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The Doing—A Review of the Skill Retention Research

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Table of Contents

The Doing—A Review of the Skill Retention Research

The problem of how to maintain skills in the most cost-effective manner has been plaguing system developers for decades. This problem is especially prevalent in the military where some tasks may not be performed for real in anyone's career but the soldier must remain prepared. It is also prevalent in automated systems in which the manual skills may rarely if ever be needed. In an early study, Van Dusen and Schlosberg (1948) examined the effect of retention interval (1, 7, or 28 days) on performance of perceptual motor tasks. There were significant decreases in performance after 7 and 28 days. Also in an early study, Ammons (1951) reported that massed practice resulted in superior performance in a rotary pursuit-tracking task on the following measures: mean duration of hits, mean duration of misses, and number of hits. However, distributed practice resulted in longer total stylus-target contact time. However, Catalano (1978) reported that a one-minute rest resulted in both greater time on target and absolute error in a tracking task. The author attributed the latter to a warm-up decrement.

Neuman and Ammons (1957) studied the effects of retention interval (1 minute, 20 minutes, 2 days, 7 weeks, and 1 year) on the number correct in the perceptual motor task. They concluded that initial retention test performance was progressively worse as the retention interval increased. Further, the amount of retraining required increased as the length of the retention interval increased. In a follow-on study, Ammons et al. (1958) evaluated the effect of degree of training (5 versus 30 trials) and length of retention interval (1 minute, 1 day, 1 month, 6 months, 1 year, or 2 years) on a perceptual motor task. The amount of training resulted in decreased task completion time. As the length of the retention interval increased, the task completion time also increased. The authors concluded that proportionately fewer trials are required by subjects having greater training to achieve former performance levels. Their subjects were 538 male undergraduate students. In a second experiment with 465 male undergraduate students, the authors looked at the effect of amount of training (1 versus 8 hours) and duration of the no-practice interval (1 day, 1 month, 6 months, 1 year, or 2 years) on time on target in a compensatory two-dimensional tracking task. As expected, increased practice resulted in increased time on target. However, after two years there was no difference between 1- and 8-hour practice groups. The amount of skill retention decreased as time increased. However, in a similar study, Adams and Reynolds (1954) examined the effect of massed versus distributed practice on performance of a rotary pursuit-tracking task. Their subjects were Air Force recruits. They reported no difference in type of practice on performance.

Fleischman and Parker (1962) compared performance on a complex, continuous tracking task over 1, 5, 9, 14, and 24 months. They reported retention of the task was "extremely great." However, there was a decrement in performance after the 14th month. They concluded that skill retention was determined by initial proficiency rather than by the type of training (formal versus informal). Further, there was no significant difference in performance after 1 week between subjects who had massed versus distributed practice.

Brown, Briggs, and Naylor (1963) reported a study investigating different types of rehearsal on reaction time and three-dimensional tracking tasks. They concluded that the amount of original training, if sufficiently long, can ellipse any positive effects of rehearsal. Their subjects were 126 male undergraduate students. In a follow-on study, Buckout, Naylor, and Briggs (1963) used the same two tasks to study the effects of length of training (one versus three weeks), visual noise (present or absent), and feedback sensitivity (95 decibels (dB) tone triggered by either large or small errors). The subjects (142 undergraduate students) with more training had better performance after the retention interval than subjects with less training. Visual noise resulted in significantly greater tracking error. However, subjects trained with visual noise had fewer tracking errors and better reaction time performance after the retention interval than subjects who were trained with no visual noise. There was no effect of type of feedback. In a similar study, Melnick (1971) compared the performance of 80 male undergraduate students who had received 0, 50, 100, or 200% over learning practice. The retention intervals were one versus four weeks. The task was the stabilometer. Melnick (1971) reported that immediate recall of the task was facilitated by over learning. After 4 weeks, subjects who received 200% over learning had better retention that subjects who had 0% over learning. Using a similar task, Thompson, Wenger, and Bartling (1978) measured word recall from a list in a series of three experiments. Multiple presentations helped more with longer (48 hours) than shorter (20 minutes) retention intervals. These results are based on three experiments with undergraduate students.

