N73-10152

# DEGRADATION OF LEARNED SKILLS

A Review and
Annotated Bibliography

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June 1972

Prepared under Contract No. NAS9-10962 by

The Boeing Company
Seattle, Washington

Manned Spacecraft Center
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

# ABSTRACT

This report provides an overview of the literature dealing with the retention of learned skills. Basic effects of task type, training, retention interval, and recall variables are discussed, providing a background against which more recent literature dealing with operational spaceflights tasks is compared and assessed. Detailed and summary abstracts of research reports having particular relevance to the problem of spaceflight skill retention are provided.

# FOREWORD

This report summarizes a literature survey accomplished as one part of a program designed to investigate the degradation of learned skills as applicable to space flight tasks. The literature search, bibliography preparation, and summary review reported here was begun in July 1970 and was completed in February 1971. This effort was conducted for the NASA Manned Spacecraft Center under Contact NAS9-10962 with Mr. Earl LaFevers of the Crew Systems Division as NASA Project Monitor. This effort was transferred to Dr. William E. Fedderson, Chief of the Behavioral Performance Laboratory, Biomedical Laboratories Division who was Project Monitor to completion.

The Boeing Program Manager was Dr. George D. Greer, Jr. and the Principal Investigator was Dr. Thomas E. Sitterley. The authors gratefully acknowledge the kind and generous assistance provided by the personnel of the Boeing Technical Library. Particular gratitude and thanks are due to Mrs. Fred (Louise) Buss who patiently transcribed long hours of recorded annotations and research reviews and typed the many drafts and final copy of this report. Finally, the authors wish to thank Gale M. Rhoades for his assistance in preparing and organizing the data for the Literature Review Cross Index Matrix.

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# 1. INTRODUCTION

The overall trend in manned space flight has been the development of missions of greater duration, complexity, and reliance on the abilities of astronauts to provide manual control intervention in both normal and emergency modes of operation. The past decade has witnessed a dramatic progression from the brief suborbital flight of "Freedom 7," in which the astronaut was largely along for the ride, to the extended lunar landing missions of the Apollo series, in which the astronaut's performance was critical to many mission phases. During this period of ever increasing mission complexity, hardware limitation and the opportunity for equipment failures increased dramatically. The success of many missions and, more than once, the lives of the crew were saved only through the astronauts' skills and thorough training.

During this decade the United States plans to develop spacecraft with even longer and more complex flights. These will include an orbiting Skylab with missions as long as 56 days, in which the astronauts will perform a wide variety of experimental, scientific, and flight control tasks, and the space shuttle, with missions of 30 days and longer. The Space Shuttle will be a significant departure from previous missions, having a greater autonomy from ground-based control and with flight control tasks far more complex than ever before. Future decades will witness space stations with missions of one year or more and manned interplanetary flights with missions of two years and longer.

The greater complexity and duration of these future space explorations, some of which are designed to be autonomous, and others of which will be well beyond the range of effective earth-based control will make astronaut performance all the more critical to overall mission success and safety. However, the benefits of months of continuous training in ground-based simulators prior to launch will no longer be available to maintain the high degree of skill proficiency currently displayed by the astronauts. Moreover, experience indicates that the probability of catastrophic failure is increased substantially if high performance and skill retention is not effectively maintained over long durations of task inactivity.

Effective maintenance of the critical space flight, procedural, and operational skills implies a requirement for a system of on-board refresher training. Depending on a number of parameters including the nature of the astronaut tasks, the time since last task performance, and the degree of task overlearning, the required training system could involve a broad range of configuration complexity. The least complex of which might be nothing more than a review of verbal and pictorial briefing aids similar to those found in current check list and flight operations manuals. A middle level of complexity could involve the utilization of simulation software within the spacecraft computers to operate on-board equipment in a training mode. Beyond this would be the application of more sophisticated combinations of software, computers, and simulation/training hardware to provide high fidelity reproduction of spacecraft system dynamics and the operational visual environment associated with critical mission operations, phases, and maneuvers.

