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A Review and Annotated Bibliography of Literature Relevant to Armor Skill Retention

February 1993

Fort Knox Field Unit
Training Systems Research Division

U.S. Army Research Institute for the Behavioral and Social Sciences

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13. ABSTRACT (Maximum 200 words) This research product addresses the progress of research on armor skill retention by reviewing 74 pertinent works. These works include book chapters, empirical studies, review and theoretical articles, and technical and research reports. The main factors affecting military skill retention are categorized and discussed according to training, task, and individual difference factors. The discussion of factors indicates that predicting armor skill retention is difficult because (a) little is actually known about armor skill retention, and (b) interactive effects were found for most of the previously identified elements of skill retention. Potential areas of research are discussed.				
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Research Product 93-03

**A Review and Annotated Bibliography of Literature
Relevant to Armor Skill Retention**

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FOREWORD

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) is dedicated to helping U.S. Army commanders and trainers understand the most efficient procedures for maintaining a proficient force. This goal has become increasingly important as training resources have become more limited. Army commanders and trainers need to know the factors that affect soldiers' retention of job-related skills. This research product provides such information in relationship to armor skills.

The work described in this research product is a part of the ARI Fort Knox Field Unit's work program under the task entitled "Training Requirements for Combined Arms Simulators." This task is supported by a memorandum of agreement entitled "The Effects of Simulators and Other Research on Training Readiness," signed 16 January 1989. Parties to this agreement are the U.S. Army Training and Doctrine Command, the U.S. Army Armor Center at Fort Knox, the U.S. Army Materiel Command, and ARI.

The information contained in this research product has been made available to commanders, trainers, and civilian training developers at the U.S. Army Armor Center and School at Fort Knox. It has also been made available to armor unit trainers.


EDGAR M. JOHNSON
Acting Director

A REVIEW AND ANNOTATED BIBLIOGRAPHY OF LITERATURE RELEVANT TO
ARMOR SKILL RETENTION

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A Review and Annotated Bibliography of Literature Relevant to Armor Skill Retention

Introduction

Military training has generated an enormous body of literature. A subset of this literature addresses issues relevant to skill retention, broadly defined as the maintenance or sustainment of learned behaviors without practice (Schendel & Hagman, 1991). A search of computerized databases and existing bibliographies revealed hundreds of documents that have been published on skill retention and the inverse, skill decay. Prophet (1976), for example, noted the existence of over 120 articles on this topic. These documents provide a plethora of information about skill retention, yet many questions and gaps in our knowledge remain.

One of the most common issues running throughout this literature involves predicting the rate of decline for specific individual skills (see Rose, Radtke, Shettel, & Hagman 1985; Rigg, 1983; and, Wisner & Sabol, 1990). Rose et al., for example, developed a method for predicting retention of procedural and perceptual-motor military skills over no-practice intervals of up to 1 year. This prediction model was based on such factors as complexity of the task to be remembered, length of the retention interval, and presence of job aids.

Questions remain, however, regarding the validity of any model for predicting the rate of armor skill decay. In addition, a large portion of the literature focuses on individual skill retention rather than collective (team or crew) retention. This product attempts to address these issues by reviewing the pertinent material on armor skill retention. It identifies what is not known about this topic and provides recommendations for areas of future research. It also includes an annotated bibliography of the armor skill retention literature (Appendix A), the existing literature reviews of skill retention (Appendix B), and the pertinent military and civilian skill retention literature (Appendix C). This document should help armor commanders, trainers, and researchers understand efficient procedures for maintaining a proficient, trained force as training resources become more limited and Army downsizing increases the reliance on Reserve Components for future mobilization.

Method of the Literature Search

To accomplish the goals set forth in the previous section, a systematic search of the armor skill retention literature was conducted. This search entailed locating articles through the use of (a) the Defense Technical Information Center (DTIC) data base; (b) the Army Research Institute (ARI) corporate bibliographies

(1981, 1986, 1990, 1992); (c) the Human Resources Research Organization's (HumRRO's) corporate bibliographies (1971, 1977); (d) reference sections of the existing literature, and (e) knowledgeable individuals in the armor training field.

Fourteen research efforts, two of which were literature reviews, were found that directly addressed armor skill retention. Ten of these works were completed before 1984. Most of the recent works, however, have limited value for armor commanders and trainers. Lampton, Bliss, & Meert (1992), for instance, used college students as their subject population.

It was decided to broaden the scope of this review to include pertinent skill retention research from other military and civilian sources. Computerized literature searches of several data bases (DTIC, Educational Resources Information Center-ERIC; and PsychLIT) were conducted to locate additional sources on skill retention. These articles were also found by (a) searching the corporate bibliographies of ARI, HumRRO, and the Air Force Human Resources Laboratory (1971); (b) searching the on-line card catalogue system at the University of Louisville; (c) going through proceedings of professional conferences; (d) examining the reference sections of the existing literature; and (d) contacting researchers from universities and military laboratories.

Over 80 references were found to be potentially applicable to military skill retention. Seventy-four of these references were included in the annotated bibliography. As stated, 15 of these articles directly addressed armor skill retention. Eleven of these articles were existing skill retention literature reviews. The remaining 48 articles consisted of research efforts from the military and civilian research literature which were relevant to armor skill retention. Of these 48 references, 11 were not acquired by the present authors; however, existing sources provided sufficient information to provide an abstract of the material. For example, Naylor and Briggs' (1961) article could not be obtained from DTIC, but an existing in-house description was available. A list of potentially useful articles which either did not directly deal with skill retention or were not procurable by the time of compilation is also attached.

Annotated bibliographies of the armor skill literature, the literature reviews, and the non-armor skill retention literature are found in Appendices A-C, respectively. A list of potentially useful articles which either did not directly deal with skill retention or were not procurable by the time of compilation can be found in Appendix D. Finally, Appendices E and F contain a listing of the corporate bibliographies and document reproduction services which were used to conduct portions of this literature search.

Summary of Findings

Analyses of the 11 different review articles by the present authors indicated the following salient variables in this literature: (a) original learning; (b) over training; (c) length of the retention interval; (d) refresher training; (e) spacing of practice; (f) functional similarity; (g) knowledge of results (KR); (h) mnemonics; (i) continuous vs. procedural tasks; (j) task complexity; (k) task organization; (l) individual ability; and (m) prior experience. These variables were grouped into the following factors of skill retention (see Figure 1):

1. training--factors associated with instructional strategies.
2. task--inherent attributes of the retention task.
3. individual differences--factors associated with the student.

This taxonomy, similar to one employed by Rose et al. (1981) and Schendel, Shields, & Katz (1978), is described in detail in the next few pages. Results of articles which were not included in previous reviews were also incorporated in this discussion.

The results of the armor skill retention research is further delineated in Figure 2. Three main points regarding this research literature can be extracted from this figure. One, nearly all of this research was done vis-a-vis the M60A1 tank. Two, all of these studies dealt with examining soldiers' retention of procedural skills with a majority of them dealing with gunnery procedures. Three, the retention interval of these studies varied from a few weeks to a few months.

Training Factors

Level of original learning: As shown in Figures 1 and 2, a pervasive finding in this literature is that the level of original learning--level of proficiency prior to the retention interval--is an excellent predictor of retention performance. In fact, nearly all of these reviews have indicated that this variable is the single best determinant of skill retention with the relationship between original learning level and retention remaining highly positive and stable for an indefinite period of time. Fleishman and Parker (1962), as cited in Schendel et al., (1991), for example, found correlations ranging from .80 to .98 between learners' initial proficiency on a three-dimensional flight-control task and later retention, which ranged from 1 month to 2 years.

LITERATURE REVIEW	TRAINING FACTORS							TASK FACTORS			INDIVIDUAL DIFFERENCE FACTORS		
	Original Learning	Over Training	Length of Retention Interval	Refresh Training	Spacing of Practice	Functional Similarity	Knowledge of Results	Mnemonics	Continuous Tasks	Complexity	Organization	Ability	Experience
Adams, 1987		+			+		i		+			i	+
Annett, 1979	+	0	-		0		+		0	0		+	+
Druckman & Bjork, 1991	+	+	-	+	0	+	i	+	+	-	+		
Farr, 1987	+	+	-	+		0			+	-	+	+	
Hagman & Rose, 1983	+	+	-	+	+	+		+	+	-		+	
Hurlock & Montague, 1982	+	+	-	+		+	+	+	+	i	+	+	+
Prophet, 1976	+	+	-	+	0				i		+		0
Rose et al., 1981	+	+	-	+	0	+		+		-	i	i	+
Schndel & Hagman, 1991	+	+	i	i	+	+	i		+		i	+	
Schndel et al., 1978	+	+	i	+	i	+	+		+		i	+	
Wells & Hagman, 1989	+	+	-	+	+	+	+	+		-	+	+	
Known for Armor Skills	+	+	-	+	+	+	+	+	+	+	+	+	+

Key:

- (+) = positive effect
- (-) = negative effect
- (i) = interactive effect
- (0) = no effect
- () = not discussed

Figure 1. Major factors affecting skill retention.

Source	Tank	Task(s) *	Retention Interval	Predictors of skill retention	Predictors of skill decay
Army Tng. Study (1978)	M60A1	MOS skills	2-25 wks		Discrete tasks, Low ability, Time
Goldberg, et al.(1981)	M60A1	Gunnery	1-5 wks	High mastery criterion	Time
Knerr, et al. (1984)	M60A1	Gunnery, Commo, Equipment	4 wks	High levels of mastery	Discrete tasks
Lampton, et al.(1992)	M1A1	Gunnery	10 wks	Increased level of mastery criterion	
Morrison (1982, 1984)	M60A1	Machinegun gunnery & Commo	Not stated	Task structure	Time
Morrison & Bessemer (1981)	M60A1	Machinegun gunnery	6 wks	Spacing practice and video demonstrations did not aid retention	Time
Osborn, et al. (1979)	M60A1	Tank crew position skills	16-32 wks	Task relevancy to crewmen	
Rigg (1983)	M60A1	MOS skills	19-22 wks	High level of mastery	Time
Rigg & Gray (1983)	M60A1	Gunnery	1-5 wks	Level of mastery	Time
Shlechter (1988)	M1	Communication	2 wks	Group learning	
Wisher, et al. (1991)	M1	MOS skills	Varied	High SQT level, soldiers self-assessment, refresher training	Gunnery skills, Low SQT level, Time

* All tasks were procedural.

