contrast, Adams (1987, p. 50), Magill (1985, p. 374), and Schmidt (1982, p. 484) argue that distributed practice has substantial effects on performance but minimal effects on learning. My primary goal for this paper is to assess which of these contrasting opinions is the more credible.

Distribution of Trials or Sessions?

Spacing manipulations come in different forms. Sessions that may be in the order of an hour or two long may be spaced by one or more hours (Keller & Estes, 1944) or across days (Hagman & Rose, 1983; Keller & Estes, 1945). Trials that may be in the order of seconds or minutes long can be spaced by seconds or minutes (Magill, 1988; Reynolds & Bilodeau, 1952) or even days (Flexman, Roscoe, Williams, & Williges, 1972). The conflicting opinions about distributed practice that can be found both in scientific and in operational training circles are generally not derived from a consideration of the data from all relevant forms of distributed practice. For example, Adams (1987) considered experiments in which trials have been spaced while Anderson (1985) considered experiments in which sessions were spaced.

The issue of distributing sessions is of interest because the scheduling of training has substantial cost implications especially where operators must return to a central establishment for continued training. In such a case, it will usually be more economical to compress training into as short a period as possible. However, a well-distributed series of sessions may be necessary to establish and to maintain high levels of skill. In this paper I review literature related to distributions of training sessions and its effects on acquisition of action skills; where action skills are to be viewed as those with both a psycho-motor and a cognitive component. A comprehensive analysis of trial-distribution effects on learning of perceptual-motor skills is provided in a review by Lee and Genovese (1988) and in commentaries on that review (Lintern, 1988; Newell, Antoniou, & Carlton, 1988).

In contrast to the supposed benefits of distributed training, it is occasionally argued that compressed training is beneficial. One of the often-mentioned advantages of regularly scheduled flight training, such as that offered by the University of Illinois, is that flight sessions scheduled over alternating days promote faster learning than the irregular distribution of sessions undertaken by many flight students (Shugarts, 1987). In addition, the University's summer semester is occasionally thought to provide a better training opportunity because students fly six days a week instead of three days a week as they do in the Fall and Spring semesters. However, this belief in the advantage of regular and compressed schedules has developed in the absence of any empirical evidence one way or the other.

Opinions relating to the supposed benefits of compressing or distributing trials or sessions are diverse. Furthermore, they are often generated without full consideration of the evidence, and occasionally without consideration of any evidence at all.

Review of Experiments

Three categories of tasks have been used in the research to be reviewed. The first includes relatively well defined technical skills that must be taught over days or weeks in an extended course of instruction. Morse code and typing are the two target skills that have been examined. A second category includes relatively short procedural skills that may be learned within an hour or two. The third includes recreational activities which may take years of intensive practice to reach full proficiency, but which may be learned to a moderate level of competence in several lessons of one or two hours each. It is unfortunate that the target skills are so diverse, but useful data on this issue is difficult to find and, given the strength of the opinions, it seemed worthwhile to explore the implications of any data that might be relevant.

Technical Skills

A set of data used by Anderson (1985) in his discussion of distributed practice is from Morse code research by Keller and Estes (1945). The standard five-week course of Morse Code instruction gave trainees 195 hours of practice, with seven hours of practice on each of five days and four hours of practice on the sixth day of each week. Keller and Estes (1945) compared the standard schedule with an experimental schedule in which 192 hours of practice were distributed over eight weeks, with four hours of practice per day for six days each week. There were no differences between the groups' skill levels at 5 weeks (when Morse code training ended for the massed group), despite the fact that the distributed group had completed only 60% of the training. The distributed-practice group was far more proficient with Morse code than was the massed-practice group at completion of Morse code training (Figure 1).

Two different schedules had been used with those students who had received four hours of practice each working day (Keller & Estes, 1944). One schedule had students learning Morse code in a four-hour block each morning. In the other, the four hours of instruction were distributed throughout the day for five days of the week. Because all trainees were to be released from duty around noon on Saturdays, this group also had a four-hour block of instruction in the morning of that day. Instruction in other communications topics was conducted in the afternoon, Monday through Friday of each week for the students in the blocked condition and during intervening Morse Code sessions for the students in the distributed condition. As described in Keller and Estes (1944), there were no differences in progress or final Morse code performance levels of the two groups (Figure 1).

Three decades later, Baddeley and Longman (1978) manipulated the length and distribution of sessions for instruction of typing. Four groups of subjects practiced typing for one 1-hour session per day, one 2-hour session per day, two 1-hour sessions per day, or two 2-hour sessions per day (i.e., 1, 2, or 4 hours per day). Sessions were scheduled over 5-day working weeks and sessions given on the same day were separated by at least two hours. A test of typing skill administered after 60 hours of training significantly favored fewer hours per day. The number of sessions over which those hours were distributed (a comparison between the use of two 1-hour sessions versus one 2-hour session) had no noticeable effect.

