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Retention of Military Knowledge and Skills

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FOREWORD

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has been investigating soldiers' retention of skills and knowledge learned during training. How well a soldier remembers what was learned in training influences how well a soldier can later perform a task and determines the frequency with which retraining needs to occur. Understanding the nature of skill retention thus has important implications for both Army training and personnel policy.

The research reported here summarizes over 25 years of work on the topic of skill retention. The report emphasizes research performed by ARI, but also includes relevant research by other military and academic laboratories. Products from ARI research include a model for predicting skill retention, endorsed by TRADOC and applied numerous times, most recently to the 'peace support operations' tasks trained to troops deploying to Bosnia. This research has also led to personnel policy changes, such as increasing the window (from 12 months to 24 months following active duty) for the initial recall of soldiers from the Individual Ready Reserve in the event of a mobilization. We plan to continue research on skill retention issues, focusing on the digital skills required for the decentralized, fluid, fast-paced operations of the future.

EDGAR M. JOHNSON
Director

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STAYING SHARP: RETENTION OF MILITARY KNOWLEDGE AND SKILLS

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Every year the Army trains soldiers on over 40,000 tasks. The more complex tasks, such as repair of a radio communications system, may require several weeks of training per soldier. The Army assumes that the huge budget of time and money needed for this training is an investment that will pay off in later job performance. That is, soldiers will retain the knowledge and skills they acquire in training long enough to perform effectively in their career assignments.

However, people forget and skills get rusty. A century of research on memory[1] has shown that large amounts of forgetting can occur naturally over periods as short as several hours or as long as many years.[2,3] This report reviews what is known about forgetting as it applies to military tasks, concentrating on major projects conducted by the U.S. Army Research Institute (ARI) during the past three decades. Included are both basic research supported by ARI at universities[4,5] and applied studies conducted in field settings by ARI researchers and by the Air Force and Navy. This review will make clear several ways the Army can minimize or reverse forgetting's effects.

How Much is Remembered for How Long?

Because forgetting may occur over any period when knowledge is not applied and skills are not practiced, Army planners and trainers need answers to the following questions:

1. How fast does forgetting occur for different kinds of skills?
2. Are some individuals more likely to forget than others?
3. What instructional strategies are effective in reducing forgetting?
4. How difficult will it be for soldiers to reacquire skills they have forgotten?

Answers to these questions are important for the development of effective initial and refresher training programs, mobilization policy, and reserve component training plans. This report addresses each question in turn.

"Knowledge, decision, and execution - these three components are present in most tasks..."

The Different Kinds of Skills

As soldiers attempt to perform an already-trained military task, they rely on several different abilities. Consider a sports analogy: a quarterback whose coach has called in a pass play. The main task has been set, but three component tasks must be performed to successfully complete it. As the team huddles, the quarterback must recall what "55 Slant Right" means in terms of the patterns the receivers will run. At the line of scrimmage, he must evaluate the set-up of the defense and, as the play unfolds, determine if the intended receiver is coming open. Once the decision to throw has been made, the quarterback must execute the pass precisely to get it within the receiver's reach. Knowledge, decision, and execution - these three components are present in most tasks, although tasks vary widely as to which component dominates.

This analysis applies to the military as well. Soldiers rely on three abilities as they attempt to perform their military tasks: (1) ability to retrieve from memory previously-learned knowledge (job-related facts, rules, terminology, order of steps to be performed in a procedure, etc.); (2) ability to combine incoming information, evaluate a situation, and decide among alternative courses of action; and (3) ability to execute the chosen action or procedural step in a sufficiently skilled manner.

In most military tasks, the first ability — knowledge retrieval — predominates. In one sense, this is true because soldiers must call to mind a number of job-related terms and rules as they carry out any task. But it is also true in the sense that there is a separate class of tasks that depend on information recall. These tasks are generally referred to as procedural tasks, because the crucial recall required is memory for the steps to be performed in a given procedure. The second ability —

sometimes called cognitive processing — dominates in such tasks as trouble-shooting faulty equipment and tactical decision-making by officers. These are often referred to as cognitive tasks.[6] In still other tasks, precise execution of well-practiced actions is the crucial aspect; such tasks are referred to in the psychological literature as perceptual-motor tasks.[7] The prime example is target acquisition and tracking.

Recent work in the neuroscience of human memory [8] indicates that these three types of abilities are located and controlled in different regions of the brain (Figure 1): verbal knowledge is encoded in the neocortex, usually in the left hemisphere; cognitive tasks are performed primarily in the frontal lobe; and the skilled execution of perceptual-motor tasks is mediated by the cerebellum. As they are dependent on different areas of the brain, it is not surprising that the studies described below have shown a different pattern of forgetting for each type.

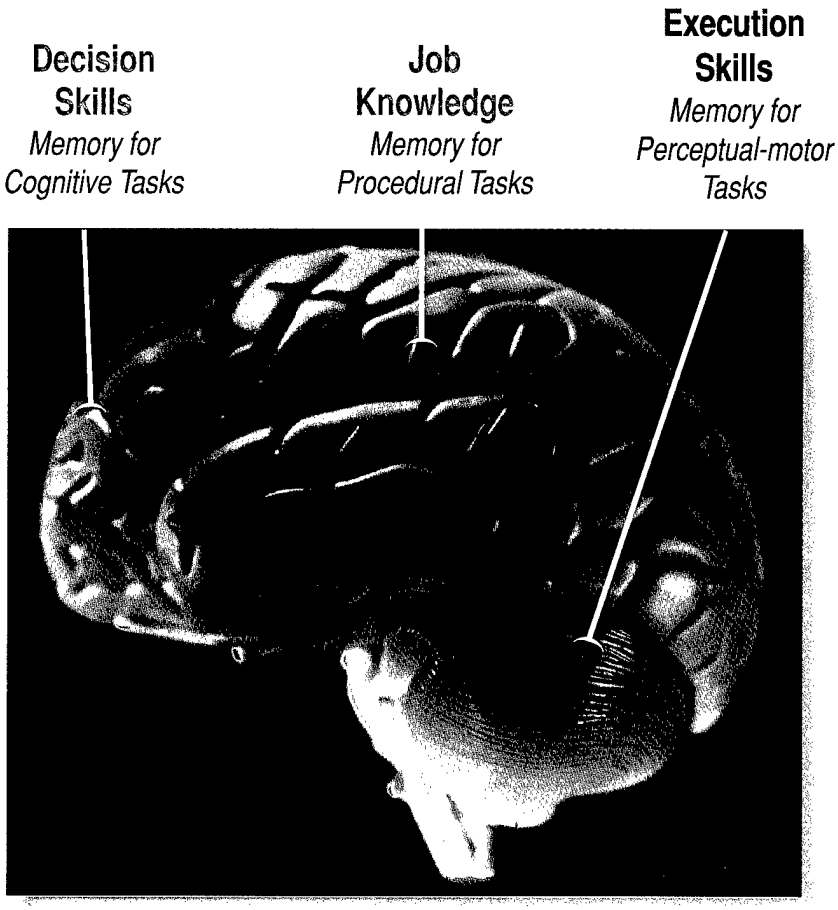


Figure 1. Brain areas that control different types of skills.

Memory for Decision Skills

Many military tasks involve cognitive components such as problem solving, judgment, and analysis leading to a decision. For example, in land navigation soldiers must interpret topographical maps to identify symbols with terrain features on the ground. And any troubleshooting task will require soldiers to reason their way to the diagnosis of a particular fault in the equipment.