Figure 2. Summary of armor skill retention research

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However, the relationship between level of original learning and retention may be more complicated than previously thought. Schendel & Hagman (1991) have found that augmented feedback may enhance acquisition but not retention. Holding & Collins (in publication) have noted that intrinsic task cues have a positive effect on students' skill retention (tested after a 15 minute no-practice period) but not upon their level of original learning. And, Farr (1987) has noted that learners with the same level of original learning may differ markedly on their retention performance, depending on such factors as refresher training.

Over training: A related pervasive finding is that over training makes skill retention more resistant to extinction. This term refers to providing students with additional practice trials once they have reached the criteria signifying skill mastery. Work by ARI (e.g., Schendel, Shields, & Katz, 1978; Goldberg, Drillings, & Dressel, 1981) has indicated several advantages of overtraining. One, it is a most potent instructional strategy for promoting retention of skills. Goldberg et al., 1981 have shown that the skill retention of M60A1 crewmen (measured after 1 or 5 weeks) is directly related to the amount of overtraining on different skills. Two, over training may be a cost-effective instructional strategy as it reduces the need for frequent refresher training. Three, the benefits of overtraining may extend beyond skill retention by allowing the skilled performer to use his/her attentional resources in the most judicious manner possible (Schendel, et al.).

Length of the retention interval. Another well documented finding is that skill decay is directly related to the length of the no-practice retention interval. Leonard, Wheaton, & Cohen (1976) found, for example, that soldiers' grenade-launching skills were much poorer after a 17-week retention interval than after a 6-week retention interval. However, the actual rate of skill decay varies from task to task. It may also be mitigated by such factors as prior practice, type of task (discrete, procedural or continuous), and the individual's abilities.

Refresher training. Once optimal retention intervals for particular skills are determined, more effective schedules of refresher training can be implemented. Refresher or sustainment training has been found to promote long-term retention (no specific length mentioned) by reinstating the student's level of task proficiency to the levels obtained during the period of original learning (Wells & Hagman, 1989). The amount of time required for refresher training is consistently less than 50% of that required for initial training (Mengelkoch, et al., 1971), but varies according to:

- (a) The amount of time between initial and refresher training;
- (b) The frequency of prior refresher training sessions;
- (c) Trainee ability level; and,
- (d) The nature of the task to be retrained (procedural tasks take longer to retrain than continuous tasks).

Spacing of Practice. Interest in the spacing of practice, which refers to the temporal distribution of training sessions, has been minimal for approximately 20 years (Adams, 1987). Past research indicates that different repetition schedules of practice for motor tasks--massed versus spaced--produce about the same positive effect on learning and retention (Holding, 1965, as cited in Schendel & Hagman, 1991). However, there are certain instances when spacing training iterations (or distributing practice), as opposed to massing practice, would be recommended. Wells and Hagman (1989) concluded that spaced training schedules would be recommended for:

- (a) Dangerous tasks where fatigue could pose a safety risk;
- (b) Poorly motivated trainees who are adversely affected by the rigorous nature of massed repetitions; and,
- (c) High-ability trainees, who tend to make more responses during massed scheduling, quickly become fatigued, and accordingly respond at a lower level of proficiency than trainees of lower ability (p. 45).

Schendel, Shields, & Katz (1976) have also indicated that the number of practice trials, not their distribution, is a key issue, especially when training time is limited. When time is limited, training should be massed to optimize original learning.

Functional Similarity: The functional similarity or fidelity between the training and transfer situations has long been considered to be a critical variable for promoting successful transfer/retention of the training materials. As noted by Druckman & Bjork (1991), transfer is positive when the training and transfer tasks contain many shared structural elements and few distinctive components. Also, Hagman and Rose (1983) have suggested that skill retention can be improved by tailoring the training situation to specific field environments. They noted, for example, that extension course training may be more appropriate than conventional classroom training for promoting task acquisition and retention for military field purposes.

The skill retention literature, however, has also indicated problems with drawing any definitive conclusions about the effects of this variable on students' retention abilities (Druckman & Bjork, 1991; Farr, 1987). For one thing, the amount of transfer obtained between the training and retention situations is a function of the functional similarities perceived by the students (Druckman & Bjork, 1991). Additionally, Farr (1987) has noted the lack of any empirical evidence regarding the effects of fidelity on students' long-term skill retention.

Knowledge of results (KR): Mixed conclusions have been found in the skill retention literature regarding the effects of KR upon students' skill retention. It was once widely believed, as indicated in the early reviews, that KR was a crucial variable in skill acquisition and retention (e.g., Annett, 1979; Hurlock & Montague, 1982). As stated by Hurlock and Montague:

The research literature is clear about one variable that must be presented during the learning process. This variable is called knowledge of results or "feedback" (p. 6).

The recent skill retention literature, however, suggests that the effects of KR are not so clear (Druckman & Bjork, 1991; Schendel & Hagman, 1991). Schendel and Hagman have noted that providing students with too much augmented feedback (from an external source) may attenuate their retention performance. Also, Druckman and Bjork suggested that instructors should give feedback either less frequently during training or eliminate it during later trials; otherwise, performance becomes dependent upon the feedback. Hence, instructors should be cautious in providing students with augmented feedback about their performance.

Also, recent works from the instructional psychology literature suggest that the effects of KR are not so clear. Kulhavy and his associates (e.g., Kulhavy & Stock, 1989) have argued that the effectiveness of feedback is basically a function of the students' perception of a need for such information. That is, students who are certain that their responses are correct do not pay attention to the feedback provided by the instructional system.

Mnemonics: Mnemonics are strategies employed to impose meaning and/or organization on complex materials or skills to facilitate learning and retention (Wells & Hagman, 1991). The reviews (Druckman & Bjork, 1991; Wells & Hagman, 1991) suggest that allowing learners to provide their own elaborations enhances their retention and transfer of procedural tasks. However, Bellezza (1981, as cited in Wells & Hagman, 1991) found that mnemonics generated for tasks with less than 10 elements have little, if any, effect on students' skill retention.

Task Factors

Continuous vs. procedural tasks: Marked differences exist in soldiers' abilities to retain continuous and procedural tasks. Continuous responses involve the repetition of a movement pattern with no clear beginning or end (e.g. steering, tracking, or bike riding); procedural tasks are made up of a series of discrete responses (e.g. flipping switches, pressing buttons).

Students have been found to have more problems retaining procedural tasks than continuous tasks (Grimsley, 1969a, 1969b; McDonald, 1967; and, Vineberg, 1975). As a result, procedural tasks must be the subject of regular refresher training (weekly or monthly) to remain proficiently executable, whereas, continuous task movements are retained well over intervals of months or years, and do not need to be the focus of concentrated refresher training.

Task complexity: Researchers from ARI projects have argued that the number of steps required in a task is a salient predictor of skill retention (Hagman & Rose, 1983; Shields, Goldberg, & Dressel, 1979). Shields et al., found that soldiers' rate of skill decay after 4-12 months for assembly/disassembly of the M16 rifle was significantly related to the number of steps in the task, with the most rapid decay affecting tasks that were not cued by the equipment or previous steps. However, their finding has not been replicated. Hagman & Rose (1983) noted that rapid skill decay occurred most for task steps which were not cued by the equipment or the next step. Definitive conclusions about the relationship between retention and this predictor variable cannot be made.

Task organization: Another task factor discussed in the literature is the effects of the task's inherent organization on retention and transfer. Morrison (1983) found that armor crewmen organize their memory for procedures according to the hierarchal goal structures of the task. One would then expect that such structured tasks are acquired faster and retained longer than tasks with less structure. The effects of task organization upon retention, however, seem to be dependent upon the learning process. Schendel & Hagman (1991) have noted that task organization was only a salient variable for those responses which were not well learned during the period of original learning.

Individual Difference Factors

Ability level. Level of ability in the military can be assessed using mental categories defined by the Armed Forces Qualification Tests (AFQT) and/or General Technical (GT) scores. With respect to military training, higher ability students usually learn faster and achieve higher levels of acquisition

than their lower ability counterparts. As a result, higher ability soldiers typically have higher levels of skill retention.

However, the relationship between ability levels and skill retention may be mitigated by other training factors. Vineberg (1975) has found that retention differences do not exist between higher and lower ability students when they are trained to the same level of original learning. Shlechter (1988) found that higher ability trainees are inclined to benefit more from self-paced training methods while lower ability students benefit more from small group instruction.

Experience. An individual's prior knowledge of and experience with similar tasks have been demonstrated to facilitate his/her acquisition and retention of new skills (Hurlock & Montague, 1982). However, dissimilar skills retained by experienced soldiers can create interference or negative transfer when they attempt to learn a new or related skill.

Final Comments

Implications for Armor Training

There are several reasons for armor commanders to be cautious in making any assumptions about their soldiers' or units' skill retention. First of all, the quantity of data directly relating to armor skill retention is limited and dated. As previously indicated, nearly all the available data on this topic were collected during the era of the M60-series tanks. Second, nearly all of the research on skill retention focuses on individual skills as opposed to collective/team skills. Furthermore, these data did not always provide clear answers for skill retention issues due to the usual constraints of conducting research in real-world environments and the contextual and interactive nature of the factors associated with skill retention.

It is possible to make some general inferences about armor skill retention. Integrating these inferences with the judgments of experienced trainers can lead to important implications for armor training. These inferences with their possible implications are summarized below:

1. Armor skills appear to decay rapidly relative to other military skill areas. There are several reasons for this inference regarding the rate of armor skill decay. One, Wisher, Sabol, Sukenik, & Kern (1991), reported that survey data from reservists activated for the Persian Gulf War indicated that the Armor School had the highest proportion of reservists (22%) who reported remembering only a few of their MOS skills and required nearly complete retraining. These self-report data indicate problems with their retention of basic armor skills. Two, armor

skills usually involve many discrete steps. Three, these skills involve many higher-order cognitive components, which are the most prone to skill decay.

2. Armor commanders should be highly concerned about the sustainment of their crewmen's skill proficiency, and must take advantage of every opportunity to provide practice for their soldiers and for themselves. These practice or refresher training opportunities should include pretesting the soldiers' level of skill mastery. Such testing provides training in and of itself. It also enables commanders to identify those skills which need additional (re)training.