The impact of providing on-board training dictates that training requirements be carefully assessed so that efficient, cost effective systems can be designed. Each increase in the level of on-board training system complexity will be accompanied by corresponding increases in the demands placed upon the limited volumetric space, weight and electrical power capacities available within the spacecraft. The system should provide, therefore, only the specific type, extent, and fidelity of training that will satisfy the goals of mission safety, reliability, and success. System design which is more elaborate or complex than required to satisfy these goals without compromise is not only wasteful of resources, but may also compromise the potential range of mission objectives.

A serious problem facing system designers, then, is the precise specification of the astronaut tasks and skills which are subject to degradation, and the identification of those parameters which can be expected to reduce or modify the nature of performance degradation. Recognition that the forgetting of learned skills can produce major consequences affecting overall successful performance is not new. Both the human performance literature and personal experience confirm that forgetting is basic to human behavior. A literature of skill retention studies has developed over the years. This report is an attempt to provide an overview of that portion of the literature that can be related to the skills and performance required of future astronauts.

## 2. LITERATURE OVERVIEW

### Scope

Skill retention can be affected by a great number of independent variables and conditions. Since an attempt to be all encompassing would rapidly result in a literature search of vast proportions, an effort has been made to limit this review to reports dealing with close to operational conditions. Many relevant works, therefore, may have been omitted. Fortunately, over 60 years of literature concerned with long term retention of skilled performance was reviewed by Naylor and Briggs (1961), who provided both important conclusions and a general organization for variables which had been examined. Their general findings have been summarized here and their work provides a background against which the more recent literature can be compared and assessed. Finally, those areas requiring further work have been identified and the implications of the reported findings have been discussed.

### Background: Naylor and Briggs Review

Naylor and Briggs (1961) classified the potentially important skill retention variables into four sets: 1) task variables, 2) learning variables, 3) retention interval variables, and 4) recall variables.

#### Task Variables

Several of the investigations they reviewed attempted to examine the relationship between discrete (procedural) and continuous (tracking type) tasks. Naylor and Briggs concluded that the research indicated an apparent superiority in skill retention for continuous tasks. However, they point out this finding is somewhat superficial since the initial difficulty and organization of the two tasks was not quantified in any of the experiments reviewed. They argue that task differences along these dimensions could account for differences in retention and recommend that subsequent research efforts give attention to these factors.

## Training Variables

The next set of retention variables involve skill acquisition. In those studies dealing with the amount of initial learning, Naylor and Briggs found a positive relationship between amount of original learning and amount of retention. They also indicate that the effect is a decreasing one with respect to length of retention interval. With retention intervals of sufficient duration, no beneficial effects were observed regardless of amount of training. Although the studies on which this conclusion was based were of the "finger maze and pursuit rotor variety," there seems to be little reason to dispute the generality of the findings.

Another group of studies examined the distribution of practice during training. Naylor and Briggs found inconsistent results in assessing relative effects of massed and distributed practice. Since the reviewed studies employed different amounts of original training, and tasks of different complexities, somewhat conflicting findings were observed. Generally, they indicated that if distribution of practice is a salient variable, its influence is markedly less than either amount of original learning or task complexity. Another area where conflicting evidence was found involved part-task versus whole-task training. Indications favoring whole-task training appeared, but the brief retention intervals made definite conclusions unwarranted.

The reviewers identified transfer effects as another area requiring extensive work. Here, skill retention was examined as a function of general and specific training. Two approaches to skill retention were identified: (1) learning to learn, and (2) learning a specific task. Again, the work reviewed involved only brief retention periods which prevented definite conclusions. The reviewers do say that retention performance on a specific task is apparently best for specific training; general training is superior when the amount of training increases and the task contains an element of uncertainty.

## Retention Interval Variables

The next set of variables reviewed by Naylor and Briggs dealt with conditions existing during the retention interval. The duration of the retention interval was found to be a most influential variable. However, because of large differences in the task retention period, distribution of practice, and amount of original learning, only two very general conclusions were deemed appropriate: (1) large decrements in performance do occur over extended times, and (2) the greatest performance decrement appears on the first retention trial.