Research on memory for cognitive tasks shows a moderate rate of decay; forgetting occurs but is relatively small for up to a year after learning. Figure 2 summarizes more than 20 studies[9], including two studies of military tasks. One tested anti-submarine warfare trainees on the application of oceanography principles immediately and four weeks after training and observed a 21% drop in scores.[10] Another measured basic electricity problem solving and found a 16% loss in skill after 8 weeks.[11]

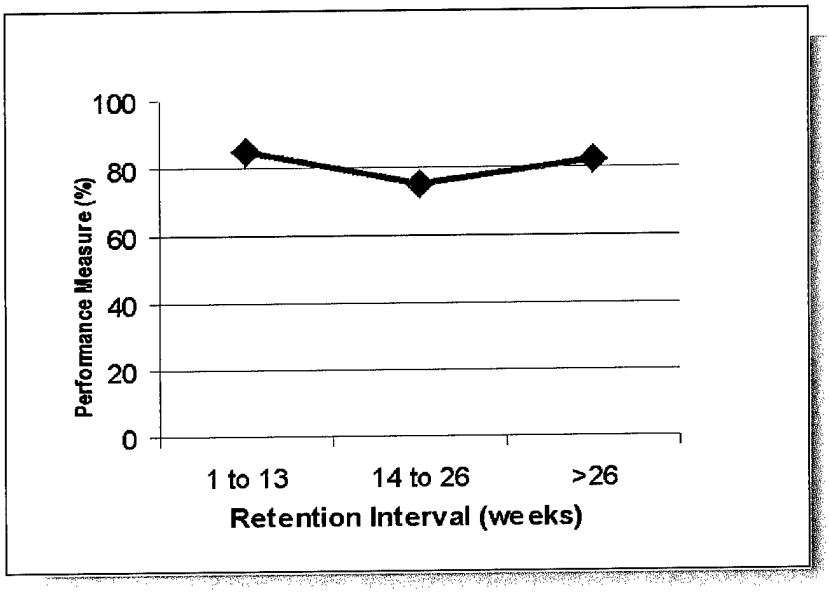


Figure 2. Average of 20 cognitive tasks.

Memory for Job Knowledge

All military tasks have a knowledge component, facts and ideas that the soldier must remember in order to perform successfully; this information may be as basic as the definitions of task-relevant terms or as complex as the order in which the task's procedural steps should be performed. To

disassemble the M240 coaxial machine-gun, for example, the soldier must remember the names, functions, and locations of the buffer assembly, the bolt assembly, the driving rod and spring, and the trigger assembly. The soldier must also remember, for example, to remove the driving rod and spring before removing the bolt assembly.

Such information is sometimes referred to as school knowledge. Studies of memory for knowledge learned in school have sometimes found remarkable resistance to forgetting for years after learning.[12] In fact, some kinds of school knowledge — for example, vocabulary from high school Spanish — apparently stay with a person for a lifetime.[13] However, a distinction based on the way performance is measured can be crucial; the amount of forgetting found depends on whether the memory test requires recognition or recall.

Recognition memory involves choosing the correct response from a number of alternatives and is usually tested with multiple-choice, matching, or true-false test items. Recall memory requires the learner to produce information without being presented with alternatives and is usually tested with short answer, fill-in, or essay test items. In general, because of the cues provided by the alternatives, recognition memory is superior to recall memory. Figure 3 summarizes the research findings from more than 40 studies[8] of recognition and recall memory for retention periods up to 52 weeks.

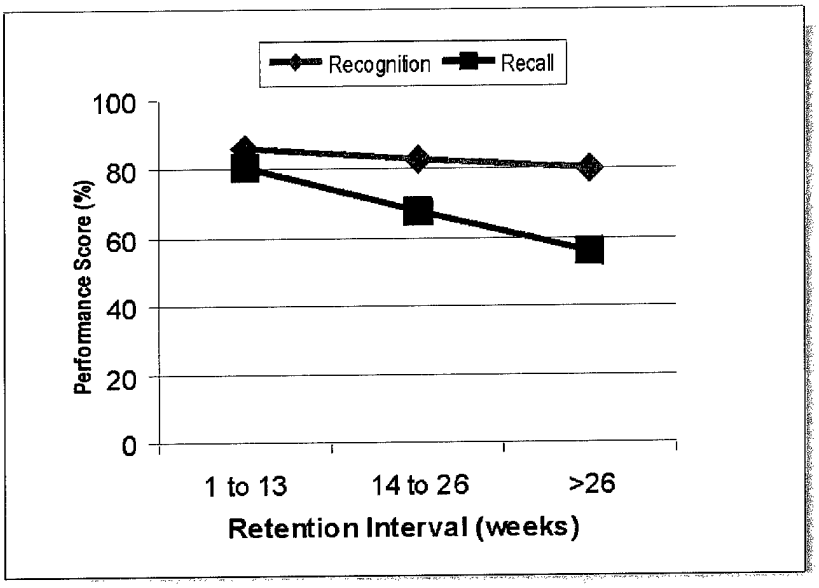


Figure 3. Average data from 40 studies of memory for school knowledge.

Several military studies contributed to the results in Figure 3. For example, a study of recognition memory for propulsion engineering training at the Navy's training center at Great Lakes, Illinois, found that trainees remembered 91 percent after 4 weeks and 80 percent after 28 weeks.[14]

As mentioned above, procedural tasks constitute a special class among tasks that rely heavily on knowledge retrieval. Because procedural tasks require the soldier to produce a set of actions, they tend to suffer from the degradation over time seen in Figure 3 for performance measured by recall. An Air Force study, for example, looked at procedural skill loss among airmen while they were in the Individual Ready Reserve (IRR); among those separated from active duty for 18 to 24 months, only 53% retained proficiency.[15]

Such procedural tasks are knowledge-dependent, because they require retrieval of memory, both for the steps that must be performed and, in some cases, for the order in which they must be done. From another perspective, however, these tasks also form a bridge to the class of tasks, discussed below, for which well-practiced execution is key.

Memory for Execution Skills

Tasks in all MOSs have an execution or performance component, although this aspect may be trivial when the performance involves behaviors practiced for years, in some cases for a lifetime. Administrative Specialists, for example, may complete many of their clerical tasks by simply filling out a form with a pencil or on a computer screen. Some MOSs, however, entail skilled performance in using tools or operating complex equipment. For example, one of the task steps in boresighting the direct fire telescope on an M198 howitzer involves rotating the M32 periscope elevation and deflection boresight knobs until the aiming cross is on the upper left-hand corner of the target. This precise rotation requires considerable manual dexterity.

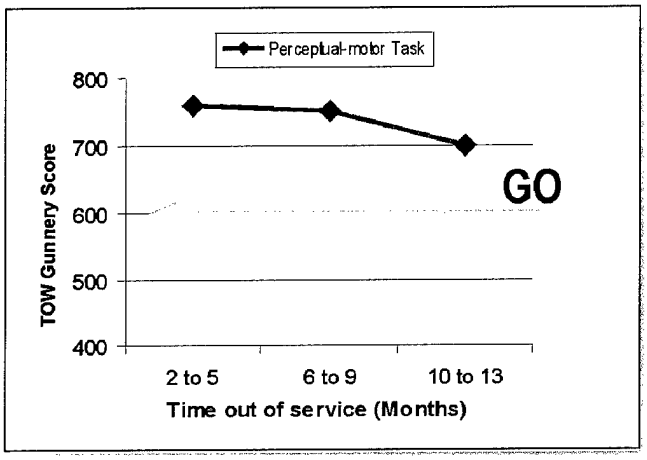
Continuous Execution versus Discrete Procedure

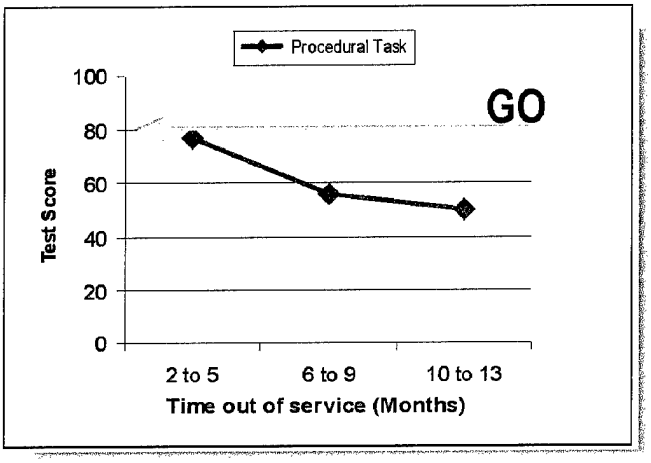
Memory researchers classify such performance skills as either continuous or discrete. Continuous skills involve movements or steps that do not have distinct beginnings or endings; examples include driving a vehicle, keeping a weapon sight on a moving target, and flying an aircraft. As noted above, these are also called perceptual-motor tasks. Discrete skills, on the other hand, are needed for tasks with definite beginnings and endings — for example, starting up a radio communications system, disassembling a carburetor, or performing a vehicle safety check. These can be recognized as what we earlier called procedural tasks.