3. Armor skills will usually decay in direct proportion to the rate of original learning. That is, high rates of original learning lead to high rates of skill retention. Armor commanders should thus provide every opportunity for their soldiers to reach a high level of original skill mastery. This goal can be achieved by providing mastery training (three consecutive correct performances) instead of standard training (one correct performance).

4. Armor skill retention is a function of several instructional and task factors. Armor commanders can maximize their soldiers' skill retention by following these training rules: (a) make the training requirements functionally similar to the on-the-job performance requirements; (b) space the practice opportunities to minimize fatigue; (c) provide performance feedback without making the soldiers overly reliant on such information; and (d) encourage the soldiers to develop an organizational model of the task. Armor commanders should correspondingly realize that skill retention is usually best for continuous, well-structured tasks.

5. As previously stated, Armor skill retention is becoming an increasingly important issue because of the downsizing of the Army and the additional reliance upon the Reserve Components. Few research efforts, however, have investigated the skill retention of Armor Reserve Component and National Guard units.

Implications for Future Research

Several important skill retention issues remain largely unexplored. Future research should continue:

1. Examining the effectiveness of simulators and other automated training devices in augmenting skill retention;
2. Examining the retention of collective skills in armor and other military units;

3. Investigating the armor skill retention and decay of members of Reserve Component and members of National Guard units.
4. Developing skill retention measurement systems (i.e., self-assessment, expert-assessment, automated assessment in devices and simulations);
5. Determining the retention intervals for specific armor skills;
6. Assessing how often to refresh training for specific skills;
7. Identifying important personality variables and cognitive styles;
8. Investigating retention performance for higher order cognitive skills, such as planning, preparing, and decisionmaking; and,
9. Examining ways to enhance skill retention in the Reserve Components.

By examining these issues researchers can begin to close the gap between what we know and do not know about skill retention. Then more definitive conclusions can be drawn regarding the skill retention of armor personnel.

Appendix A

Annotated Bibliography: Armor Skill Retention Literature

1. Army Training Study: M60A1 Weapon System. (1978). Retention of basic armor training skills within the unit: A study report. Fort Knox, KY: Author.

Two-hundred seventy crewmen were retested on 11 skills which they had recently mastered during their basic armor training (BAT). The retention interval between the BAT testing and the retention tests varied from 2 to 25 weeks. The Go rates for the retention tests ranged from nearly 50% of the soldiers passing the breechblock test to 90% of them passing the advanced driving tests with an average GO rate of nearly 80% across the different tests. The lower GO rate on the breechblock tasks was attributed to the greater number of steps involved in completing this task. The results also indicated that the higher ability subjects' retention performance was better than their lower ability counterparts. Finally, the results did not indicate any significant relationship between retention performance and the soldier's rank, age, marital status, education level, and career intention.

2. Goldberg, S. L., Drillings, M., & Dressel, J. D. (1981). Mastery Training: Effect on skill retention (Tech. Rep. No. 513). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A120 762)

This research sought to determine the effects of mastery training and length of retention interval on retention of a procedural skill. Forty-two armor crewmen were individually trained to boresight and zero the main gun of the M60A1 tank. Crewmen were trained to either of two criteria: one correct performance (standard training) or three consecutive correct performances (mastery training). Retention was tested either 1 or 5 weeks after training. The results indicated that: (a) there was a significant effect of both amount of training and length of retention interval on recall of the task, but no interaction between the variables; (b) crewmen performed better on the retention test after the shorter retention interval or after more intensive training; and (c) differences in performance among the groups were mostly caused by differences on the first retention trial and mental category. While mastery training aided retention, the authors noted that only 15% of the mastery trained crewmen performed the task correctly on the first retention trial. They concluded that mastery training might be most useful for tasks with few steps and tasks that: (a) must be recalled from memory; (b) must be performed correctly on the first trial, and, (c) lack adequate refresher training resources. (Revised from document abstract)

3. Knerr, M., Harris, J. H., O'Brien, B. K., Sticha, P. J., & Goldberg, S. L. (1984). Armor procedural skills: learning and retention (Tech. Rep. No. 621). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A153 227)

This research investigated learning and retention of 8 armor tasks selected to represent tasks that varied in length, complexity, and extent of practice in operational units. The results supported previous findings that: (a) performance decays during the interval between completion of armor school and unit placement; (b) tasks with more steps and complexity decay more rapidly; and, (c) frequent practice improves armor skill retention, provided that the tasks are performed the same way in the unit as they were during initial training. If tasks are performed differently in the unit from the way they were originally trained, then performance will appear to decline even with high rates of practice. Appendixes contained tables potentially useful in efforts to estimate the requirements for initial and refresher training.

4. Lampton, D. R., Bliss, J. P., & Meert, M. (1992). The effects of differences between practice and test criteria on transfer and retention of a simulated tank gunnery task (Technical Rep. No. 949). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

This investigation examined the effects of different practice and test criteria on the transfer and retention of a simulated tank gunnery task. Three groups of 15 male undergraduates practiced track-and-shoot tasks using the Videodisc Gunnery Simulator (VIGS). Practice difficulty was controlled by setting the kill zone area (the percentage of target-silhouette area--50%, 100% or 150%--that is scored as a kill when hit). After practice, participants were immediately tested with the kill zone set at 100%, and then tested after a 10 week retention interval. Performance was measured in terms of target kills, aiming error, and time to fire. The results revealed that practice with a more difficult criterion yielded larger kill percentages and slower firing times than did practice and testing with the same criterion. This trend toward significance remained for transfer ($p = .061$) and retention ($p = .057$).

5. Morrison, J. E. (1984). Methods for empirically deriving the structure of memory for procedures. Journal of Applied Psychology, 69(3), 473-481.

To determine the structure of memory for procedures, 12 novice and 12 experienced male soldiers verbally recalled and performed two procedural tasks. Proximity analyses revealed that soldiers organized their memory for procedures according to a hierarchical

structure of task goals. Experienced personnel were less accurate than novice soldiers in their recall and performance of tasks; however, there were no systematic differences in derived memory structures between the groups. Morrison suggested that the poorer performance of experienced soldiers was due to the lack of recent practice, despite the experienced soldiers' advantage in overall frequency of performance. Structures derived from verbal recall were highly indicative of task performance for the novice soldiers. Combined with a rational analysis of task goals and subgoals, proximity analysis can provide a useful description of the memory requirements of procedural tasks. (Document abstract)

6. Morrison, J. E. (1982). Retention of armor procedures: A structural analysis (Tech. Rep. No. 591). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A140 003)

Proximity analyses were performed on verbal recall and hands-on performance of selected procedures to determine the structure of memory for armor procedural tasks. These analyses confirmed that armor crewmen organized their memory for procedures according to the hierarchical goal structures of the tasks. Comparisons of entry-level and field unit armor personnel showed significant decrements in skill performance over time; however, there were no systematic differences in memory structure between the two groups. Structures derived from verbal recall were highly indicative of hands-on structures for crewmen still in training, but the relationships between verbal and hands-on structure was not as strong for armor crewmen in field units.

7. Morrison, J. E., & Bessemer, D. W. (1981). Training and retention of armor machine gun tasks (Research Rep. No. 1317). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A128 824)

This report examined the retention of armor machine gun tasks in platoons within 3 Armor One Station Unit Training (OSUT) companies. Each platoon was assigned to one of three M85 training schedules; a single four-hour block, two four-hour blocks received in one day, or two four-hour blocks separated by at least one week. One of the three companies was also shown videotaped demonstrations of M85 tasks. GO/NO GO data on M85 and M240 tasks were gathered by evaluators from the Directorate of Plans and Training (DPT) at Ft. Knox. M85 performance was measured at the end of the OSUT cycle, whereas M240 scores were gathered at both mid and end-of-cycle tests. Execution times on M240 tasks were also collected. The findings indicated: (a) no effect of training schedule and introduction of videotaped demonstrations on M85 task performance or M240 retention; (b) poor performance on M85 mechanical training tasks for the end-of-cycle test; (c) reliable degradation in M240 performance between

mid and end-of-cycle tests; and (d) task execution times revealed subtle changes in performance, which were not indicated by the GO/NO GO scores. (Revised from document abstract)

8. Morrison, J. E., Drucker, E. H., & Campshure, D. A. (1991). Devices and aids for training M1 tank gunnery in the Army National Guard: A review of military documents and the research literature (Research Rep. No. 1586). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A240 628)

This project analyzed six training devices and aids that are relevant to gunnery training in an armory environment. The devices were M1 Top Gun; M1 Videodisc Interactive Gunnery Simulator (VIGS); M1 Mobile Conduct-of-Fire Trainer (M-COFT); Guard Unit Armory Device Full-Crew Interactive Simulation Trainer, Armor (GUARD FIST I); Simulation Networking (SIMNET) battlefield simulation system, and Hand-Held Tutor (HHT). The authors discussed the training effectiveness of these devices and aids with respect to (a) skill acquisition; (b) skill retention; (c) prediction of performance; and (d) transfer of training. However, in their review of the literature, the authors noted that there was "very little research that addressed the effects of training devices and aids on the retention of gunnery knowledge or skills" (p. viii). The research that did address skill retention was reported in the validation and verification tests performed in 1984 with U-COFT by the General Electric Company and maintained that armor crews should be retrained using U-COFT every 3-10 weeks.

9. Osborn, W. C., Campbell, C. H., & Harris, J. H. (1979). The retention of tank crewman skills (Research Rep. No. 1234). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A086 399)

This study examined armor crewman skills between completion of basic armor training and the early months of field unit assignment. Performance tests were administered at the end of formal training and again after 4 to 8 months on the job. For both testing periods, overall proficiency remained unchanged from the school to field testing. When examined by task category proficiency declined for tasks common to all crewmen and increased for tasks specific to a crew position. Specific test results should aid in determining when to retrain specific armor skills. (Revised from document abstract)

10. Rigg, K. E. (1983). Optimization of skill retention in the U.S. Army through initial training analysis and design: Prototype skill sustainment guide (MGA-5181-PRO). Monterey, CA: McFann, Gray & Associates, Inc. (AD A132 190)

This report summarized the results of a McFann, Gray & Associates (MGA) software test designed to estimate training and retention outcomes. Sixty-eight soldiers, who were randomly selected from units at Fort Campbell and Fort Lewis, participated in this research effort. All soldiers were trained to criterion for 40 selected armor tasks and then were retested prior to their unit refresher training. The author reported that the MGA software provided an accurate estimate of the soldier's training and retention performance. However, empirical data were not presented in this document to substantiate this claim. (Revised from the document's executive summary)

11. Rigg, K. E. & Gray, B. B. (1980). Estimating skill training and retention functions through instructional model analysis (MRO-FR-0378). Monterey, CA: McFann, Gray & Associates, Inc.