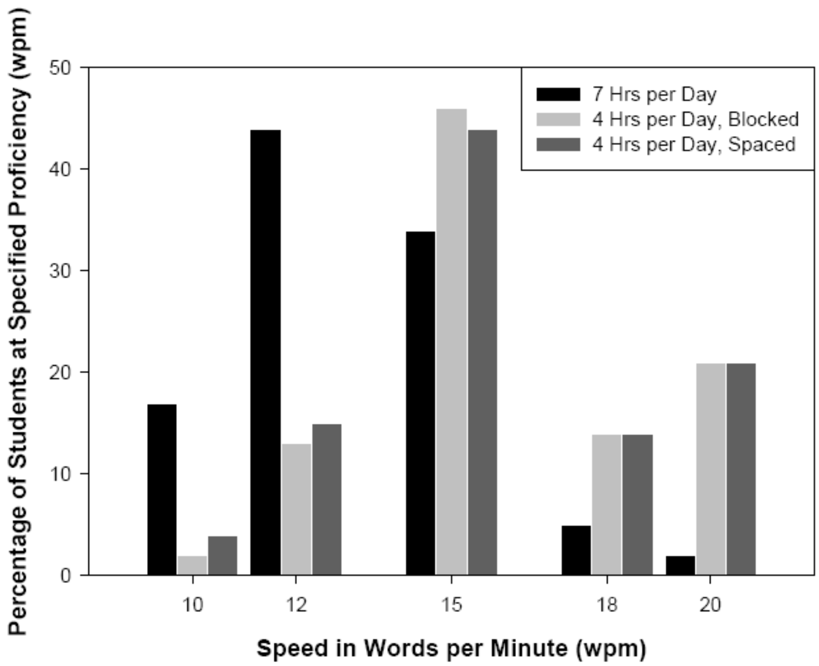

Figure 1. Percentage of Morse Code students who passed various receiving speeds at the end of approximately 200 hours of training (adapted from Keller and Estes, 1944, 1945).

Procedural Skills

Flexman et al. (1972) have provided data that show a learning advantage with compressed trials of a procedural task. A group of student pilots were pre-trained on several flight tasks in a 1-CA-2 SNJ Link ground-based trainer, which simulated the North American T6/SNJ aircraft and had been built from the cockpit of a wrecked T6/SNJ. Following pre-training, these experimental subjects were taught the same tasks to criterion in the T6/SNJ aircraft. A control group of student pilots, not pre-trained in the simulator, were also taught the flight tasks to criterion in the aircraft.

One of the training tasks was the start-up procedure for the T6/SNJ. This task required approximately two minutes to complete and had 16 steps that had to be executed accurately and in correct sequence to start the aircraft safely. Particularly in view of the fact that the simulator had been built from a cockpit of the target aircraft, the simulated starting procedure appeared to provide an excellent representation of the procedure used in the aircraft.

Intensive instruction on this task was not possible in the aircraft because of the battery drain resulting from each start and because of the possibility of overheating the starter motor. Control subjects practiced this procedure once at the beginning of each of their instructional flights, generally separated by one or more days. Experimental subjects first learned the procedure in the ground-based trainer in a session of massed trials that required less than one-hour of instructional time. The experimental subjects required fewer practice trials (ground-based trainer and aircraft trials combined) than did the control subjects (aircraft trials only) to learn the complete procedure and to demonstrate criterion performance in the airplane (three successive trials without error). The faster learning of the experimental group was attributed to the fact that experimental subjects had the bulk of their practice in one massed session of trials rather than distributed one trial at a time over days.

Hagman (1980) examined distributed practice with a procedure in which military trainees were taught an alternator maintenance task either with three massed practice trials on one day or with one practice trial on each of three successive days. This task required approximately 15 to 45 minutes to complete depending on the level of skill of the student. In a single-trial test of alternator maintenance approximately two weeks later, the spaced practice group completed the task in significantly less time and with fewer errors.

Recreational Activities

Young (1954) examined effects of changing the distributions of sessions in badminton and archery classes. There were apparently different students in the badminton and archery classes although there is a possibility that some subjects could have been in both classes. Sixteen badminton and nineteen archery lessons were scheduled over several weeks for two days or four days each week. Some badminton skills were learned more effectively with the more distributed schedule and archery was learned more effectively with the more compressed schedule.