Research has shown that memory for continuous (perceptual-motor) skills is different from memory for discrete (procedural) skills.[16] As said above, skill at discrete, knowledge-dependent procedural tasks may show considerable decay in just a few weeks or months. However, studies dating back to the 1950s have found high long-term retention of continuous skills. Perceptual-motor tasks, such as typing, aircraft flight control, target tracking, marksmanship, or the proverbial bikeriding, show virtually no skill loss for periods as long as two years without practice.[17] In a study of helicopter pilots in the IRR[18], for example, even airmen who had not flown for many years retained flying skills well and were able to reacquire any lost skill quickly.

Figure 4 shows data on memory for a typical example of one perceptual-motor task and one procedural task. These examples are taken from a study of skill retention conducted by ARI during the partial mobilization of the IRR during Operation Desert Storm.[19] Memory for perceptual-motor skills, represented by the marksmanship scores at TOW gunnery, shows much the same resistance to decay as was seen (Figure 3) in recognition memory for school knowledge. Discrete, procedural skill, however, may be forgotten much more rapidly; in Figure 4, scores on a test of memory for several quartermaster procedural tasks are below the "Go" level (80%) for all retention periods.

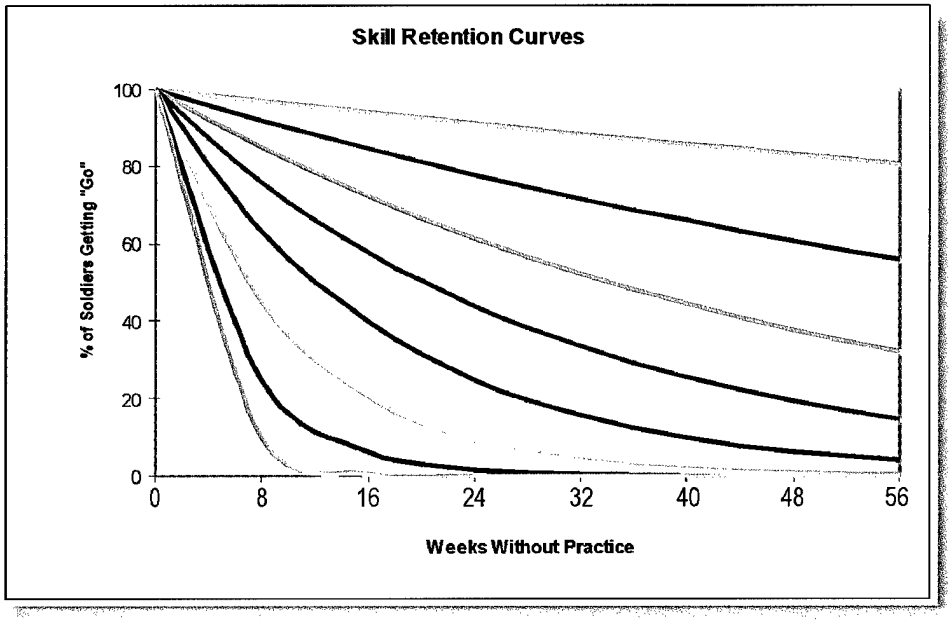
Figure 4. Typical memory for perceptual-motor (continuous) and procedural (discrete) tasks.





Many procedural tasks show this quick decline. It has been found, for example, that only 20% of civilians trained on the first aid task of giving cardio-pulmonary resuscitation (CPR) are proficient six months later.[20] There are also exceptions, however. A study of Army basic combat skills showed an average loss of as little as 5 percent after 6 weeks for some tasks (e.g., first aid for shock) and as great as 52 percent for others (e.g., clearing an M16 rifle).[21] Figure 5 shows the set of curves that performance would be expected to follow. Each curve represents a different procedural task. Note that some of these tasks, those

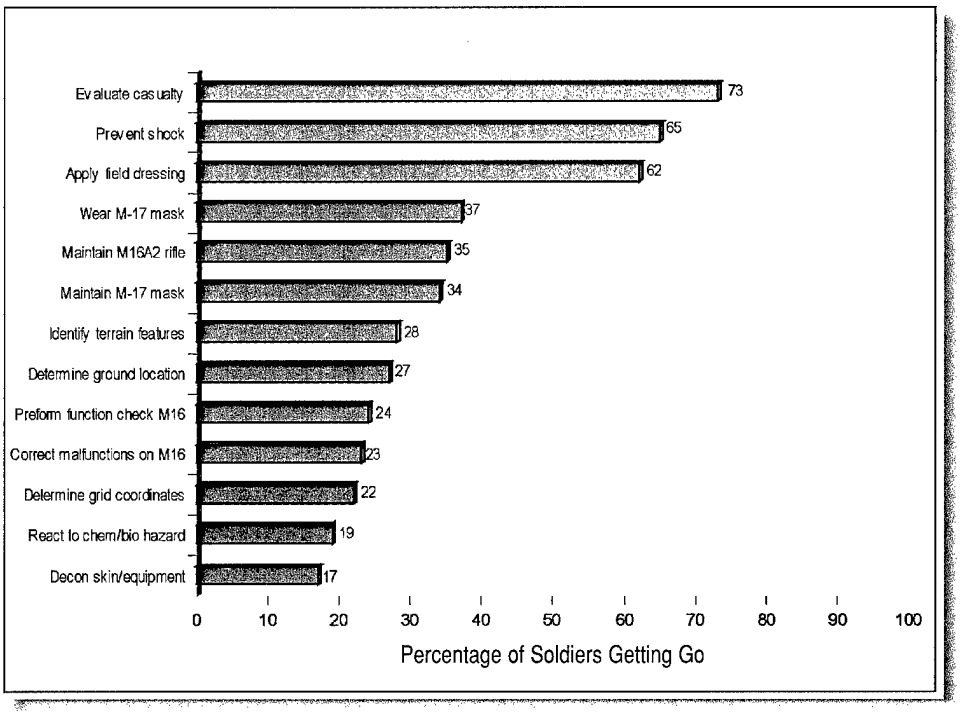
Figure 5. Theoretical set of curves for the decay of skill at different procedural tasks.



represented by the upper curves, suffer so little forgetting that they show fairly constant performance, month to month. Other tasks, those on the lower curves, show constant performance after the first few months, because most of the decay they will suffer has already occurred. But there are many tasks in between these two extremes.

The variability of real-life results for discrete procedural skills is shown in Figure 6. The data are from an ARI study of skill retention by 197 volunteers from the IRR.[22] After being called back to active duty for a mobilization exercise, these soldiers were given hands-on tests of their memory for common soldiering tasks. All these soldiers, who had been away from active duty for an average 36 months, performed all the tasks. The percent of soldiers able to perform at a "Go" level ranged across tasks from 73% (for Evaluate a Casualty) to 17% (for Decontaminate Skin and Equipment).

Figure 6. Mobilized IRR soldiers' performance on procedural tasks before retraining.



This variability among discrete procedural tasks is important, because, as mentioned, such procedural tasks

constitute most of the tasks trained by the Army. For example, a similar wide range of retention was found for procedural tasks and instrument-flying skills needed by helicopter pilots, although their basic (perceptual-motor) flying skills were retained well.[23] Some way to account for this wide range of resistance to forgetting is needed. ARI's approach to this problem is described below.

Factors Affecting Procedural Skill Retention

The inconsistency among individual studies of procedural skills occurs because a number of factors that affect forgetting vary from one study to the next. In the following sections, research is discussed in turn that identifies two classes of factors — task factors and individual soldier factors.