This document reports the findings of a study that applied a mathematical model (the Markov chain model) to data collected during initial training in order to: (a) describe initial training; (b) predict training outcomes in terms of time, costs, efficiency, and end of course performance; and, (c) predict the level of field performance after a retention interval with no practice. Forty-two armor crewmen were trained to boresight and zero the main gun of the M60A1 tank. The study was designed with two levels of initial training: one correct performance or three consecutive correct performances; and with two retention intervals: one or five weeks. Results obtained using the Markov model proved to be highly predictive of field performance based on initial performance in training. The authors note that the Markov model may not be applicable to skills that are learned gradually or to skills that are repeated several times as sub-elements of another procedural skill (e.g. placing safety on FIRE position).

12. Shlechter, T. M. (1988). The effects of small group and individual computer-based instruction on retention and on training lower ability soldiers (Research Rep. No. 1497). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A203 793)

The effects of having various numbers of soldiers at a terminal for computer-based instruction (CBI) in a procedural task were examined. Soldiers in each of two experiments were trained to use the Communications-Electronics Operating Instructions (CEOI) extracts. Twenty-four soldiers participated in Experiment 1.

Eight were non-systematically assigned to each of three conditions: "GRP", or four at a terminal; "PR" or two at a terminal; and "IND", or one at a terminal. All soldiers took a pretest, a posttest immediately after training, and a second posttest 2 weeks later. Thirty-four soldiers who were in sustainment training participated in Experiment 2. Twelve were in the GRP condition, 10 in PR, and 12 in IND. All were pretested and took three posttests: one immediately after training, another 2 weeks later, and another 8 weeks after training. Soldiers in the PR conditions retained more information than those in the IND condition. Significant differences were not found for the soldiers' scores on the immediate posttest.

13. Sticha, P. J., Edwards, T. D., & Patterson, J. F. (1984). An analytical model of learning and performance of armor procedures (Research Note No. 84-24). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A138 000)

This report documented the development of a model to investigate issues regarding acquisition and retention of procedural armor skills. Learning and retention models were developed for eight tasks performed by the driver, gunner, and loaders of the M60A1 tank. Sequencing control was modeled using the SAINT (System Analysis of Integrated Networks of Tasks) simulation system. Models described acquisition, retention, retrieval, and choice of task information and were validated by comparing their predictions to two samples of data, one composed of soldiers in training, and one from soldiers in operational armor units.

14. Wisher, R. A., Sabol, M. A., Sukenik, H. K. & Kern, R. P. (1991). Individual ready reserve (IRR) call-up: Skill decay (Research Report 1595). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A239 371)

Soldiers from the Individual Ready Reserve (IRR) who were called up for the Persian Gulf War were tested to determine the extent of skill decay since release from active duty. Results from tests (e.g. hands-on performance, written, weapon qualifications) were merged with data from personnel files and responses to a 31-item questionnaire on job experience, attitudes, and personal impact of call-up. The major findings were that: (a) knowledge about Army jobs decayed mostly within 6 months; (b) weapons qualification skills decayed mostly after 10 months; (c) previous skill qualification scores were the best predictor of skill decay; (d) skill decay was higher in Armor and Combat Engineering fields and lower in Infantry, Maintenance, and Supply fields; and (e) skill retention was higher for those who entered the IRR directly from active duty. (Revised from document abstract)

Appendix B

Annotated Bibliography: Reviews of the Skill Retention Literature

1. 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.

Adams has reviewed over 360 articles, which span the past 100 years, on learning, retention, and transfer of human motor skills. This review focused on: (a) knowledge of results; (b) distribution of practice; (c) transfer of training; (d) retention; and (e) individual differences in motor learning. The main finding concerning retention was that performance on a discrete procedural task, like throwing switches in sequence, was forgotten more rapidly than performance in a continuous task like tracking. Forgetting of procedural responses was completed in a year, although there can be savings, because relearning is rapid.

2. Annett, J. (1979). Memory for skill. In M. M. Gruneberg & P. E. Morris (Eds.), Applied problems in memory, (pp.215-247). New York: Academic Press.

This chapter reviewed skill acquisition and retention research from 1885 (Ebbinghaus) to 1979. It also discussed several research findings pertaining to memory for different kinds of skill by distinguishing between natural vs. artificial tasks, motor vs. verbal tasks, continuous vs. discrete tasks, integrated vs. non-integrated tasks, type and amount of training, duration of the retention interval, interference and/or facilitation by activities in the retention interval, conditions of recall, and individual differences. The pertinent conclusions were that refresher training, level of skill at the end of original learning, and duration of the retention interval are crucial factors in skill retention.

3. Druckman, D. & Bjork, R. A. (1991). Optimizing long-term retention and transfer. In D. Druckman & R. A. Bjork (Eds.). In the mind's eye: Enhancing human performance (pp. 23-56). Washington, D.C.: National Academy Press.

This chapter reviewed major training variables that effect long-term retention and transfer of cognitive-motor procedural skills. The authors concluded that: (a) post-training performance improves as original learning increases; (b) automatic skills have a higher likelihood of being retained without refresher training; and, (c) procedural task forgetting is affected by the task's organization, number of steps, degree of cuedness, and amount of elaboration possible. They also concluded that transfer is enhanced when: similarity between training and the transfer task is high; and, sufficient feedback is provided.

4. Farr, M. J. (1987). The long-term retention of knowledge and skills: A cognitive and instructional perspective. New York: Springer-Verlag.

Farr reviewed 133 articles that revealed several factors which influence knowledge and skills over relatively long periods of nonuse. He has identified major variables influencing long-term retention in order of importance as: (a) the degree of original learning; (b) task characteristics (type and complexity of organization); (c) length of the retention interval; (d) instructional strategies and conditions of learning; (e) methods for testing retention and conditions of retrieval; and, (f) individual differences. Farr proposed several ways to promote long-term retention. First, one must consider the real-world environment in which the learner must function. Second, selectively overtrain more difficult tasks. Third, present the material or skill to be learned in a way that elaborative processing can create associative links. The appendices include detailed analyses of 8 major literature reviews that dealt with long-term retention.

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

This article reviewed thirteen experiments conducted or sponsored by the Army Research Institute examining retention of military tasks. Selected findings of this review were: (a) increasing the amount of task repetition enhanced retention; (b) testing during training enhanced retention; (c) spacing, rather than massing repetitions increases retention; (d) tailoring training for specific training environments improved retention; and (f) using mnemonic techniques during training did not necessarily promote better retention than rote memorization.

6. Hurlock, R. E., & Montague, W. E. (1982). Skill retention and its implications for navy tasks: An analytical review (SR-82-21). San Diego, CA, Navy Personnel Research and Development Center. (AD A114 211)

This review identified variables contributing to skill loss in the Navy. Findings were organized into five categories-- personnel characteristics, task variables, training factors, job conditions, and retraining factors. Significant retention variables included original learning, nature of the learning environment, overlearning, ability level, type of task, number of steps or subtasks of a job, quantity of practice (refresher training), quality of feedback, length of nonuse, and recall conditions. The authors concluded that the existing scientific literature has had little application to naval skill deterioration because the previous research conditions differed from those found in the complex naval working environment.

7. Prophet, W. W. (1976). Long-term retention of flying skills: A review of the literature (Final Report 76-35). Alexandria, VA: Human Resources Research Organization. (AD A132 188)

This study reviewed the literature on long-term retention of flying skills. Findings were organized in three broad categories: general retention factors; task or skill factors; and, retraining factors. General retention factors included level of learning, length of retention interval, habit interference and transfer, and rehearsal effects. Task/skill factors included control and procedural tasks, instrument and contact tasks, information processing tasks, and "other" task factors. Retraining factors included use of devices, nature of training, and individual factors in retraining. Results suggested that basic flight skills could be retained for extended periods of non-flying, but instrument and procedural skills exhibited some decay.

8. Rose, A. M., McLaughlin, D. H., Felker, D. B., & Hagman, J. D. (1981). Retention of soldiering skills: A review of recent ARI research (Tech. Rep. No. 530). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A119 307)

This report reviewed 16 research studies sponsored or conducted by ARI on the acquisition and retention of Army tasks and skills. The findings suggest that the most important training factors for acquisition and retention of such skills are the: (a) criterion for proficiency or mastery upon completion of training, (b) use of practice and test trials during training, and (c) use of structured training materials. They also reported that soldiers tended to have retention problems with difficult, uncued, and non-critical tasks.

9. Schendel, J. D., Shields, J. L., & Katz, M. S. (1978). Retention of motor skills: Review (Tech. Paper No. 313). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A061 338)

This review dealt with the variables known to affect the retention of learned motor behaviors over lengthy no-practice intervals. These variables were dichotomized into task and procedural variables. Task variables included: (a) duration of the no-practice period, or retention interval; (b) nature of the response required to accomplish a particular motor task; (c) degree to which the learner could organize or order the elements that defined the task; (d) structure of the training environment; and (e) initial or "natural" ability of the learner in performance of a task without prior practice. Procedural variables included: (a) degree of proficiency attained during initial training; (b) amount and kind of refresher training; (c)

transfer of skills from previous tasks; (d) presence of interfering activities (e) distribution of practice during retraining; (f) use of part-task versus whole-task training methods; and (g) introduction of extra test trials prior to final testing.

10. Schendel, J. D., & Hagman, J. D. (1991). Long-term retention of motor skills. In J. E. Morrison, (Ed.), Training for Performance (pp. 53-92). New York: John Wiley & Sons.