The retention interval has also been studied from the standpoint of interpolated activity, e.g., rehearsal task learning and positive transfer effects arising from covert verbal behavior as well as imaginary (totally cognitive) practice. These studies all showed that the retention of perceptual-motor skills over extended periods of time are significantly enhanced by covert or cognitive activities not involving physical practice of the skill. Overt practice of the motor skill was found superior to other forms of practice. Additionally, the greater the similarity of the practice conditions to the test conditions, the greater the benefits of practice.

## Recall Variables

The number of variables potentially important during recall was found to be large. They included the recall measures to be used, the environmental setting of the recall conditions, warmup, mental set, and the effects of various transfer variables. The reviewers general conclusions were: (1) that the selection of the dependent variable can markedly affect the degree of skill retention in evidence. Consequently, care should be taken to select only those dependent variables which have significance in the operational situation; (2) the degree of fidelity of the retention test environment, with the learning environment, positively influences retention; and (3) warmup activity is beneficial to observed retention. The authors concluded their review by indicating three needs to be met by future investigations:

(1) To reduce the number of potentially influential variables and to determine some ranking of importance for them.

(2) To investigate the importance of task organization (i.e., amount of uncertainty inherent in the task).

(3) To clarify the relationship between measures on initial retention test trials and savings measures; both relative and absolute scoring methods as well as difference measures within methods produce apparent inconsistencies in results. Naylor and Briggs point out the relationship of each over extended retention periods must be known before successful comparative analysis between studies can be made.

## Recent Literature

### Objectives

More recently, many investigations have been undertaken to delineate the effects of several variables on skill retention. The purposes have been to examine effects of type and amount of training, task organization and equipment parameters, rehearsal, and secondary task interference. The general objective for all of these studies was to determine the shape of retention decrement function. The number of potentially influential variables has remained large just as the number of problems cited above suggests. However, there are two variables which appear to enjoy consensus relative to their strong influence on skill retention; these are amount of original training and the length of the retention interval.

To simplify the task of determining a general skill retention function, a simple expedient has been employed. Tasks have been dichotomized into continuous (e.g., tracking) and procedural (discrete, sequential) tasks. The earlier literature (see Naylor and Briggs, 1961) indicated that continuous tasks are retained best. The reason for this finding is not entirely clear. The notion that there are two "kinds" of tasks is without foundation. The primary difference between tasks requiring discrete and continuous responses is largely a question of organization. Typically, the procedural task has less spatial or temporal organization than does a tracking task. A suggestion by Naylor and Briggs that task organization be investigated was acted upon by Noble and his associates in a series of studies (see Trumbo et al, 1965; Swink et al, 1967; Noble et al, 1967). Their findings indicated that the idea of a task dichotomy can be rejected.

Other investigators have examined task conditions, rather than categories, e.g., time sharing conditions (Naylor, 1963), secondary task effects ( Trumbo et al, 1967; Naylor et al, 1968). Some have involved highly specific task conditions, e.g., flying skills (Menglekoch et al, 1960), Apollo vehicle tasks (Grodsky, 1965; Cotterman & Wood, 1967), and combat skills (McDonald, 1967). These studies sought to determine the shape of the retention decrement function for only a certain set of conditions. Performance predictions based on these types of studies can be highly successful when applied to appropriate situations, but few findings can be expected which may be generalized to other applied settings.

The diversity of the problems attacked in the skill retention literature is indicative of the level of organizational development within the field. There is little chance that a retention function can be detailed completely in the near future than when Naylor and Briggs presented their literature review. While the work subsequent to that review may not have produced clearcut relationships, some general trends have developed and effective procedures for further investigation have been developed. These findings will be set forth in the following material dealing with methods and results.

Methods

The tasks utilized in perceptual motor skill retention studies can be classed in one of three categories: (1) simulation tasks, (2) tasks involving essential elements, and (3) abstract tasks only peripherally relevant to operational settings. The last category is descriptive of the majority of studies reviewed by Naylor and Briggs (1961). In these studies devices such as the pursuit rotor or finger maze are representative of the tasks typically used. In the later literature, few tasks of this type are reported. The few abstract tasks which were found employed equipment such as the star discriminator (Macek et al, 1965;

Duncan & Underwood, 1953); a ball throwing task (Grose, 1967; Stebbing, 1968); a balancing board (Roehrig, 1964). In general, studies which employed abstract tasks were concerned with determining a general relationship of some independent variables on retention performance.