Task Factors

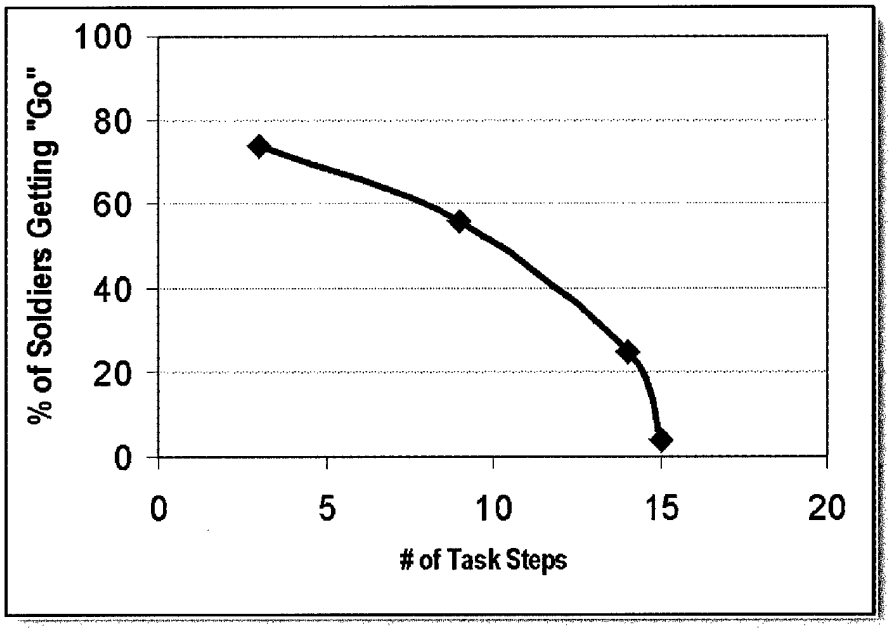
Forgetting of a procedural task is affected by four factors that relate to the task itself: (1) how complex the task is, (2) how great the task demands are for knowledge, decision, and execution, (3) whether a good job aid is available as the soldier performs the task, (4) whether the task is performed under the stress of a time limit. After describing these factors below, we will show how ARI research integrated the factors into a method for predicting memorability of individual tasks.

Task Complexity

Three primary factors combine to determine a value we will call task "complexity." This overall measure turns out to be highly predictive of whether a task will be forgotten. A complex task is the opposite of one with an inherent organization that produces a "simplicity" or unity, where each task step follows logically or naturally from the one before.[24] The component factors are: (1) how many steps there are in the task, (2) whether the steps must be performed in a set sequence, and (3) whether there is built-in feedback that indicates correct performance of task steps.

Number of task steps. Several studies have shown that, as the number of task steps increases, retention performance decreases.[25] The best example of this effect is an ARI study of more than 500 soldiers performing tasks learned in

Figure 7. Task difficulty affected by adding task steps.



basic training. All the soldiers, having demonstrated their ability to perform the tasks at the end of training, were then re-tested at periodic intervals. Figure 7 shows performance for four of the tasks 12 months after training. The tasks and number of steps are: (1) report enemy information, 3 steps; (2) load and fire M203 grenade launcher, 9 steps; (3) perform cardiopulmonary resuscitation, 14 steps; and (4) don gas mask, 15 steps.[26]

Note that the drop in performance from the 3 step task to the 9 step task is only 18%, while the drop as steps increase from 9 to 14 is 31%; and the addition of just one step from the 14 to 15 step tasks causes another 21% drop. As the number of task steps increases, the performance decrements become more severe. This is an example of the limitation on human memory known to psychologists as "the magic number 7 plus or minus 2"[27]; when one is asked to remember more than 9 items, the mind is likely to become a blur. This is especially true if the items must be remembered in order.

Steps done in sequence. In some military tasks, such as "Identify Terrain Features on a Map," the steps can be performed in any sequence. Other tasks, such as "Splint a Fracture," have only one correct sequence. For a third type of task, for example, "Perform Operator Maintenance on an M16A1 Rifle," some steps must be performed in sequence and others can be performed in any order.

Psychologists have long known that memory for order information is especially slippery. Army research on memory for sequence has confirmed the expectation that tasks one can perform in any sequence are easiest to remember. Somewhat surprisingly, however, it turns out to be easier to remember a specific sequence for all steps than for only some of the steps[28]; that is, the hardest task to remember is one that has a fixed sequence imbedded in other interchangeable steps.

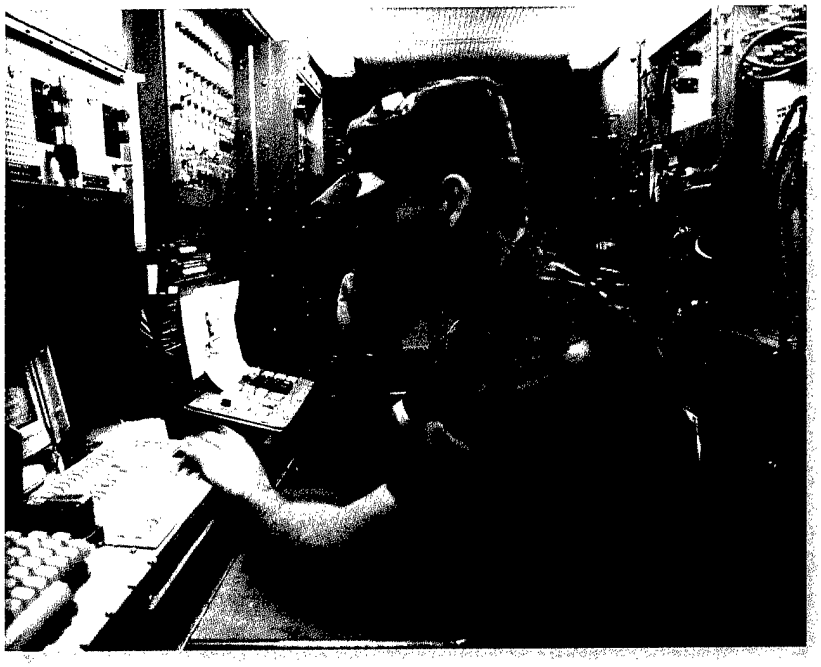
Built-in feedback. Some tasks provide feedback for some or all of the task steps, indicating when a step has been performed correctly. Examples of tasks with feedback are disassembly tasks where removing one part reveals the next part to be tackled or tasks where performing a step causes observable results, such as a panel lighting up or a warning buzzer sounding. Feedback makes task steps less likely to be forgotten.

For sequential tasks, feedback may be especially beneficial when it acts as a cue for remembering the next step to be performed. In the ARI retention study of basic training tasks, the task steps that were forgotten most frequently were those that were not cued by the sequence of steps or by the equipment.[26] For example, when disassembling an M16 rifle, soldiers frequently forgot the first step, the safety step of clearing the weapon.

Task Demands

The task components of knowledge, decision, and execution, used earlier to classify tasks in general, return here as aspects of tasks within the procedural class. That is, procedural tasks can vary greatly in these aspects, as described below, and this variation is reflected in how well soldiers can retain memory for the tasks.

Knowledge Demands. Memory for tasks that involve recall of terms, definitions, names, locations, and other facts (see Figure 3) is directly affected by the number and complexity of facts that must be remembered. The findings for number of facts are similar to the findings for number of task steps described above. Tasks that do not require soldiers to recall any auxiliary facts, or only a few, are remembered best; tasks that require 4 to 8 such items are remembered well; but tasks that require recall of more than 8 pieces of information suffer rapid decay without constant practice.



A related consideration is how hard these auxiliary facts are to remember. Some tasks require concurrent recall of only a few items, but those items, by their nature, easily slip the mind. For example, call signs and radio frequencies are notoriously forgettable, because they are assigned at random for exactly the purpose of being non-predictable.

Failure to recall just one such crucial fact may make some tasks impossible.

Cognitive Skill Demands. As discussed above (see Figure 2), memory for cognitive skills is fairly stable for periods as long as a year after learning. However, cognitive skills do suffer some decay;[29] they are more likely to be forgotten than simple motor skills, such as saluting or marching. Tasks with several cognitive elements, those that require multiple steps of judgment or decision-making, will suffer more degradation over time than tasks with just one or two such steps. Further, some cognitive components are more complex than others; tasks that demand processing of large amounts of technical information or rapid decision making (e.g., setting priorities for targets) may be blocked by the breakdown (overload, burnout) of one complex cognitive skill.