This chapter identified some of the key variables in the long-term retention of motor skills. For example, refresher training can be used to offset the effects of forgetting. Also, retraining time has been shown to vary depending on such variables as length of retention interval, nature of the task, frequency of refresher training sessions, temporal spacing of successive sessions, and learners' initial ability levels. An example of a retention prediction matrix (Rose et al., 1985) for 9 military tasks was presented.

11. Wells, R. & Hagman, J. D. (1989). Training procedures for enhancing reserve component learning, retention, and transfer (Tech. Rep. No. 860). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A217 450)

This report cites over 220 articles identifying specific training procedures for enhancing learning, retention, and transfer of military skills within Reserve Components. The pertinent findings are that: (a) repetition facilitates proficiency on all but the simplest verbal and perceptual-motor tasks; (b) verbal tasks are retained better with distributed practice versus massed practice; (c) perceptual-motor skills are retained at nearly the same level regardless of the type of practice; (d) testing during training promotes retention of verbal and perceptual-motor skills; and (e) elaboration on materials to be learned increases learning and retention.

Appendix C

The Pertinent Military and Civilian Skill Retention Literature

1. Begland, R. R. (1979). The effect of different question types on retention in audio-visual materials (NTIS Nr. AD-A075 652). Fort Monroe, VA: U.S. Army Training Developments Institute.

The effects of the insertion of different types of questions upon learning and retention of an audiovisual lesson were examined. A total of 345 male soldiers attending Advanced Individual Training (AIT) viewed a Training Extension Course (TEC) lesson dealing with the operation and nomenclature of a night vision device and then completed a written post test. Four versions of the TEC lesson were used: the standard lesson used by the Army, the lesson with all embedded questions and feedback deleted, the lesson with 21 comprehension questions inserted, and the lesson with 21 simple verbatim questions inserted. The post-test was given to 168 soldiers immediately after viewing the lesson and to the other 177 soldiers after a delay of 48 to 126 hours. The main result was that the immediate post-test soldiers scored an average of 25.3% of the possible points, while the delayed post-test group scored an average of 18.4%. This difference was significant, demonstrating the loss of knowledge gained from a TEC lesson within a few days. (Revised available in-house abstract; hard copy not procured)

2. Berstein, B. R. & Gonzalez, B. K. (1971). Learning retention, and transfer in military training (NAVTRADEVCCEN 69-C-0253-1). Orlando, FL: Naval Training Device Center. (AD 733 964)

Five experiments explored the influence of imagery, fidelity of simulation, and retention interval on learning, retention, and transfer. Experiments I and II piloted the methods and procedures to be used for experiments III, IV, and V. In experiment III, assessing imagery, 10 undergraduates were trained about 1-1.5 hours to operate a synthetic communications system. Fourteen days after training, subjects returned for a transfer session. Experiment IV assessed the interaction between imagery and verbal skills. Thirty male introductory psychology students took a paper and pencil test. Experiment V investigated the effect of simulation fidelity on transfer performance. Subjects were trained using one of three levels of fidelity. The findings provided no evidence that imagery improves performance or that high physical fidelity enhances training effectiveness. Measures of retention revealed considerable improvement (20-60 percent) in speed and accuracy performance after 2 and 7 day retention intervals. After 14 days, speed showed no difference and accuracy decayed 30 percent from the first session level.

Students exhibited a 30 percent retention decay from their first session level. (Hard copy not procured)

3. Blaiwes, A. S., & Regan, J. J. (1970). An integrated approach to the study of learning, retention, and transfer: A key issue in training device research development (NAVTRADEVCEM Tech. Rep. IH-178). Orlando, FL: Naval Training Device Center. (AD A712 096)

This paper categorized 181 reports according to learning, retention, and transfer and briefly discussed the relationship between these topics. Four general research issues were discussed that characterized learning, retention, and transfer research. These issues were identifying: (a) the subtasks that should be included in training simulation; (b) which variations in stimulus and response characteristics of the training system should be incorporated; (c) which instructional devices, materials, and methods should be introduced; and (d) how much generalization should be built into training devices. A summary focused primarily on the methods, materials, and devices that enhance transfer.

4. Dressel, J. D., (1980). Mnemonically enhanced training (Working Paper). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

This project compared the effectiveness of a rote-repetition mnemonic training technique on the acquisition and retention of an 18-step procedural task (installing an M14 anti-personnel mine). Fifty-one soldiers taking part in One Station Unit Training (OSUT), learned the task with a mnemonic strategy (e.g. each task operation was represented by a letter and the sentence preserved the correct order of task performance) or without the use of the mnemonic strategy. Retention was tested one month later by a relearning procedure. Results revealed that retention did not vary as a function of the training method. Dressel concluded that soldiers did not need to use the mnemonic method, because the task contained a manageable number of steps and could thus be remembered from rote training. (Revised from abstract in Hagman & Rose, 1983; hard copy not procured).

5. Gardlin, G. R. & Sitterley, T. E. (1972). Degradation of learned skills: A review and annotated bibliography (D180-15081-1, NASA-CR-128611). Seattle, WA: Boeing Company.

This review investigated the decay of learned skills pertinent to space flight. Detailed abstracts were included for 21 of the 116 studies most relevant to NASA's interest. Short summaries were included for 25 studies with less direct application. The major findings were that: (a) motor skill retention varied almost directly with the amount of original learning; (b) less trained

subjects exhibited improved retention for procedural tasks with higher organization; (c) part-task training improved retention when focused on temporal aspects of procedural tasks, while whole-task training proved superior for single tasks; and, (d) rapid relearning occurred for tracking tasks, even after 2 years. The authors concluded that the level of performance in the final training period (initial mastery or original learning) was the best predictor of motor skill retention regardless of the retention interval length. (Revised from existing in-house abstract; hard copy not procured)

6. Goldberg, J. H., & O'Rourke, S. A. (1989). Prediction of skill retention and retraining from initial training. Perceptual and Motor Skills, 69, 535-546.

This research examined a method for predicting retention and retraining performance of a manual skill after controlled training. Forty men were trained to criterion performance on low- or high-workload tracking tasks, then retested and retrained after no-practice intervals of 1 to 6 weeks. Retention and retraining performance times were modeled as a function of (a) average tracking completion time during initial training and (b) a power-model point-estimate of training completion times. The power model predicted retention and retraining times slightly better than average times, but both models were significant ($.64 < R < .78$). Performance times were not related to duration of retention and were marginally related to training workload. Later performance was well predicted by earlier task performance, but retention was independent of the elapsed no-practice time period. (Abstract)

7. Grimsley, D. L. (1969a). Acquisition, retention, and retraining: Effects of high and low fidelity in training devices (Tech. Rep. No. 69-1). Alexandria, VA: Human Resources Research Organization. (AD 686 741)

This study extended the work of a previous study (RINGER) to include an examination of retention. The task to be learned required performing 92 simple procedural tasks (operation of switches, plugging in headsets, making brief verbal announcements, etc.) in proper sequence. Training was closely monitored and assisted by instructors through unsystematic reinforcement and cuing. Training to error-free completion of the procedural task require a maximum of 3 hours per individual. Subject's were tested and scored by alternate instructors who merely counted number of correct steps completed. Then after 4 weeks, and again after an additional 2 weeks, subjects were retested. Following the tests they were retrained to correct errors and their retraining performance was recorded. There were no significant differences between the various trainees' performances on any tests, nor were there significant differences in their time and accuracy in relearning to correct tested

errors. All subjects retained material equally well for 6 weeks regardless of fidelity of device.

8. Grimsley, D. L. (1969b). Acquisition, retention and retraining: Group studies on using low fidelity training devices (Tech. Rep. No. 69-4). Alexandria, VA: Human Resources Research Organization. (AD 686 741)

This study investigated the effect of varying training device fidelity on acquisition, retention, and retraining of a procedural task. One hundred and twenty trainees in Advanced Individual Training were randomly divided into 10 groups. Subjects with Armed Forces Qualification Test scores below 30 were not included. Subjects learned a 92-step procedural task on devices of differing simulator fidelity (functioning duplicate, non-functioning duplicate, or artist's representation). The results showed no significant differences in training time, initial performance level, amount remembered after 4 and 6 weeks, or retraining time between groups trained on high versus low fidelity devices. In addition, subjects who knew in advance that they would be retested exhibited no retest score advantage over subjects without access to this information. Thus, Grimsley has concluded that the fidelity of training devices can be very low without adverse effect on training time, level of proficiency, retention, or time to retrain. This conclusion remains true whether the training time is administered individually or in groups.

9. Grimsley, D. L. (1969c). Acquisition, retention and retraining: Training category IV personnel with low fidelity devices (Tech. Rep. No. 69-12). Alexandria, VA: Human Resources Research Organization.

Seventy-two trainees enrolled in Advanced Individual Training were individually trained to perform a 92-step procedural task on the control panel of a Nike-Hercules guided missile system (the same task as used in other studies by Grimsley). Results indicated that: (a) low aptitude personnel trained on low fidelity training devices can achieve high performance levels on complicated procedural tasks; (b) category IV trainees needed more time to master the task than higher ability men; (c) there were no differences in training time, initial performance level, or amount retained after 4 and 6 weeks. He concluded that the training device fidelity can be low, with no adverse effect on training time, level of proficiency, amount remembered over time, or time to retrain.

10. Hagman, J. D. (1979). Typewriting: Retention and relearning (Research. Rep. 1211). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A072 369)

Retention and relearning of typewriting skills among 38 administrative specialists (71L MOS) were examined after the no-practice retention interval between Advanced Individual Training (AIT) graduation and unit duty. Without practice, average typing speed dropped 12% and errors increased 86% between AIT graduation and unit duty. As a result, net typing proficiency fell below the minimum AIT graduation standard. Twenty-five minutes of additional typing practice reinstated a significant amount (28%) of lost typing speed and 19% of lost net typing proficiency. It was concluded that brief refresher training (1.5 to 2.5 hrs) is sufficient for Administrative Specialists to regain typewriting skill. (Revised from document abstract)

11. Hagman, J. D. (1980a). Effects of presentation and test trial training on motor acquisition and retention (Tech. Rep. No. 431). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A086 406)

This experiment examined the relative effects of three different training methods on the acquisition and retention of a positioning motor task. The first group of 15 subjects was given three alternating presentation and test trials. The second group was given five presentation trials followed by a test trial per cycle. The last group had a single presentation trial followed by five test trials. Group acquisition performance was compared at the last trial of each cycle while retention was compared 3 minutes and 24 hours after acquisition. Absolute error scores indicated that acquisition and short-term retention were best when training emphasized presentation and test trial alternation and presentation repetition within cycles. Long-term retention was best when training stressed test trial repetition. These results have suggested that testing is an effective way to enhance long-term retention of motor skills.