Naylor and Briggs (1963) also examined the effects of type of rehearsal: whole task, temporal, spatial, or no rehearsal. The subjects were 68 undergraduate students. The task was reaction time. Performance was more accurate with rehearsal. Whole-task rehearsal resulted in the best performance. In a series of two similar experiments, Naylor, Briggs, Brown, and Reed (1963) examined the same types of rehearsal but on a procedural task. The effectiveness of the rehearsal was not in the expected order but rather the most effective to least effective rehearsal was as follows: part task, simplified, whole task, and no rehearsal. In the second experiment, for a tracking task, whole-task rehearsal resulted in superior performance to part-task or no rehearsal. The effect of rehearsal decreased with an increase in the amount of original training. Whole-task rehearsal was superior up to five days of training; part-task after eight days of training; but after 10 days of training there was no rehearsal effect. Naylor, Briggs, and Reed (1962) also looked at the amount of training. Subjects were required to perform a procedural task with either a high or low degree of task organization. The authors concluded that task organization has greater influence on performance with less amount of training. Naylor, Briggs, and Reed (1968) examined the effects of training time (2 versus 3 weeks), retention interval (1 versus 4 weeks), and task coherence (sequential versus nonsequential numbers). As expected both performance and retention were better after three than after two weeks of practice. Performance was better after a 1-week rather than a 4-week retention interval. Subjects with more original training had less performance loss.

Macek, Vilter, and Stubbs (1965) examined the effects of type of rehearsal on skill retention in a three-phase study. In the first phase and the first experiment, rehearsal was performed using verbal analogs: clock hours, calendar months, adjectives describing behavior, or no verbal analog. In the second experiment the same analogs were used but for six rather than 12 slots. In experiment 3, warm-up conditions were varied: cognitive warm-up, perceptual-motor warm-up, a combination of the first two, and no warm-up. The authors concluded from these three experiments that the greater the rehearsal relevancy, the smaller the initial retention decrement. Warm-up after two weeks was not as effective as weekly rehearsal over a six-week retention period. In the second phase, a single experiment was conducted using only four subjects. The independent variables were number of trials, retention interval, and level of experience. The results indicated that the effect of experience on initial retention performance was modest but resulted in markedly better performance after a short while. Continued warm-up reduced the difference between low and high experienced subjects. In phase three, warm-up without a visual display resulted in poorer performance overall than warm-up with a visual display regardless of the retention interval of 1, 4, or 5 weeks.

Using a different type of task, Melton (1964) examined the effects of target movement pattern (random versus nonrandom), display/control relationships (normal versus reverse), and retention interval (5 minutes, 1 day, 1 week) on tracking performance. As expected tracking performance was better in the normal than in the reverse condition and retention loss was greater for the reverse display. Unexpectedly, however, there was no effect of retention interval in the random target motion condition. This may have been due to insufficient training. Recovery from the retention loss occurred during the second or third retention trial. The subjects were 336 male undergraduate students. In a similar study, Swink, Trumbo, and Noble (1967) examined the effect of retention interval (3 versus 5 months) as well as task predictability (100 versus 75%), sequence length (number of targets 8 to 48), and training criteria (equal practice versus repetition). As expected, task predictability resulted in better performance. Their subjects were 120 male undergraduate students. Trumbo, Noble, Cross, and Ulrich (1964) also found a significant effect of predictability. In addition, there was a positive correlation between retention loss in a tracking task and retention interval (1 week, 1 month, or 5 months). A year later, Trumbo, Ulrich, and Noble (1965) reported that there was no effect of type of pretraining or display specificity after one month. In a later study, Trumbo, Noble, and Swink (1967) examined the effects of secondary task uncertainty in a series of three experiments. Their general conclusions were: 1) the performance of a secondary task decreases retention and 2) the decrement due to the secondary task is independent of the decrement produced by an 8-day retention interval.

Bernstein and Gonzalez (1971a) took a different approach. They asked their subject which types of training were most effective for a reaction-time task. The response was imagery was useful in learning. Their subjects were male undergraduate students. In a follow-on experiment, the authors reported that subjects (forty male undergraduates) trained with imagery outperformed those trained without imagery. The task was a reaction time task. Imagery had its greatest effect early in the test trials. Their findings were replicated in a series of basic psychology experiments reported in Bernstein and Gonzales (1971b). In still another approach, Baker (1974) investigated the effect of immediate versus delayed test time on reading performance. Not surprisingly, the subjects, 108 undergraduate students, retained more of the relevant than the incidental information.