Execution Demands. Almost all tasks involve some degree of motor control of finger, hand, and arm movements. It turns out that tasks which require an intermediate degree of motor control are remembered best; these are usually continuous execution tasks, such as typing or flying a helicopter. As discussed in the section on execution skills, memory for these continuous tasks remains high for long periods. On the other hand, some discrete procedural tasks that require a high degree of motor control may also be done rarely, such as the occasional repair of delicate equipment. In such cases, the unpracticed performance is likely to be poor. Whereas the well-practiced hand is steady, the anxiety caused by knowing that one's skills are dull may be enough to interfere with completing the task. Surprisingly, however, ARI researchers[30] found that tasks with only a minor requirement for fine motor control, such a hammering a nail, or those that involve sheer strength, are more vulnerable to decay than are tasks that require moderate precision and accuracy. Perhaps the concentration needed for that precision aids in the formation of solid overall task memories.

Testing Factors

The following two factors relate to the situation under which the soldier's memory for a particular task is tested. To insure that the resulting measure is a valid one, the same conditions should hold during training sessions.

Job and Memory Aids

These aids, designed to facilitate job performance by minimizing the need for recall, come in all shapes and sizes. Some memory aids are taught to soldiers in training; for example, **S-A-L-U-T-E** is included as a mnemonic device in the Soldier's Manual of Common Tasks. By providing retrieval cues, it helps soldiers to remember that, when completing the task Report Enemy Information, they should include information on the enemy's **S**ize, **A**ctivity, **L**ocation, **U**nit, **T**ime, and **E**quipment. Job aids include technical manuals that are meant to be used on the job, instructions printed on forms detailing what information goes where, and labels with start-up instructions attached to equipment. Most maintenance tasks require use of technical manuals as job aids, and many operator tasks involve job aids in the form of checklists to ensure that the equipment is ready for operation.

But job and memory aids vary in quality. A truly effective job aid allows the user to perform the entire task with no additional information or help. Such an aid is clearly written, using terminology familiar to the typical user, and easy for the soldier to use while performing the task. A poor job aid, on the other hand, requires the user to have additional expertise or information to perform the task; it only really helps someone who mostly has no need for it.

"Research has consistently found low error rates when high-quality job or memory aids are used..."

Research has consistently found low error rates when high-quality job or memory aids are used to perform tasks. An Army study of Chaparral missile system crews, for example, found no decline in performance on six tasks up to four months after initial training. Soldiers performed each task, as intended, with easy access to their technical manuals.[31]

Time Limits and Stress

Some tasks have time limits that must be met for some or all task steps. Examples are assembling an M60 machine gun, donning a gas mask, and performing CPR. Time limits have a direct effect on retention of proficiency by defining what it means to say a soldier is "sharp" on a particular task. One effect of the passage of time without practice is a general slowing of both physical and mental performance; "rusty" soldiers may fail to meet a strict time limit, even when they know what needs to be done. However, only time limits that are difficult to meet have the effect of making a task hard to remember; such strict time limits also add to the stress experienced by the soldier being tested on a task, and the stress may make it hard for the soldier to concentrate on the important aspects of the task. In fact, time limits help mimic the situations in which some tasks must be done. It is mostly the set of tasks soldiers must learn to perform well under stress — those related to combat and safety — that include established time limits.

Predicting Military Task Retention

All this has been taken into account in the development of an ARI research product. In 1981, under the sponsorship of the Army Training Board, ARI undertook a 3-year effort to organize and integrate many of the retention research findings just described into an instrument for predicting how rapidly individual procedural tasks are forgotten.[32] The result of this effort is the User's Manual for Predicting Military Task Retention[30], also called the User's Decision Aid or UDA by current users. The UDA was designed to guide the user through a process of numerically rating an individual task on the factors just discussed.

The output is a single score that predicts the decline in performance among soldiers who start out 100% proficient. It identifies a curve that gives the percentage of soldiers in a unit who will be able to perform the task correctly after a given interval of no practice. Training managers can use the UDA to answer questions such as:

How quickly will a particular task be forgotten?

Among several tasks, which is most likely to be forgotten or remembered after a given interval?

When should reacquisition training on a particular task be conducted to keep group performance from falling below an acceptable level?

The UDA process was not designed to address the difficulty of learning a task or how to conduct training. It focuses on task characteristics and does not take into account any techniques or strategies used during initial training or during the retention period to counteract forgetting. (These issues will be discussed in a later section.) Figure 8 displays a flowchart for the rating process.

The Army conducted an extensive validation study of the UDA on 22 tasks for the Cannon Crewman MOS.[33] Each task was rated by five task experts; the inter-rater reliability was high (average correlation greater than .90). That is, there was strong agreement among the answers the raters gave for particular tasks. Soldiers were trained to 100% proficiency on all tasks, and retention tests were given at intervals of 2, 5, and 7 months. The UDA scores accurately predicted retention performance (percent of soldiers performing at a "Go" level) at all three intervals, with the best accuracy (correlation greater than .90) at the 2-month interval.

The study also compared the UDA to another approach for predicting performance — directly measuring task difficulty by determining what percentage of soldiers performed at a "Go" level on their first attempt at the task immediately after training. The results showed that the UDA and this "acquisition performance" measure were about equally accurate as predictors of retention at each retention interval (all correlations greater than .60), with the UDA noticeably the better predictor at the shortest interval. The researchers argued that the UDA is more cost effective, since it can be applied on a few subject matter experts without requiring the collection of large amounts of acquisition performance data. The UDA can be applied even to proposed tasks and can provide predictions of retention even before any widespread training has been given.

Since its development, the UDA has been applied successfully to tasks in a number of military specialties, including vehicle mechanics[34], radio and communication network operators[35], quartermasters[19], combat engineers and masonry/carpentry specialists[36], field medics and air defense missile crews[37], as well as to the tasks involved in peace support operations.[38] ARI has plans to continue research using the UDA. Studies will be conducted, in the near future, on the applicability of the UDA to predicting the retention of digital skills, those needed by soldiers who operate the Army's increasingly complex computer-based systems.[39]

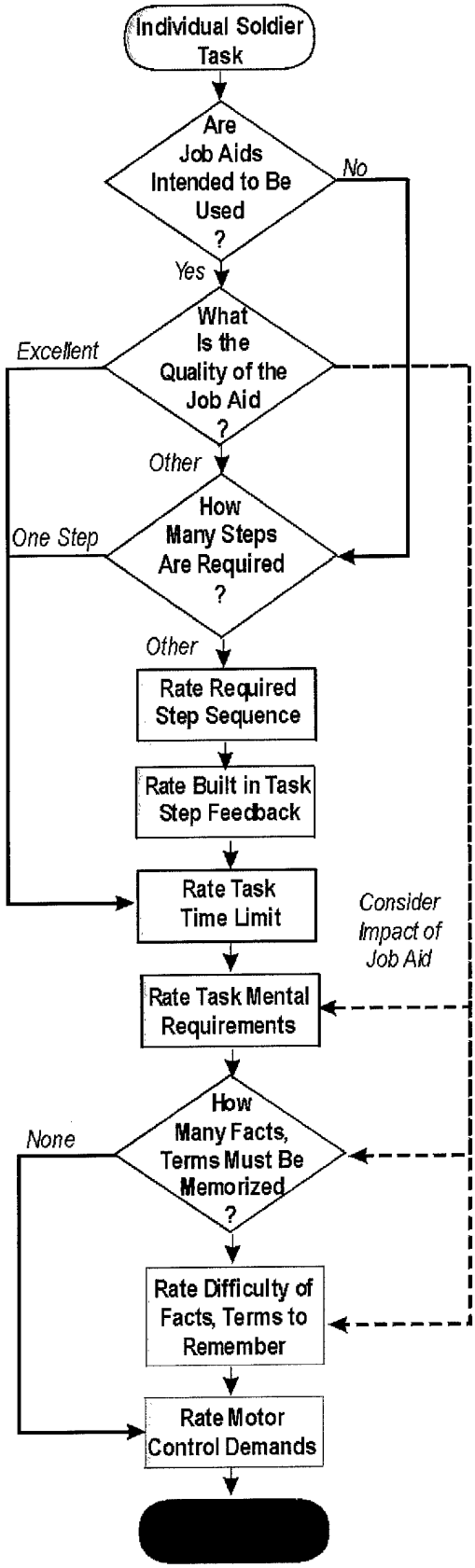


Figure 8. Flowchart for predicting task retention.