12. Hagman, J. D. (1980b). Effects of training task repetition on retention and transfer of maintenance skill (Research Rep No. 1271). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A101 859)

This experiment investigated the effects of task repetitions on the performance of a simple task. Subjects were military fuel and electrical repairmen. The task repetition levels varied from 0 to 4 repetitions of the task. An apparent ceiling of 3 repetitions of the tasks during training was found to enhance both acquisition of the skill and 2-weeks retention of the skill

in task performance. However, the task repetitions did not enhance transfer of the skill to similar equipment. Maintenance task retention improved in terms of both speed and accuracy as the number of task repetitions (up to 3) performed during training increased.

13. Hagman, J. D. (1980c). Effects of training schedule and equipment variety on retention and transfer of maintenance skill (Research Rep. No. 1309). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Science. (AD A120 167)

This experiment examined the effects of training schedule and equipment variety on maintenance task retention and transfer. During training, four groups of 15 student Fuel and Electrical Repairers (63G MOS) performed the task of testing charging system electrical output. Each group performed three task repetitions under one of four training conditions formed by the factorial combination of two training schedules (massed, spaced) and two levels of equipment variety (present, absent). Massed scheduling allowed no rest pauses between successive task repetitions; spaced scheduling allowed one-day rest pauses between repetitions. When equipment variety was present, students performed one repetition on each of the three charging systems. When equipment variety was absent, all three repetitions were performed on the same charging system. The first retention test occurred immediately after training and the second occurred an average of 14 days later. It was concluded that: (a) spacing of task repetitions during training is an effective way to improve both retention and transfer of maintenance skill; and that (b) added transfer improvements can be obtained by coupling spaced task repetitions with increased equipment variety during training.

14. Hagman, J. D. (1980d). Effects of presentation and test trial training on acquisition and retention of movement end-location (Tech. Rep. No. 492). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A100 867)

This research on a linear positioning task examined the effects of presentation and test trial training on acquisition and retention. The retention segment of the experiment consisted of a single test trial performed at both 3 minutes and 24 hours after the 18th trial of acquisition. Long-term retention was better when training emphasized test-trial repetition. Thus, testing proved to be an effective way to improve long-term retention of motor skill. The author concluded that training should emphasize testing more than presentation.

15. Hagman, J. D. (1981). Testing during training: Why does it enhance long-term motor task retention? (Tech. Rep. No. 535). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A120 761)

This study examined the reasons why testing during training is more effective than repeated presentation in promoting long-term motor task retention. Sixty professional and clerical employees of the Army Research Institute performed a linear positioning task consisting of 18 training trials divided into three cycles of six. Cycles included presentation-trials and test-trials. Presentation-trials were experimenter-defined movements terminated by a mechanical stop. Test-trials were learner-defined recall movements unconstrained by the mechanical stop. Training methods varied in their emphasis on presentation or test trials. Results indicated that groups which emphasized testing during training showed no post-training recall error increases. Groups which emphasized presentation showed increases in recall error over the post-training retention interval. Twenty four hours after training the "test" groups exhibited better retention than the "presentation" groups. The author argued that the increased retention due to testing can be attributed to learner-defined, as opposed to experimenter-defined movements and that testing during training benefitted movement distance and end-point cue retention.

16. Hagman, J. D., Hayes, J. F., & Bierwirth, W., (1986). A method for estimating task retention: Research pays off. Army Trainer, 6, 54-55.

This article described and explained the "User's Manual for Predicting Military Task Retention" (Rose, Radtke, Shettle, Hagman, 1985) to the military trainer. It reviewed the three steps (determining a task's retention rating, determining the no-practice interval, and predicting soldier retention performance) in the process of estimating task retention. This method for predicting task retention can be used to assess how quickly specific tasks are forgotten, the percentage of soldiers who can perform a task correctly up to one year of no practice, and how often sustainment training should be conducted.

17. Hall, E. R., Ford, L. H., Whitten, T. C., & Plyant, L. R. (1983). Knowledge retention among graduates of basic electricity and electronic schools (Tech. Rep. No. 149). Orlando, FL: Training Analysis and Evaluation Group, Department of the Navy. (AD A131 855)

This study examined knowledge decay during the interval (about 28 days) between graduation from Basic Electricity and Electronics (BE/E) School and entry into a Construction Electrician (CE) "A" School. The results showed that BE/E knowledge did decay and that the amount of decay was related to student ability

characteristics. The average student lost about 24% of AC theory knowledge and about 6% of DC theory knowledge. In addition, higher ability students exhibited less decay of BE/E information than lower ability students. Decay had no apparent affect on subsequent "A" School achievement.

18. Healy, A. F.; Erickson, K. A.; Bourne, L. E., Jr. (1990). Optimizing the long-term retention of skills: Structural and analytic approaches to skill maintenance (Research Note 90-104). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A226 130)

This research identified the characteristics of knowledge and skill most resistant to decay and disuse. The research was divided into two parts. The first part was concerned with experimental analysis of factors influencing and improving retention of skill components. The second part was concerned with analysis and assessment of the structure of acquired memory and skills and how to monitor differential retention of components. For the analytic approach five methodologies were developed and investigated. Four natural skills were investigated. For the structural approach, an experimental paradigm was designed to assess the detailed encoding of new knowledge at presentation and at delay using verbal report techniques and chronometric measurement of retrieval components. Several studies of retention of vocabulary items were completed. They found evidence for a surprising degree of long-term skill retention. A theoretical framework focusing on the importance of procedural reinstatement was formulated which enabled understanding of the memory performance. (Abstract from ARI bibliography; hard copy not procured)

19. Holmgren, J. E., Hilligoss, R. E., Swezey, R. W., & Eakins, R. C. (1979). Training effectiveness and retention of training extension course (TEC) instruction in the combat arms (Research Rep. No. 1208). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A069 942)

This project examined the training effectiveness and retention of TEC instruction relative to conventional classroom instruction. TEC lessons in five subject areas were evaluated. The five tasks considered were: (a) field artillery--use of the gunner's quadrant; (b) air defense artillery--use of the Target Alert Data Display System (TADDS); (c) armor--M551 tank target engagement simulation; (d) infantry--use of the squad radio; and (e) firing and zeroing the M60 machine gun. The retention intervals used were 8-9-weeks for Active Army soldiers and 7-12 weeks for National Guard soldiers. Results indicated that TEC trained soldiers performed better than conventionally trained soldiers on

the initial and retention tests. Performance declined for both groups across all tasks.

20. Hughes, C. R., Butler, W. G. Sterling, B. S., & Bergland, A. W. (1987). M1 Unit-Conduct of Fire Trainer (TRAC-WSMR-TEA-16-87). White Sands Missile Range, NM: Department of the Army, U. S. Army TRADOC Analysis and Command.

The effect of the Unit-Conduct of Fire Trainer (U-COFT) on retention of live-fire gunnery skills was one of the issues examined in this Post Fielding Training Effectiveness Analysis (PFTEA). Six battalions participated in this experiment. Five received M1 U-COFT nine months prior to the experiment, while the sixth received theirs after the experiment. One month after the research began, all six battalions were tested on a crew qualification exercise (Table VIII). Three months later, a stratified sample of 15 crews from each battalion fired a special Table VIII without firing the pre-qualification tables (VI and VII). The results revealed, for the non-U-COFT trained group, a sharp division between those who were still in Reticle Aim Groups 1-2 and those in Groups 3-6 (at retest). The majority of those who were still in the earlier matrix exercises showed a drop in Table VIII scores, whereas the majority of those who had progressed to Reticle Aim Group 3 and beyond showed gains in Table VIII scores. The authors conclude that exposure to U-COFT does not ensure skill retention and that the crews must make progress in the matrix. (Revised from Morrison et al., 1991; hard copy not procured)

21. Johnson, S. L. (1981). Effect of training device on retention and transfer of a procedural task. Human Factors, 23, 257-272.

This experiment investigated the effectiveness of three different training devices with respect to initial training, retention, and transfer of learning. The training devices evaluated were designed to require varying degrees of visual imagery utilization through reductions in the stimuli that provide visual cueing and feedback. The procedural tasks were comparable to operating an industrial plant's master control panel or an air vehicle. The results indicated that: (a) training devices do not need to have high fidelity in order to train procedural tasks, and (b) training strategies that require trainees to provide their own cueing and feedback from memory lead to increased retention (70 days) of procedure-following skills. (Revised from document abstract)

22. Jones, M. B. (1986). Nonimposed overpractice and skill retention (Research Note No. 86-55). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A168 572)

This project investigated the role of nonimposed overpractice in predicting individual performance in skill retention. Nonimposed means that no external constraint or scoring convention prevents further improvement. Nonimposed overpractice refers to the shape of individual performance curves late in acquisition. Flatter performance curves late in acquisition depict the individual's limits and outcomes of overpractice. Three experiments were performed. In Experiment I, 27 Navy enlisted volunteers practiced each of six video-computer tasks for 15 daily sessions. Retention was measured after 4-6 months for two tasks, after 10-12 months for two tasks, and after 16-18 months for two tasks. It was found, in all three experiments, that nonimposed overpractice improved retention. The more an individual practiced, even though performance in acquisition no longer improved, the better retention was likely to be. In addition, nonimposed overpractice even improved performance among individuals who performed well in acquisition, and would have been expected to perform better than others in retention.

23. Konoske, P. J., & Ellis, J. A. (1987). Cognitive factors in learning and retention of procedural tasks (Tech. Rep. No. 87-14). San Diego, CA: Navy Personnel Research and Development Center.

This project developed a taxonomy of qualitative explanations--linear, structural, and functional--for teaching procedural tasks and tested the effects of these explanations on learning, initial performance, and retention of a procedural assembly task (constructing a model crane). Linear explanations provided student with information about what to do with the system or in the situation. Structural explanations provided information about how and why the system/situation was constructed. Functional explanations provided information about how and why the system/situation worked. Three experiments tested initial learning and retention of the procedural assembly task. The results indicate that the advantages of qualitative explanations depend on the user's prior expertise and familiarity with assembling models.