In contrast are those investigations which sought to determine the effect of an independent variable on the retention of a highly specific task. Several recent investigations can be classed as simulation tasks. When the tasks of interest are significant and unique enough, simulation capabilities can be effectively employed. Increased electronic computer sophistication has permitted system simulations of high fidelity to be performed. A recent simulation involved training activity during a mock seven-day (real time) space mission (Grodsky and Lutman, 1965; Grodsky et al, 1965; Grodsky et al, 1966; Grodsky and Glazer, 1967). One simulation device, the Link Trainer, was employed in an investigation of the retention of certain instrument flying skills (Mengelkock et al, 1960). Grimsley (1969 a, 1969 b) employed part of the equipment used in the Nike Hercules Guided Missile System, necessary for the completion of a 92-step procedural task, in an effort to determine the effects of the fidelity of equipment used during training on the retention of operational skills. A frequent condition of these studies is that few subjects are used (Grodsky et al, 1965; Macek et al, 1965). The paucity of subjects is a natural derivative of the time and dollar costs which arise in the use of full scale simulation. Moreover, few subjects, other than those involved in the operational task, have adequate background to permit them to perform at representative levels.

The majority of the studies reviewed can be classed in the second category. These studies were undertaken by investigators who desired to have subjects perform tasks which were directly relevant to operational tasks, but were not identical with them. Typically, some major aspect of an applied task was isolated and examined without reference to the total operational concept. Consequently, data are generated which have relevance to elements in other operational tasks. Examples of experimental tasks which have been utilized and which capture essential elements of operational tasks are frequently seen in the area of compensatory or pursuit tracking activities (Fleischman & Parker, 1962; Hammerton, 1963; Melton, 1964; Naylor et al, 1962; Naylor & Reed, 1962; Swink et al, 1967; Trumbo et al, 1965; Trumbo et al, 1967; and Youngling et al, 1968).

Procedural tasks have also received investigative attention and can also be classed in the second category above. A procedural task is typically composed of familiar elements, e.g., switches, knobs, pushbuttons, etc. The sequence of required responses can be varied by the investigator to permit various levels of organization and difficulty. Thus, the task can be designed to include completely random sequences or sequences which have a logical, systemmatic pattern.

Early studies tended to use arbitrary (random) performance sequences (Neumann & Ammons, 1957; Ammons et al, 1958) which are not representative of operational tasks. However, in more recent studies (after the publication of the Naylor and Briggs literature review) the organizational aspect of procedural tasks began to receive attention. Several investigations have been performed which involved procedural tasks having face validity with some aspect of an operational task (Naylor et al, 1962; 1963; 1968; Trumbo et al, 1965).

Continuous tasks have been investigated by means of two types of displays. In one type, a CRT displayed a target and a cursor. The subjects' task was to either null the target motion or pursue it. The second display type used meters with moving pointers. Typically, three or more meters were displayed, and were represented as displaying vehicle attitude or rate information. The subjects were instructed to either acquire certain values on the meters, or position the pointers into a designated null region by means of appropriate control movements.

One source of methodological difficulty arises in many tracking investigations where a sine wave forcing function has been applied to either a meter or a CRT as a central component of the display information. It has been found that in tasks using sinesoidal motion, test subjects proficiency can become so great that error scores are rendered meaningless. Relative task difficulty has also been identified as extending the methodological difficulty in sine wave tracking tasks (Hornby & Wilson, 1964). Since task difficulty level is not explicit in final acquisition scores (typically used as a measure of initial training), Hornby & Wilson have suggested that the rate of decrease of error scores is positively related to task difficulty. Further, they have cautioned that the effects of other independent variables could be masked by differences in task difficulty. While they do not address themselves to skill retention specifically, it is clear that differences in task difficulty may be important in the prediction of skill retention, and can be expected to lead to different levels of skill retention. For example, Trumbo, Noble and their associates have frequently used a uni-dimensional tracking task; Briggs and Naylor and their associates have used both two and three dimensional tracking tasks; Hammerton (1963) used a complex three dimensional, second order tracking task. Clearly, conclusions from these studies may be confounded as a result of failing to first assess relative task difficulty and its effect on the levels of skill achieved by subjects for the various tasks.