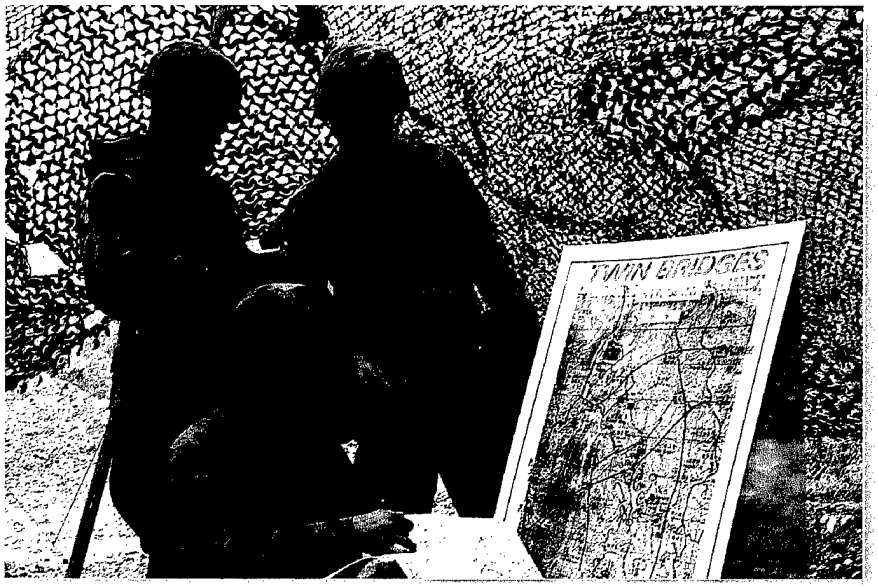
Individual Factors

In addition to the factors captured by the UDA, two others that affect forgetting of procedural tasks are tied to the individual soldier: (1) original learning (mostly a matter of training time, how much opportunity the soldier has had to learn the task in the past) and (2) aptitude (an individual difference factor, how strong an "aptitude for learning" the soldier brings to the task situation). As one might expect, these two strongly interact.

Original Learning

"Original learning" refers to the amount of knowledge and skill the trainee has acquired by the end of training but before a job assignment. In military courses, original learning can range from just passing a course with a grade of 65 or 70 percent, to continuing to practice and learn even after reaching a criterion of 100 percent (e.g., field stripping an M16A1 rifle). Practicing a task after it has been learned well enough to be performed correctly is referred to as "overlearning." The level or degree of original learning is probably the most significant single factor affecting forgetting[3]; in particular, a task that is "overlearned" turns out to be highly resistant to decay.[40]

For example, an ARI study of electrical repairers found that increasing the number of training sessions on a complicated test station reduced both performance time and errors two weeks after training.[41] Another ARI study of training to boresight and zero the main gun of the M60A1 tank compared soldiers trained to one correct performance with soldiers trained to three successive correct performances. After five weeks with no practice, the group trained to three correct performances had fewer errors.[42]



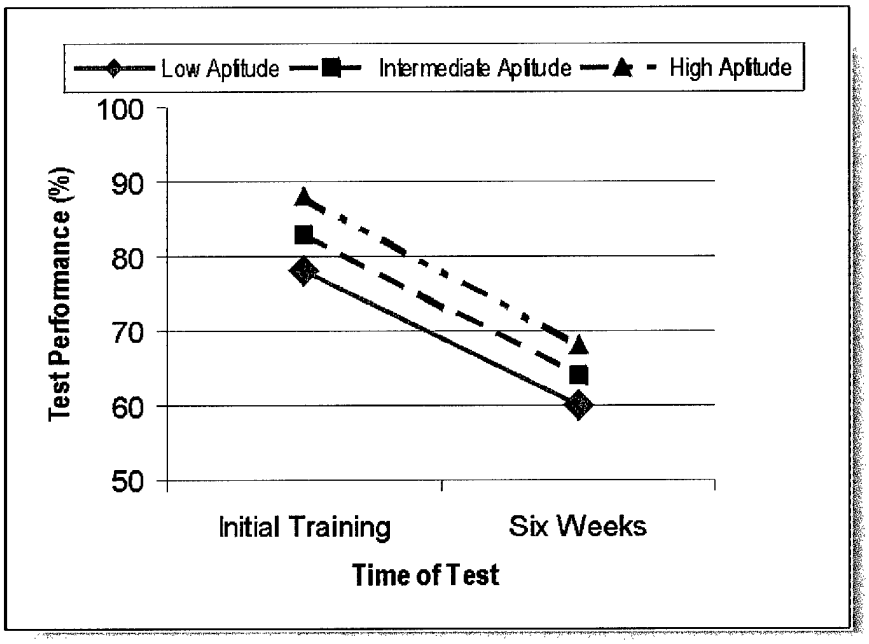
Aptitude

Aptitude for learning is usually measured by a paper-and-pencil test and is predictive of an individual's success in a school setting. Military enlisted personnel vary widely in such aptitude as measured by the Armed Services Vocational Aptitude Battery (ASVAB). Training and job assignments are based in part on ASVAB scores or, rather, on one of the composite scores obtained by adding together an individual's scores on several subtests. The composite score most useful as a general predictor of an enlistee's ability to benefit from original training is known as the Armed Forces Qualification Test (AFQT). This is a combination of subtest scores measuring verbal and numerical aptitudes. The power of AFQT scores and other ASVAB composites to predict training success (and, therefore, level of original learning) is well established, for example, by work at the Air Force's Armstrong Laboratory.[43] Research for ARI's Army Selection and Classification Project (Project A)[44] showed that aptitude measures also predict later job performance; while measures of vocational interest and spatial and perceptual-motor abilities were important predictors of such measures as General Soldiering Proficiency, measures of aptitude for learning were the best predictors.

However, the influence of aptitude on skill retention is not so clear. On the one hand, several studies have shown that, although high-aptitude trainees learn more than low-aptitude trainees do, their rate of forgetting is sometimes the same. For example, in an Army study of 13 basic training tasks (see Figure 9), high-aptitude soldiers out-performed low-aptitude soldiers both at the end of basic training and six weeks later; but the performance differences between the high and low aptitude soldiers on the six-week test were the same as at the end of basic training.[21] In a similar ARI study of knowledge and skill among radio operators[45], although ASVAB soldiers' aptitude scores explained about 25% of the variability in their performance both immediately after training and three weeks later, an individual's aptitude score did not predict how much one's performance would decay over those three weeks.

On the other hand, higher-aptitude soldiers are more likely than lower-aptitude soldiers to reach the level where overlearning — practice beyond the point of correct performance — can occur, if the same amount of training time is available to all. Since, as noted above, those who overlearn a task will show less memory decay over periods without practice, higher-aptitude soldiers will show greater skill retention in these situations.

Figure 9. Soldier aptitude and memory for basic training tasks.



This effect was shown in the already-mentioned study (Figure 4) of IRR soldiers called to duty for Operation Desert Storm.[46] Demographic data (e.g., time since separation from active duty, aptitude, length of active duty, and civilian occupation) as well as performance data were collected on thousands of soldiers from more than 25 MOSs. Performance measures included both written job knowledge tests and hands-on performance tests. The researchers found that the best predictor of skill retention for an individual was the amount of overlearning, as measured by a combination of aptitude (AFQT score) and time on active duty.

High-aptitude trainees, by definition, learn more quickly than do their lower-aptitude peers. Further, the more time soldiers, of any aptitude level, spend on active duty, the more opportunities they have to practice the knowledge and skills acquired in training. Therefore, both high aptitude and long active duty time are predictive of the experience of overlearning; and this experience of overlearning is predictive of resistance to forgetting.