24. Larson, J. A., Earl, W. K., & Henson, V. A. (1976). Assessment of U. S. tank crew training (TCATA Test Report FM 331). Fort Hood, TX, TRADOC Combined Arms Test Activity.

During a case study of a CONUS battalion, Table VIII gunnery results were obtained at the completion of a formal gunnery training program, a tank degradation test, off-season firing, and

tank gunnery program. Even though many uncontrolled factors were present during this period, the results provided a general assessment of crew gunnery performance at different times in the gunnery season. A significant degradation in off-season gunnery performance was found. Mean first round firing times also showed a degradation during off-season firing, from 11.0 to 19.5 seconds for day firing and from 12.6 to 20.4 seconds for night firing. The battalion experienced a good deal of turbulence during the study period, and it was not possible to determine the degree to which degradation in performance was due to this factor as well as to retention loss. The performance of 7 crews who were intact during the one year time frame was approximately equal to that for crews experiencing turbulence. Thus, it appears that a formal gunnery program improves performance to the same general extent for stable and turbulent crews. (Revised from existing in-house abstract; hard copy not procured)

25. Leonard, R. L., Jr., Wheaton, G. & Cohen, F. P. (1976). Transfer of training and skill retention (Tech. Rep. No. 76-A3). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A036 059)

This experiment examined the retention of training course material in a simulated operational situation and the effect of refresher training on transfer of hand grenade skills over a 17 week period. Subjects were 150 enlisted Army personnel who were divided into six groups. The intervals between training and transfer (0, 6, or 17 weeks) and the intervals between refresher training (6 or 17 weeks) varied across groups. Training was provided by the Training Extension Course (TEC) materials on selection, maintenance, and the use of hand grenades. A "post-training" paper-and-pencil instrument consisting of 75 items was synthesized from the testing materials provided with the TEC lessons to assess retention. The post-test consisted of four subtests: I--Selection of Grenades; II--Maintaining the Hand Grenade; III--Arming the Hand Grenade; and IV--Throwing the Hand Grenade. A fifth subtest involved Identifying Components of a Hand Grenade. After a 6-week delay from initial training, subjects provided with refresher training outperformed those having no refresher training on subtests I and II but not on subtests III and IV. After 17 weeks subjects given refresher training outperformed unrefreshed subjects on subtests I, II, and IV. (Revised from document abstract)

26. MacPherson, D., Patterson, C., & Mirabella, A. (1989). Application of ARI skill retention model to wheel vehicle maintenance tasks (Research Rep. No. 1538). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A219 684)

A Skill Retention Model has been developed which describes forgetting behaviors for technical tasks in terms of the number

of steps in the task and the quality of the job aids. Seven subject-matter experts (SMEs) regarding wheeled vehicle mechanical/instructors examined this model for nine wheel vehicle tasks. The SMEs identified three out of nine tasks that were rapidly forgotten. The authors recommended ways to improve training and calculated the effects of provided training upon students' retention abilities. (Revised from ARI SR-11)

27. McDonald, R. D. (1967) Retention of military skills acquired in basic combat training (Tech. Rep. No. 67-13). Alexandria, VA: Human Resources Research Organization. (AD 663 785) (ED 022 103)

Performance data were collected in the three general Basic Combat Training (BCT) proficiency areas (rifle marksmanship, physical combat fitness, end-of-cycle tests) from independent groups of soldiers (60 per group) during BCT, Advanced Individual Training (AIT), and Combat Support Training (CST). The general military subjects measure was given as a paper-and-pencil test. All other performance measures were tested hands-on. Important findings were that: (a) a significant performance decrement was found for these skills across the year-long retention interval; (b) no significant decrement over the course of one year was evident for physical combat proficiency; and (c) the mean percentage of performance measures passed fell from 86% to 69% over the retention interval.

28. Mengelkoch, R. F., Adams, J. A., & Gainer, C. A. (1971). The forgetting of instrument flying skills. Human Factors, 13, 397-405.

An aircraft simulator was used to assess the forgetting of instrument flying skills. There were 125 discrete procedural items per trial scored on a error/no-error basis. An error was recorded if the item was either omitted, performed incorrectly, or occurred out of place. Twenty-six ROTC male undergraduate students, naive to flying, participated in this study. After a four-hour academic training program and one familiarization trial in the simulator, Group 5 (N=13) received 5 trials during original training, resulting in intermediate proficiency. Group 10 (N=13) received 10 trials during original training, resulting in high proficiency. The main findings were that discrete procedural responses were more susceptible to forgetting than flight control responses (maintaining altitude, bank, airspeed, level-off at altitude, roll-out on new heading). It was also found that the number of trials taken to relearn procedures was less than the number during original training. This finding suggests that flight training programs should focus on retraining procedures.

29. Mirabella, A. (1989). Contributions of the U. S. Army Research Institute to the training technology field activity-Aberdeen (Research Rep. No. 1536). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A214 346)

This report summarized ARI's efforts to develop training guidelines for improved acquisition, retention, and transfer of vehicle maintenance skills. The need for such guidelines came after previous studies showed very high failure rates for the performance of expert and novice mechanics on tasks dealing with diagnostics and removal/replacement of faulty parts. For example, the false removal rate (good parts mistakenly removed) was about 42% of all removals. The results of the Training Technology Field Activity (TTFA) projects summarized included various recommendations to improve the 63W10 course at the Ordinance School. One set of guidelines dealt with producing effective review graphs for classroom instruction. Another set dealt with developing effective instructional principles. (Revised from ARI SR-11)

30. Morgan, B. B., Jr., Lassiter, D. L., & Salas, E. (1989). Networked simulation application for team training and performance research. Proceedings of the Symposium on Interactive Networked Simulation for Training (pp. 16-21). Orlando, FL.

This paper described a research program--its methodology and potential applications--using interactive networked simulation procedures. The authors noted that few studies have investigated how teams acquire, maintain, and lose teamwork skills. In addition, the authors discussed the development of a test-bed for the study of team training and performance and the use of Simulation Networking (SIMNET) as an existing simulation test-bed for studies in this area.

31. Naylor, J. C., & Briggs, G. E. (1961). Long-term retention of learned skills: A review of the literature (Tech. Rep. No. 61-390). Columbus, OH: Ohio State University, Laboratory of Aviation Psychology. (AD 276 043)

This review examined literature relating to flight skill retention. The authors noted that most of the experiments located dealt with verbal, rather than motor skill retention. The main results are that: (a) extra amounts of original learning facilitate retention; (b) complex task performance decays more than simple tasks over longer retention intervals; (c) continuous tasks are retained better than discrete or procedural tasks; (d) task integration or organization may cause the superior retention associated with motor tasks; and (e) rehearsal facilitates skill retention. They concluded that many

of the studies reviewed lacked long enough retention intervals.
(Revised from existing in-house abstract; hard copy not procured)

32. O'Hara, J. M. (1990). The retention of skills acquired through simulator-based training. Ergonomics, 33(9), 1143-1153.

This study examined merchant marine cadets' loss of watchstanding skills (standing on the bridge or deck to verify course steered, position, navigation, collision avoidance, equipment tests, and arrival preparation) across a 9-month retention period following a simulator-based training program developed to enhance these skills. The effects of retraining experience, as it influenced retention decay, were also evaluated. Two groups of merchant marine cadets were tested immediately following the training and again nine months later. One group was given a refresher experience and tested 6 months into the retention interval. The instrument used to measure retention was composed of a series of items describing observable watchstanding behaviors. The results indicated that: (a) watchstanding skills improved following training; (b) these skills declined over the nine month retention interval; and (c) retention decay was partially mitigated by refresher training. (Revised from document abstract)

33. Palmer, R. L., & Buckalew, L. W. (1988). SINCGARS operator performance decay (Research Rep. No. 1501). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A210 716)

This study examined the decay of operational skills and knowledge in two groups of recently trained operators who went without exposure to Single Channel Ground and Airborne Radio (SINCGARS) for several weeks. Performance levels were measured with the SINCGARS Learning-Retention Test (SLRT), a simulated hands-on performance test emphasizing skills and operational knowledge retention. The results indicated that operators might lose about 10 percent of their prior performance levels within the first few weeks. However, this figure varied considerably, depending on the type of soldier, the length of the non-exposure period, and other conditions. It was also found that performance level was correlated with soldiers' Armed Services Vocational Aptitude Battery (ASVAB) General Technical (GT) scores. Correlations between GT and SLRT scores obtained at the different testing times were .43 and .50. A relationship, however, was not found between performance decay and GT. (Revised from ARI SR-11; hard copy not procured)

34. Rose, A. M., Czarnolewski, M. Y., Gragg, F. E., Austin, S. H., Ford, P., Doyle, J., & Hagman, J. D. (1985). Acquisition and retention of soldering skills (Tech. Rep. No. 671). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A160 336)

This research investigated the acquisition and retention of field artillery tasks and the effects of overtraining, previous testing, and soldiers' abilities on this task. It also developed a User's Decision Aid (UDA) based on ratings of task characteristics that estimated retention functions for each task, and assessed the relationship between predicted and obtained retention functions. One hundred and forty five Cannon Crewmen (MOS 13B10) were tested on 26 tasks. Each soldier was trained to proficiency on each task. After performing all tasks correctly, soldiers received mastery training (test-train-retest) for half of the tasks. Of the five tasks, three--Boresight telescope, micrometer test, and sight target--were passed by less than 25% of the soldiers. Soldiers were most accurate on Crew tasks. Performance on Individual tasks varied. Retention tests were administered 2, 5, and 7 months after the acquisition phase. Almost all tasks showed forgetting after two months. After five months all but one task showed considerable forgetting. After seven months soldiers performed better than after five months. The authors noted several confounding factors explaining this last result. The UDA now exists in both paper and pencil and in computer form and has been validated against existing retention data.