Harmon and Miller (1950) contrasted four schedules of nine lessons for the instruction of billiards. The schedules were one lesson per day (including weekends), three lessons per week, one lesson per week, and nine lessons extended over 55 days in a sequence that became progressively more distributed (i.e., lessons on days 1, 2, 3, 5, 8, 13, 21, 34, and 55). There were no differences, as assessed in the ninth lesson, between groups with the one-lesson-per-day, three-lessons-per-week, and one-lesson-per-week schedules. However, the group with the 55-day progressively-distributed schedule showed better performance in the ninth lesson.

In a follow-up study, Langley (cited in Harmon & Miller) showed that another progressively distributed schedule, in which the nine lessons were distributed over 43 days (lessons on days 1, 2, 3, 8, 15, 22, 29, 36, and 45), was as good as the extended schedule of Harmon and Miller and better than their more compressed schedules. In a second follow-up study, Lawrence (cited in Harmon & Miller) tested the retention of some of the one-lesson-per-day and progressively-distributed-schedule subjects from the Harmon and Miller experiment. Again, an advantage was shown for the progressively-distributed schedule.

Discussion

Some distributions of sessions over days has been shown to assist learning of Morse code (Keller & Estes, 1945), typewriting skills (Baddeley & Longman, 1978), badminton (Young, 1954), billiards (Harmon & Miller, 1950), and alternator maintenance (Hagman, 1980). On the other hand, massing of practice can sometimes offer an advantage (Flexman et al., 1972; Young, 1954) while some variations in distribution of sessions within days and across days do not have any effects (Keller & Estes, 1944; Baddeley & Longman, 1978; Harmon & Miller, 1950). A progressively distributed schedule appears to offer some advantage (Harmon & Miller, 1950) and it should be noted that the schedule used by Flexman et al. (1972) can also be thought of as progressively distributed in that there was early massed practice in the simulator followed by a number of trials in the aircraft spaced by a day or more.

The experiments from which these data have been gathered might be viewed as too diverse to permit any systematic analysis. Nevertheless, there has been little systematic research on this topic and strong opinions about the effects of distributed practice find their way into the published literature. The primary goal for this discussion is to assess whether the empirical work or a rational analysis can lend any support to these opinions.

Cognitive Encoding

Anderson (1985) has attempted to deal with the enhanced learning effect of spaced practice with an appeal to more elaborate cognitive encoding of the representations of skill. Within the framework presented by Anderson, the development of skill follows a path from deductive processing to memory retrieval and pattern recognition. He relates this view to the progressive movement through cognitive, associative, and autonomous stages that are sometimes thought to underlie the acquisition of skill (Fitts & Posner, 1967).

Anderson's appeal to elaboration of cognitive encoding as an explanation of distributed practice effects evolves from a consideration of the spacing effect found in verbal memory experiments where recall is better for those items within a long list of verbal items that are spaced farther apart during learning (Melton, 1970). However, it is a considerable leap to extend an explanation derived from a paradigm in which learning instances within a session are separated by a varying number of other learning instances to one in which training sessions on a complex skill are distributed by hours or days.

Unscheduled Practice Between Sessions

Instead of working on the efficiency of learning during practice, the distributed schedules may promote mental practice (Prather, 1973) during the interval between training sessions, or may even encourage deliberate practice outside of formal classes. In none of the experiments reviewed here was there any reported attempt to control activities between instructional sessions. It is indeed likely that the Morse Code students of Keller and Estes would practice or rehearse Morse code exchanges and routines among themselves after class hours. It is also likely that students enrolled in classes for recreational activities would participate in those activities between classes. Extended intervals between classes would certainly provide expanded opportunities for that extra experience.

If informal practice could be established as the reason for the effectiveness of distributed sessions, it would provide a rationale for developing means of encouraging mental rehearsal and informal practice. One strategy, suggested by the Morse code research, is to establish instructional settings that will encourage students to interact after class hours. Another might exploit the current advances in e-Learning by providing out-of-class opportunities to practice with entertaining simulations of critical tasks.

Nevertheless, appeals to continued learning during intervals between sessions or more efficient practice within sessions as a result of a distributed schedule cannot fully explain the diverse patterns of data observed here. For example, why is a two-day-a-week schedule better than a four-day-a-week schedule for teaching badminton, while there is no difference between the effectiveness of daily, three-per-week, or weekly lessons for teaching billiards. In addition, how can compressed schedules be more effective under some circumstances. The relative success of the progressively distributed schedules of Harmon and Miller (1950) and of Langley (cited in Harmon & Miller) further complicate this issue.

Implications for Instruction

At a more pragmatic level, the data reviewed here are of interest because they show that distributions of practice can effect learning. Although this conclusion may be regarded as little more than folk wisdom by some, others would certainly disagree with it (e.g., Adams, 1987). Those who fail to recognize the effects of distributed practice have paid attention only to data from perceptual-motor experiments in which inter-trial intervals were manipulated and have ignored the data from experiments in which spacing between sessions has been manipulated. On the other hand, it is not clear that those who promote the benefits of distributed practice (e.g., Hopkins et al., 1982) are aware of the data that bear on their view, or of its ambiguity.