Carron and Marteniuk (1970) measured the performance of 150 male high school students on a stabilometer after a 14-day retention interval. Subjects varied in balancing ability. After the 14-day retention interval, subjects with high balancing ability improved while low balancing ability subjects degraded. In a study looking at a longer retention interval, Carron (1971) reported that subjects with higher abilities on a stabilometer task retained their balancing performance better after two years than lower abilities subjects did although all groups did poorer over the two-year retention interval. Aptitude also had effects on performance on monitoring and rifle assembly tasks by Army recruits (Fox, Taylor, and Caylor, 1969). Not unexpectedly, recruits with lower aptitudes required more training. Grimsley (1969a) focused on training simulator fidelity. Sixty Army trainees received simulation on a missile launch control station in which everything worked, there was no electric power, or a reproduction. Unexpectedly, retention loss was equivalent over all three groups. Further, fidelity was unrelated to the amount of retraining necessary. In a related study Grimsley (1969b) examined the effect of method of retraining: instruction alone, instruction with the reproduction panel, or demonstration on the panel with the electrical power on. The retention intervals were 4 weeks, 4 weeks and then 2 more weeks, or 6 weeks. There was no difference between the 4- and 6-week retention intervals; however, the 6-week retention interval had fewer correct than the 4 and then 2-week retention interval. Using similar subjects, Vineberg (1975) measured performance of 200 Army soldiers on the Comprehensive Performance Test right after basic training and 6 weeks after basic training. Vineberg reported the average decrement over time was 18 to 26%.

Leonard, Wheaton, and Cohen (1976) also studied skill retention of Army personnel. They measured performance immediately after initial training, six weeks after initial training, seventeen weeks after initial training, six weeks after refresher training, and seventeen weeks after refresher training. Longer retention intervals were associated with poorer performance. Refresher training improved performance on some but not all tasks compared to those who did not have the refresher training.

In a more operational setting, Menglekoch, Adams, and Gainer (1960) examined the effects of amount of training (5 versus 10 trials) on instrument flying performance. There was greater retention loss on procedural tasks than for the tracking task. The loss was also greater for static or emergency procedures than for dynamic procedures. The performance of the more highly trained group was always superior to the less trained subjects. The number of training trials to attain the performance level on the final training after a retention interval of 120 days was greater for the group receiving more initial training in absolute but not in relative number of trials. The immediate performance after the retention interval was always superior in the greater trained group. The authors concluded that amount of training does count.

Caines and Danoff (1967) compared performance of military pilots who completed proficiency flying versus those who had flying duties. Their subjects included 84 F-4C pilots, 14 A-4E pilots, and 78 C-130E pilots. Pilots who had proficiency flying had more flying deficiencies than pilots who had flying duty. The deficiencies covered the complete range of takeoff, general air work, navigation, tactical information, bombing, tactics, and landing. Tasks associated with processing high rates of information while performing a simultaneous motor task had the greatest number of deficiencies. Further, pilots with two or more years of proficiency flying had significantly more deficiencies than those with less than two years of proficiency flying.

In nonmilitary flying, Hollister, La Pointe, Oman, and Tole (1973) examined the effect of recency of flight experience of private and commercial pilots on three test flights. They reported performance was positively related to total flight time and negatively related to years since certification as well as age. There were no effects of score on written quizzes, the subject’s own skill assessment, or the type of initial training received. The highest grades were received on those aspects of flight that were the most highly practiced: preflight and takeoff. The lowest scores were received on the infrequently practiced aspects such as stalls and instrument flight. In a similar study, Seltzer and McBrayer (1971) reported that performance of commercial pilots during a check ride declined continually until about 5.5 years after certification. The authors stated, “This loss of proficiency is attributed partly to the motor skills of the individual pilot and also to his lack of knowledge.” The time for a commercial pilot to regain proficiency was 25 minutes of ground instruction and 1.5 hours of flight instruction. The time for private pilots was longer: 50 minutes ground instruction and 2.5 hours of flight. In the same year, Wilson (1973) examined the effect of prolonged non-flying periods on the pilot’s ability to perform a simulated carrier landing. For the study 15 naval aviators performed three carrier landings in a simulator. The aviators were current, one year stagnant, or two years stagnant. There was a small decrement between the current and one-year groups but no difference between the one- and two-year groups. There was also a tendency for the aviators with more than 1,100 total flight hours to do better than aviators without as many flight hours.

Killian (1965) compared self-rated performance of second officers who had less than or more than 1,000 flight hours experience. All subjects had recently upgraded to first officers at United Air Lines. There were neither self-reported performance decrements nor any difference between high and low experienced pilots. Wright (1973) used a similar approach and had Army aviators complete a survey. The results suggest "flight excusal followed by refresher training would provide operational units with better qualified aviators at less cost than the traditional flying program" (p. 1).