35. Rose, A. M., Radtke, P. H., Shettel, H. H., & Hagman, J. D. (1985). User's manual for predicting military task retention (Research Product 85-26). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A163 710)

This manual represents an expanded version of a user's manual (ARI RP 85-13) for estimating proficiency on military tasks over periods of no practice. The method requires that each task be rated on how easy it is to remember. For practical purposes, the method, developed for both paper-and-pencil and computer-based formats, is geared toward helping trainers decide the: (a) tasks that are most likely to be forgotten; (b) number of soldiers that should be able to perform a task correctly after given intervals of no practice; and (c) frequency of sustainment training needed.

36. Schendel, J. D., & Hagman, J. D. (1980). On sustaining procedural skills over prolonged retention intervals (Research Rep. No. 1298). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A120 758)

Task retention (M60 machine gun assembly/disassembly) was examined at two intervals (4 and 8 weeks), and between the overlearning groups and the control (no overtraining) group. The results showed that soldiers forgot as much after four weeks as after eight weeks. The data also indicated that the scores for the two overtrained groups' scores were equivalent to each other and substantially better than the control group's. Hence, retraining after four weeks was equivalent to providing initial overtraining.

37. Schendel, J. D. & Hagman, J. D. (1982). On sustaining procedural skills over a prolonged retention interval. Journal of Applied Psychology, 67, 605-610.

This research assessed three alternative approaches for sustaining procedural skills over a prolonged retention interval. It also sought to determine if soldiers could estimate the amount of refresher training that they needed to regain proficiency. Soldiers (N=38) were assigned to groups according to past experience on the experimental task--disassembly/assembly of the M60 machine gun. The first group was trained to criterion and then given 100% initial overtraining. This group's 8-week retention and retraining performance was compared with a group receiving the same amount of additional training midway through the retention interval. The control group was trained to criterion but received no additional training prior to the retention testing and retraining. Refresher training estimates were collected immediately prior to the retention test. Cost and effectiveness considerations heavily favored the overtraining group. In addition, most soldiers accurately assessed the amount of refresher training they required to regain proficiency. (Revised from document abstract)

38. Schendel, J. D., Morey, J. C., Granier, M. J., & Hall, S. (1983). Use of self-assessment in estimating levels of skill retention (Research Rep. No. 1341). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A141 042)

This research examined self-assessment as one method for predicting task retention and refresher training requirements. Before zeroing their M16A1's for annual rifle qualification, 147 male and 6 female soldiers completed a questionnaire designed to collect information about prior marksmanship experience and perceptions about how they were going to shoot at record fire. The main findings were that subjects' self-assessments were a

poor method for predicting task retention scores as they only predicted approximately 10% of the variance in the retention data. Also, most subjects tended to overestimate the success of their performance.

39. Schmidt, R. A., & Shapiro, D. C. (1988). Optimizing feedback utilization in motor skills training (Research Note No. 88-05). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A191 559)

This project examined the use of feedback [i.e. knowledge of results (KR)] on goal achievement for the maximization of skill learning and retention. Two variations of KR were studied: (a) relative frequency (the proportion of trials receiving KR) and (b) summary (the entire set of trials) KR. In each case, alterations in KR which degraded training performance actually produced enhanced performance on a delayed retention test when KR was not presented. These experiments suggest that enhanced KR in acquisition may generate over reliance by the learner on KR, which would prevent the learner from retaining important features of the task when feedback is removed or degraded (e.g. marksmanship). (Revised from ARI SR-11; hard copy not procured)

40. Schrenk, L. P., Daniels, R. W., & Alden, D. G. (1969). Study of long-term skill retention. NAVTRADEVCEEN 18224, Contract N61330-1822, Honeywell, Inc. (AD A692 770)

This project sought to determine how individual and team skills involved in anti-submarine warfare (ASW) degraded over time and which form of refresher training was most effective. Phase I compared ASW skill retention between teams that had received shore based simulator training either 0, 4, 8, or 16 weeks earlier. Major performance measures were time and number of shots required to hit a target. The main findings of Phase I were that: (a) crew performance markedly degraded over the 16 week period; and (b) initial decrement slowed performance, resulting in subsequent losses in procedural skills. Phase II explored the effect of full-team refresher training. Some groups received part-task refresher training and a control group received no refresher training. All groups were retested after initial training and retested on a parallel form 16 weeks later. It must be noted that Phase I and II of this study were to be conducted on a "non-interfering" basis with standard naval training and operations. This mandate jeopardized the results because of a 35% team member turnover, instructor turnover, teams not receiving refresher training or retention testing at the scheduled times, and instructor/monitor overloads and errors in recording team member responses. The authors concluded that part team training was inferior to control group and full team refresher training, and procedural skills exhibited greatest degradation.

41. Shields, J. L., Goldberg, S. L., & Dressel, J. D. (1979). Retention of basic soldiering skills (Research Rep. No. 1225). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A075 412)

One hundred and eighty-two soldiers were tested on 20 common soldier procedural tasks that included: reporting enemy information, loading and firing grenade launcher, donning gas mask and learning cardiopulmonary resuscitation (CPR). Three hundred and forty-one soldiers were tested on the same tasks after 5 to 12 months in a unit. Retention intervals ranged from 4-12 months following initial basic training for 523 soldiers. The main finding was that soldiers forgot steps not cued by the equipment or by the previous steps, such as those involving safety.

42. Shields, J. L., Joyce, R. P. & Van Wert, J. R. (1979). Chaparral skill retention (Research Rep. No. 1205). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A069 945)

This project evaluated retention of Chaparral skills to determine the most effective schedule of refresher training. Soldiers were tested immediately after Advanced Individual Training (AIT) on several Chaparral tasks (pre-energizing, energizing, and de-energizing the launch station; before-operations performance measure checks on the M730 carrier; installing and operating a field telephone; and performing emplacement and operator checks and adjustments on the target alert data display set), and retested upon arrival in their battalions, and again 4 months later. Comparison groups were tested after one or two-month retention intervals. Results showed that performance generally did not decline. Authors attributed this finding to the use of job aids that helped the soldiers.

43. Singer, R. N., Gerson, R. F., & Ridsdale, S. (1979). The effects of various strategies on the acquisition, retention, and transfer of a serial positioning task (Tech. Rep. No. 399). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A081 995)

This project analyzed the effectiveness of various learner strategies upon initial learning, retention, and transfer of a motor skill. Male and female undergraduates were randomly assigned to one of five strategy conditions: imagery, kinesthetic, labeling, informed-choice, and control. The task, using a curvilinear repositioning apparatus, required participants to replicate six limb movements to predetermined locations. Following the learning trials, subjects were given a retention test and transfer task involving six new positions. Results indicated that "imagers" were more accurate in their

responses than the four other groups. Control subjects were more accurate and less variable than either the kinesthetic, labeling, or informed-choice groups.

44. Singer, R. N., Ridsdale, S., & Korienek, G. G. (1979). The influence of learning strategies in the acquisition, retention, and transfer of a procedural task. (Tech. Rep. No. 408). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A086 405)

This project analyzed and compared the effectiveness of different learning strategies on a sequential procedural task. Subjects were randomly assigned to one of five conditions: imagery, chunking, verbalization, informed-choice, and control. The task required participants to manipulate a sequence of buttons and switches on a computer-managed task apparatus. Results indicated that "imagers" performed better on acquisition and transfer than the chunking, verbalization, or informed-choice groups.

45. Thompson, T. J., Morey, J. C., Smith, S. & Osborne, A. D. (1981). Basic rifle marksmanship skill retention: Implications for retention research (Research Rep. No. 1326). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A134 017)

Three experimental Basic Rifle Marksmanship (BRM) training programs were developed and compared with the current program. All subjects (N=1.151) fired a Record Qualification Course which was the standard training performance exam. All available subjects (N=388) were retested approximately 6 weeks after completion of the BRM. The record fire scores of experimental programs were significantly better than those of the standard program in the initial qualification training.

46. Vineberg, R. (1975). A study of the retention of skills and knowledge acquired in basic training (Tech. Rep. No. 75-10). Alexandria, VA: Human Resources Research Organization.

This study assessed retention of basic combat skills. Thirteen subtests of the Comprehensive Performance Test (CPT) were administered to soldiers during the last week of BCT and again six weeks later during AIT. Results indicated that the probability of the average soldier passing a CPT subtest: (a) at the end of BCT was .81; (b) during retention testing 6 weeks later was .63; and (c) at the end of basic training was .55. Proficiency decreased between 18% to 26%. These decrements in performance varied across subtasks and mental categories. (Revised from in-house abstract; hard copy not procured)

47. Wisher, R. A., & Sabol, M. A. (1990). Predicting decay of Mobile Subscriber Equipment (MSE) operator skills. Proceedings of the 17th Army Science Conference, Durham, NC.

This project described the initial stages in developing a model to predict the decay of complex skills [operation and maintenance of the Mobile Subscriber Equipment (MSE) communication system]. The authors hypothesized that conceptual understanding of a system is the key to retention of skills over extended intervals of non-use. Phase I involved application of current skill prediction techniques (Rose, et al., 1985) to 85 MSE skills. An MSE Knowledge Test was constructed that assessed active and reserve soldier's conceptual understanding of the system. The maximum score of active and reserve soldiers on the MSE test, taken 90 days after formal training, were 73% and 65%, respectively. Results indicated that the Switch Operators (31F) scored higher than the Transmission Operators (31D) on all of the subtests.

Note: Phase one of this study is presented in:

- Sabol, M., Chapell, L., & Meiers, C. (1990). Predicted decay of Mobile Subscriber Equipment (MSE) operator skills (Research Product 90-11). Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences.

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This project investigated the effects of periods of little or no flying on flying skills of Army Aviators. A survey questionnaire was submitted to Army Aviators who had experienced extended periods of flying excusal or proficiency flying status. Fifty-eight usable questionnaires were obtained from aviators with extended flying excusal, and 117 from aviators who had flown the minimum required to retain flying status. The responses provided judgements on losses in visual flying rules (VFR) and instrument flying rules (IFR) skills over varying periods of time and in relation to whether or not proficiency flying was performed. Results indicated that flying minimums slightly reduced the rate and amount of reported skill loss with the effects more pronounced in the IFR than VFR. It was also found that the degree of refresher training required to regain minimal or sufficient skills to be pilot-in-command was a negatively accelerated positive function of the nonflight interval until 16 months where the curve flattened.

Appendix D

Miscellaneous References

The following documents that are not included in the annotated bibliography, but may be of some interest and use to researchers and trainers.

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