Unfortunately, the guidance offered by these data to designers of applied instructional programs is modest. They do support the long-established intuition that distributions of practice can have an important and often facilitating effects. On the other hand, the conditions under which the distribution of sessions has any effect have not yet been fully specified and it remains uncertain whether an enhancement or a decrement is to be expected. Possibly the strongest recommendations to emerge from this review is that intensive early practice followed by less intense sessions will not be detrimental and will often enhance the efficiency of a training program. Further, this review suggests that the amount of instruction provided in any one day or any single topic should be limited. If all potential advantages of session scheduling are to be exploited in the instruction of action skills, a systematic research effort is needed to uncover the underlying factors at work.

References

Adams, J. A. (1987). Historical review and appraisal of research on the learning, retention, and transfer of human motor skills. Psychological Bulletin, 101, 41-74.

Anderson, J. R. (1985). Cognitive psychology and its implications (2nd ed.). New York: W. H. Freeman and Co.

Baddeley, A. D., & Longman, D. J. A. (1978). The influence of length and frequency of training session on the rate of learning to type. Ergonomics, 21, 627-635.

Fitts, P., & Posner, M. (1967). Human performance. Belmont, CA: Brooks/Cole.

Flexman, R. E., Roscoe, S. N., Williams, A. C., Jr., & Williges, B. H. (1972). Studies in pilot training: The anatomy of transfer. Aviation Research Monographs, 2(1). Champaign, IL: University of Illinois, Aviation Research Laboratory.

Hagman, J. D. (1980). Effects of training schedule and equipment variety on retention and transfer of maintenance skill" Research Report 1309). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences.

Hagman, J. D., & Rose, A. M. (1983). Retention of military tasks: A review. Human Factors, 25, 199-213.

Harmon, J. M., & Miller, A. G. (1950). Time patterns in motor learning. Research Quarterly, 21, 182-187.
Hopkins, C. O., Snyder, H. L., Price, H. E., Hornick, R. J.,

Mackie, R. R., Smillie, R. J., & Sugarman, R. C. (1982). Critical human factors issues in nuclear power regulation and a recommended comprehensive human factors long-range plan. Critical discussion of human factors areas of concern. Human Factors Society.

Keller, F. S., & Estes, K. W. (1944). Distribution of practice in code learning" (OSRD 4330, OEM SR-830, Service Project SC-88). New York: The Psychological Corporation. (ATI 35335)

Keller, F. S., & Estes, K. W. (1945). The relative effectiveness of four and seven hours of daily code practice" (OSRD 4750, OEM SR-830, Service Project SC-88, Report #3). New York: The Psychological Corporation. (ATI 35419)

Lee, T. D., & Genovese, E. D. (1988). Distribution of practice in motor skill acquisition: Learning and performance effects reconsidered. Research Quarterly for Exercise and Sport, 59.

Lintern, G. (1988). Distributed practice: Are there useful insights for application or theory? Research Quarterly for Exercise and Sport, 59, 298-302.

Magill, R. A. (1985). Motor learning: Concepts and applications" 2nd ed.). Dubuque, IA: Wm. C. Brown Publishers.

Magill, R. A. (1988). Activity during the post-knowledge results interval can benefit motor skill learning. In O. G. Meijer K. Roth (Eds.), Complex motor behavior" (pp. 231-246). Amsterdam: Elsevier Science Publishers.

Melton, A. W. (1970). The situation with respect to the spacing of repetitions and memory. Journal of Verbal Learning and Verbal Behavior, 9, 596-606.

Newell, K. M., Antoniou, A., & Carlton, L. G. (1988). Massed and distributed pactice effects: Phenomena in search of a theory? Research Quarterly for Exercise and Sport, 59.

Prather, D. (1973). Prompted mental practice as a flight simulator. Journal of Applied Psychology, 57, 353-355.

Reynolds, B., & Bilodeau, I. M. (1952). Acquisition and retention of three psychomotor tests as a function of distribution of practice during acquisition. Journal of Experimental Psychology, 44, 19-26.

Schmidt, R. A. (1982). Motor control and learning. Champaign, IL: Human Kinetics Publishers.

Schultz, D. P., & Schultz, S. E. (1986). Psychology and industry today: An introduction to industrial and organizational psychology" (4th ed.). New York: MacMillan Publishing Company.

Shugarts, D. A. (1987). Combination private-IFR under study. Aviation Safety, VII(5).

Young, O. G. (1954). Rate of learning in relation to spacing of practice periods in archery and badminton. Research Quarterly, 231-243.