In a different operational setting, Cotterman and Wood (1967) compared the performance of twelve test pilots performing a simulated lunar landing after 4, 8, 9, and 13 weeks. They reported that the longer the retention interval, the less probable that the landing would be successful. Youngling, Sharpe, Ricketson, and McGee (1968) examined the performance of simulated space missions as a function of retention period (30, 90, or 120 days). Their results indicate performance loss for the group that received less training (60 versus 120 trials) was twice that of the 120 trial group. There was a linear relationship between the length of the retention interval and the performance loss. Performance at the more difficult level (defined as performance tolerance) was retained better. Finally, reacquisition was more rapid after 30 than after 200 days.

In yet another operational setting, Johnson (1978) examined the effects of type of training and cognitive style on retention of a conveyor painting process that included 83 sequential steps and 24 numerical settings. There were three types of training:

1. Conventional practice: The trainee repeatedly performed the exact behavior as in the operational environment.
2. Reproduction practice: The trainee reproduced the control actions and system responses using pencil and paper.
3. Blind practice: The trainee reproduced the same motor responses as in the conventional practice group but there was no visual stimulus.

The retention interval was 70 days. The subjects were paid individuals aged 16 to 34. There was no significant effect of the retention interval. Further, there was not a significant correlation between the number of errors on the last training trial and the retention scores. In a related study, Singer, Ridsdale, and Korienek (1979) examined the effects of learning strategy on acquisition, retention, and transfer of a visual tracking task. Strategies were use of imagery, rhythm, anticipation, informed choice, and none. The use of rhythm resulted in better performance than no strategy.

In yet another operational environment, Sitterley and Berge (1972) measured performance of space vehicle control from launch to orbit as well as emergency procedures over time (1 versus 6 months) and type of training (no practice, immediate rehearsal, distributed rehearsal, warm-up, and a combination of immediate and delayed rehearsal). In the no practice condition, there was a reliable decrement in altitude error at orbit insertion with time. The duration of the retention interval was not significantly related to the amount of degradation observed. In addition, performance improved with one warm-up practice and was at proficiency after five warm-up practices. These authors concluded, "In general, continuous control performance degradation was relatively moderate until 3 months had elapsed without practice…. The data suggested that skill degradation had reached its peak at about 4 months" (p. 63). They added "Procedural performance, on the other hand, showed strong degradation after only 1 month without practice and a sharp increase in degradation at 4 months" (p. 63). In a follow-on experiment, Sitterley (1974) measured ability to land a space vehicle after four months. There were four types of training: no practice, static rehearsal, dynamic display, and self-paced static retraining. There were no crash landings for the group trained with static rehearsal and further this group had no significant skill degradation. These results are similar to an earlier study by Sitterley, Zaitzeff, and Berge (1972) on visual approach and landing tasks.

In an excellent review, Gardlin and Sitterley (1972) concluded from the research available at that time that “retention performance on a single specific task is apparently best for specific training; general training is superior when the amount of training increases and the task contains an element of uncertainty” (p. 4). Further, “test subjects typically reacquired their final training levels with the number of retraining trials fewer than 50 percent of the original training trials” (p. 15). They concluded, “It seems clear that the literature has identified the level of performance on the final training period as the primary predictor of skill retention for any given retention interval duration” (p. 20). In a later review, Smith and Matheny (1976) stated “Two major points supported by the literature and other evidence are cited: the first is that over learning of a task promotes its retention and the second is that motor skills will be retained longer than procedural or verbal materials” (p. 5).

In a similar review, Prophet (1976a) stated, “The single most important factor in determining absolute level of performance after periods of non-practice has consistently been found to be level of learning or skill prior to the nonpractice period” (p. 55). In addition, the “amount of decrement, i.e., the absolute amount forgotten, is largely independent of the level of initial skill or training and is much more a function of length of the nonpractice interval” (p. 55). Finally, the author stated, “The literature suggests that there is no fundamental difference between continuous control tasks and procedural tasks, as far as learning and retention are concerned if task organization is taken into account” (p. 62). This author also produced an excellent annotated bibliography (Prophet, 1976b). In a related conclusion, Hammerton (1963) reported that initial performance at the end of a six-month retention interval was significantly better for subjects receiving extensive training on a tracking task. In review focused only on motor skills, Schendel, Shields, and Katz (1978) concluded, “The single most important determinant of motor retention is level of original learning” (p. 1). They summarized that continuous control tasks are typically remembered for months or years. An example is riding a bicycle. The authors add that individuals with higher initial ability tend to achieve higher levels of proficiency and retain skill also at a higher level of proficiency.

Based on the above research, it is clear that practice of emergency procedures is especially critical as related to automated systems and skill retention. The first step in responding to an emergency is detecting that something went wrong.

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