This expectation was confirmed when both groups — soldiers with high aptitude and those with long prior active duty — did well on the measures of skill and knowledge retention, before any retraining was given. Also, as expected, soldiers with both high aptitude and long prior service did best. The surprising finding was that the length of time between separation from active duty and the IRR call-up (i.e., the retention interval) had little effect on forgetting. Increased length of separation was only a weak predictor of a decline in retention performance; the other predictors — lower aptitude and shorter active duty — were much stronger predictors of performance decline. The lack of a retention interval effect here is explained by assuming that most of the IRR soldiers had already suffered most of the forgetting they ever

would for most of the tasks studied; after many months without practice, they were at the far right of the curves in Figure 5.

A subsequent ARI study involved mobilized IRR soldiers who had been field medics.[38] Again, the length of time a soldier had been separated from active duty did not have much predictive value, although aptitude and length of active duty did. Civilian occupation turned out to be important, since soldiers whose civilian jobs were in the medical field (e.g., hospital worker or emergency ambulance technician) showed little skill decay for their medical military tasks. However, for those medics mobilized from non-medical civilian jobs, the set of AFQT scores was a strong predictor of their ability to perform medic tasks, even before any retraining was given.

The same predictive power of AFQT scores was reported for retention of common task performance by soldiers mobilized from the IRR[47], but only for those who had previously spent a full two-year tour on active duty. Once again, among soldiers given repeated opportunity to learn and practice their tasks, followed by a long period without practice, the higher-aptitude soldiers could recall the tasks significantly better. This effect may be due directly to increased original learning or indirectly to better retention. Either way, it exemplifies the interplay of aptitude and opportunity to learn that yields the benefit of "overlearning."

Improving Skill Retention

The ultimate goal of all this research is to provide Army trainers with information they can use to improve soldiers' retention of knowledge and skills. Several methods for doing so follow.

Optimize the Schedule of Refresher Training

For soldiers deployed to Bosnia and Hungary as part of Operation Joint Endeavor, ARI developed a Trainer's Guide for Refresher Training (Figure 10) that, on the basis of results from the UDA, ranked 27 tasks needed for this operation in terms of their vulnerability to decay.[21] For example, the tasks "Extraction from Minefield" and "React to Civilian on Battlefield" were predicted to show major problems due to decay after only two months without practice. This information was provided so that those in charge of training for these soldiers could foresee when skills would decline below acceptable levels; they could thus create an optimal schedule for their soldiers' refresher training.

Maximize Original Learning

Another research-based approach available to trainers and training managers for improving skill retention is to maximize the amount of original learning that soldiers carry with them from their initial training.

"Amount of original learning or overlearning... during training is the best predictor of how good... skill retention will be."

TRAINER'S GUIDE FOR REFRESHER TRAINING
-- OPERATION JOINT ENDEAVOR --

RANKING OF TASK RETENTION
(Task ranked #1 is hardest to remember.)

% Go = percent of soldiers predicted to perform the task at 'Go' level after two months of non-use

Rank	Task	% Go
#1 -	Extraction from Minefield	0 %
2 -	React to Civilian on Battlefield	8 %
3 -	React to Sniper	9 %
4 -	Prevent Shock	18 %
5 -	Carbon Monoxide Inhalation	28 %
6 -	Apply Tourniquet	29 %
7.5 -	React to Indirect Fire.	30 %
7.5 -	Winter Driving	30 %
9 -	Vehicle Search	34 %
10 -	Negotiation	36 %
11 -	Rules of Engagement	42 % (27%)
12 -	React to Media	54 %
13 -	V Corps Convoy Mine Strike Drill	56 %
#14 -	Living in the Cold	62 % (48%)
15 -	Identify/Detect Trip Wires	68 %
17 -	Driving Postcheck	71 % (44%)
17 -	Working in the Cold	71 %
17 -	Identify/Detect Booby Traps	71 %
19 -	Sleeping in the Cold	73 %
20 -	Recognize/ React to UXO	75 %
21.5 -	Mine Detection	76 %
21.5 -	Locate a Mine by Probing	76 %
23 -	Driving Precheck	89 % (62%)
24 -	Personal Search	90 % (62%)
25 -	React to Mines	96 % (68%)
26 -	Field Dressing/Pressure Dressing	98 %
27 -	Indications of Mines/Booby Traps	99 % (84%)

NOTE: Tasks with two 'Go' percentages have job aids; percentages in parentheses apply when job aids are not available.

See the reverse side for factors to consider when scheduling these tasks for refresher training.

The following task... establishing priorities...

1. CRITICALITY:
Decide how critical each task is to your particular unit's mission -- give priority to the most critical tasks.

2. RECENCY:
Determine how long it has been since your unit has performed each task -- give priority to tasks not done recently.

3. PREDICTED RETENTION:
Locate the tasks you expect to train within the ranking on the reverse side of this sheet -- give priority to tasks with high ranks (#1 is 'highest').

About This Guide

Purpose: General guidance for scheduling refresher training.

Intended Users: Trainers of the stability operations tasks required for soldiers deploying to Bosnia or Hungary.

Origin: Instructors at 7th ATC, Hohenfels, provided judgments on characteristics of tasks taught there.
Using methods developed from earlier research, the U.S. Army Research Institute converted these expert judgments into predictions of task retention.

March 1996

Figure 10. Pocket job aid for optimizing refresher training.

This can be accomplished by increasing the number or length of training sessions or the number of practice repetitions.[50] We mentioned above that amount of original learning or degree of overlearning that a soldier experiences during initial training is the best predictor of how good that soldier's skill retention will be.

Test During Training

Another technique for improving retention is to employ frequent testing during training. In a series of studies involving motor skills, ARI researchers found that repeated testing trials resulted in superior retention.[49]

Provide Spaced Practice

A further means of improving retention is to use spaced or "distributed" repetitions during practice sessions. Substantial laboratory research shows that inserting a time interval between repetitions of a task during learning increases retention. Army researchers have extended this finding to Army tasks. In a maintenance task study, one group of fuel and electrical repairers performed three task repetitions in succession (massed repetitions), while another group performed the same task every other day (spaced repetitions). When both groups were tested two weeks later, the massed group took 51 percent longer to complete the task and committed 40 percent more errors than the spaced group.[50]

Use Task-oriented Training

Task-oriented training involves using the context of the task to teach the factual knowledge and cognitive skills required for task performance. It is often contrasted with topic-oriented training, in which information is taught more abstractly, without reference to job applications. For example, in military courses on the principles of basic electricity and electronics, the instruction rarely mentions how and where concepts and principles such as Ohm's or Coulomb's Law will be applied when trainees begin their job assignments. Researchers have shown that task-oriented training is effective at producing both high original learning and good retention. For example, a Navy-sponsored study[51] compared task-oriented and topic-oriented instruction on metal fasteners (e.g., bolts, screws, nuts) in a basic mechanics course. Trainees in both the topic- and task-oriented training conditions were taught to a 90% criterion; after 6 months, the task-oriented trainees recalled significantly more than did the topic-oriented trainees.

Encourage Peer Tutoring

Finally, a large number of research studies have shown that peer tutoring, having students teach each other, enhances original learning. But two studies by Navy researchers also showed the effects of peer tutoring on retention. In the first study, performance for both the peer tutors and the students who received the tutoring was near 100% at the end of initial learning. Six months later, however, the peer tutors remembered significantly more than did the students they tutored.[52] The second study examined the effects of tutoring over longer retention intervals. Tutors were found to retain more than non-tutors did for periods as long as eight years.[53] This is apparently an example of the old saying, "To teach is to learn twice."

Skill Reacquisition

Despite the best efforts of Army trainers and their use of proven techniques for optimizing retention, soldiers will still experience decay of their military knowledge and skills. Personnel called to duty from the IRR or active duty soldiers deployed overseas may have lost sharpness because of a lack of practice opportunities in the months (or even years) preceding activation or deployment. The problem of retention then becomes the problem of skill reacquisition during a "rapid train-up."

ARI was asked to address this issue in 1993. In addition to assessing the extent of skill decay in both active duty and IRR soldiers, ARI researchers began to develop guidelines for retraining and for predicting how rapidly skills can be reacquired.

This research program was based on the earlier work on skill retention described above,[22,54] especially the results for medics mobilized to active duty from civilian jobs in the medical field. The finding that civilian jobs strongly affected retention of military skills led ARI researchers to explore strategies for reestablishing job context for IRR soldiers. The researchers reasoned that soldiers whose civilian jobs were similar (although not identical) to their military specialties did not need time to reinstate the "frame of mind" or job context required for their military tasks. If job context could be reestablished for IRR soldiers by using exportable technology, such as computer-based training or videotape presentations, the time required for reacquisition training could be reduced.

"The problem of retention then becomes the problem of skill reacquisition during a 'rapid train-up'."

To test this hypothesis, the researchers prepared two different videotape presentations that showed two sets of three medical-related common tasks being performed in accordance with the 1994 Soldier's Manual of Common Tasks. One video was shown to half of a sample of 100 soldiers, and the other video was shown to the remaining half. Several days later, all soldiers performed all six tasks.

The demographic findings were consistent with the previous IRR studies: (1) Soldiers who had completed a full tour of active duty performed better than those who had received only a few months of MOS training, (2) soldiers with above-average aptitude performed better, and (3) retention interval had little effect on performance. Performance for tasks shown on the videotape was significantly better than for tasks not shown; on some tasks, performance differences were as great as 30 percent.

Exposure to a simple five-minute presentation thus had a dramatic effect on task performance, apparently by re-establishing job context for the mobilized soldiers. Many reported that the videotapes were "very useful," in that they "brought back a lot" of task knowledge. On the basis of these results, the researchers proposed that videotape and similar technologies (e.g., internet-based training) could be employed in future mobilizations to shorten the time required for reacquisition.[36]

The Reacquisition Curve

Finally, in addition to assessing skill decay and exploring retraining strategies, these same researchers[55] combined data from several of their IRR studies, in order to document, at least roughly, how much time mobilized soldiers need to reacquire skills. Figure 11 displays two data points from each of three studies, one for retention and one for retraining. That is, each study contributed, for its set of procedural tasks, the performance of soldiers after zero retraining (the retention measure) and their performance after the specific amount of retraining time (averaged across tasks) used in that study. A final point is added to the figure to represent the obvious expectation that, if soldiers were provided with retraining that lasted as long as their original training, all would become proficient.

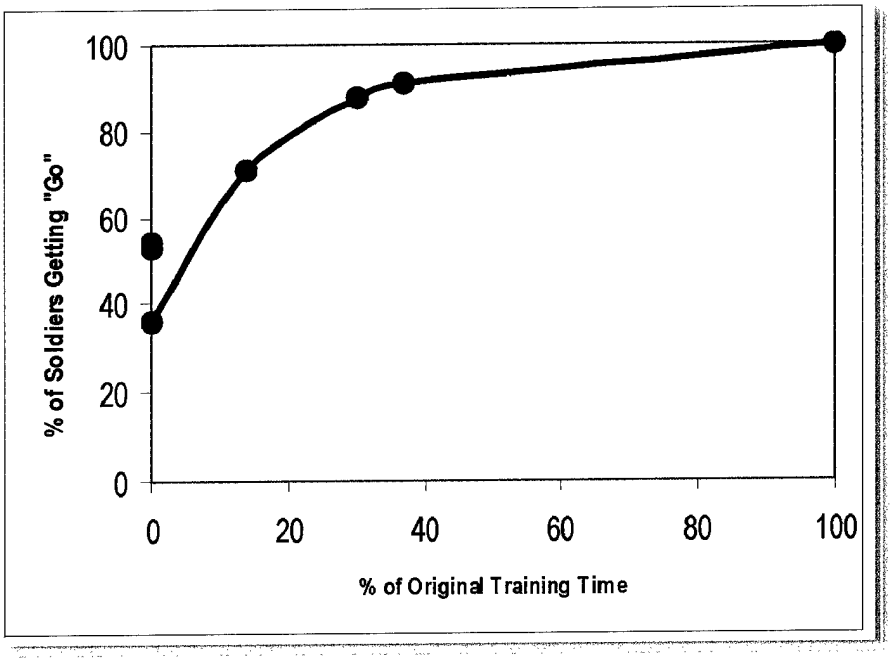


Figure 11.
The reacquisition curve.

The performance measure in Figure 11 is the percentage of soldiers who performed the tasks successfully. The time available for retraining is expressed as a percentage of the original amount of time required in the Army school to train each task, according to the official Program of Instruction (POI). For each study, this value was averaged across all tasks. Note that this POI time is an alternative method of gathering a set of data similar to the "acquisition performance" investigated by the developers of the UDA and found to be a good predictor of retention. Both provide a general measure of how difficult tasks are to train, although in this case the measure is averaged over the dozen or so tasks included in each rapid train-up.

The fact that a smooth curve was obtained when data from several different studies were combined in this way supported the idea that a general relationship was being revealed. That is, Figure 11 was considered a first approximation of the relationship between how long it takes to train a task originally and how much time is needed to retrain soldiers to the point where any desired percentage of soldiers will be back up to speed on the task. It is assumed to apply to any situations (combinations of tasks and retention intervals) that would yield the same

retention performance as found in these studies, an average 38% of the soldiers remembering enough to receive a "Go" with no additional training.

The figure can be used by trainers to plan how much retraining time is needed in such situations to reach a preset level of proficiency, say 90%. It suggests, for example, that 35% of original training time is needed to retrain soldiers from a 38% level of proficiency to the point where 90% of them will perform at a "Go" level. Application would be as follows: If it has been determined, by long experience, that 10 hours of school time is needed to successfully train a particular task, then about 3 1/2 hours should be devoted to retraining soldiers, 100% of whom once knew the task but 62% of whom have now forgotten it. These 3 1/2 hours of retraining would bring the group back to 90% proficiency; according to Figure 11, providing more than 3 1/2 hours of retraining would not produce much additional benefit. This figure, then, gives a rough recommendation for how much retraining should be scheduled for this task. More research is needed to describe the similar curves that should apply when tasks have undergone different degrees of skill decay.

"Army trainers and planners can predict how rapidly individual procedural tasks will be forgotten... [and so] optimize the schedule of refresher training."

Conclusions

In the post-Cold War world, the option to rapidly mobilize and deploy highly skilled personnel is essential. But the success of this option for the Army depends upon soldiers' retention of the military knowledge and skills they once learned or on their capacity for rapid re-learning.

ARI has been studying the retention of knowledge and skills for three decades. This research has resulted in a detailed understanding of the patterns of forgetting that occur in job knowledge and in cognitive and perceptual-motor skills. We have identified the factors that affect forgetting of procedural skills and developed the User's Manual for Predicting Military Task Retention. With this manual, Army trainers and planners can predict how rapidly individual procedural tasks will be forgotten; this information enables them to optimize the scheduling of refresher training.

Researchers have also identified instructional strategies, such as providing spaced practice and peer tutoring, that Army trainers can use to improve soldiers' retention of what they were originally taught and speed their re-sharpening of skills grown dull. Army planners can now identify those individuals least likely to suffer major skill decay while in the IRR. They can even make rough predictions of the time needed to reacquire proficiency on different tasks. All these are potential improvements in the retraining portion of any future mobilization.

The Army Research Institute continues to take a systematic, scientific approach to training. Our research products, serving to upgrade both sustainment and retraining of skills, demonstrate the value of this approach to the readiness of the Army.

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13. ABSTRACT (Maximum 200 words):

This report reviews what is known about forgetting as it applies to military tasks. It includes research conducted by the Army Research Institute as well as related work performed by the Air Force and Navy and leading academic institutions. The report distinguishes the memory for knowledge and skill related to procedural tasks, cognitive tasks, and perceptual-motor tasks. Memory for task knowledge has been demonstrated to be quite good. Memory for cognitive skills has been demonstrated to be quite good. Memory for psychomotor skills varies, depending on whether the task is continuous, such as riding a bicycle, or discrete, such as executing the separate performance steps involved in disassembling a rifle. Throughout the report, figures depict the relative sustainment or decay of a skill as reported in the research literature. A final section concerns the factors that influence the reacquisition of a skill after extended periods of nonuse, as might occur during a mobilization.

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