A second source of methodological difficulty arises when attempts are made to generalize from the published data. The difficulty is really twofold: the first occurs when generalization is attempted between studies to form general skill retention concepts; the second is seen when attempts are made to generalize within a single study or a set of studies to an operational situation. In both cases, it is necessary to utilize data which was produced by a specific subject population. The majority of studies reviewed used undergraduate university students since a generally consistent subject population is essential in drawing conclusions between studies involving non-subject variables. However, not all investigations utilized subjects from the same populations; for example, Hammerton (1963) and Roehrig (1964) utilized their male and female colleagues; Lavery (1964) employed housewives aged 21 to 35 years, and Grimsley (1969a, 1969b) used enlisted military men. When attempts are made to generalize from the investigations to operational situations, the representativeness of the experimental subjects to the real world performers is largely unknown. The data arising from university undergraduates are not necessarily unrepresentative of real world performance, but no comparative studies were found which related the degree of correlation between the experimental subjects and their real world counterparts.

A third methodological difficulty arises in the domain of performance measures. The cited literature frequently discusses skill retention in global terms. Frequently, the research problem is stated as the effects of some independent variable on "skill retention." Implicit in this statement is that the "skilled performance" has been measured or characterized by one or two dependent variables. Performance can be viewed along several dimensions and each of these may be measurable in more than one way. Performance dimensions utilized in the skill retention literature may be classified as belonging to one or two aspects of performance: spatial accuracy or timeliness. It is clear that data regarding the retention of skill performance in one of these categories is not necessarily related to the retention of skilled performance in the other category. The distinction between temporal and spatial performance was utilized to determine both the effects of task organization on skill retention (Trumbo et al, 1965), and the effects of types of rehearsal on skill retention (Naylor and Briggs, 1963). It was found that these two indicants of performance responded differentially to the independent variables.

Just as more than one dimension is required to describe performance more than one measure can be applied to each dimension. The notion has been the source of considerable discussion in the skill retention literature (Bahrick, 1964, 1965; Bilodeau, 1965; Underwood, 1965). These discussions have pointed out that arithmetic means are usually the statistic applied to skill retention data. The suggestion has been made that a great deal of insight could be gained by employing measures of variability and correlation. Since the value of a mean can remain constant while variability increases, it is possible that more sensitive measures of retention decrements could be devised. Subsequently, the development of appropriate rehearsal schedules designed to maintain performance above critical levels could be expected (e.g., a critical level might be specified along a temporal and an accuracy dimension with values stated in terms of both a mean and a variance for each dimension). None of the experiments reviewed used variance as a measure of skill.

Skill retention performance can also be examined from absolute or relative reference points. When an absolute measure is used, comparisons in skill retention are made between groups of subjects which have been systematically exposed to the independent variable(s) and whose performance is measured in absolute units, e.g., seconds of elapsed time, number of errors, magnitude of error in inches, time on target, etc. Comparisons between groups can also be achieved through the use of difference scores. A difference score is obtained by subtracting retention test performance scores from final acquisition scores. By themselves, difference scores insufficiently describe skill retention (even when the difference is expressed relatively as a percentage of the final acquisition score). Individual, absolute measures are usually reported as well as difference scores in the literature. Relative difference and absolute scores, collectively, permit the evaluation of skill retention to be based both on the level of performance on the initial retention trial, and on the degree or amount of loss during the no-practice interval.

An unique approach to performance measurement was provided in analysis of a skill retention investigation (Cotterman and Wood, 1967). Criteria were established for one to four parameters for each of several astronaut tasks. Performance was measured in terms of each parameter and, by assuming a normal distribution, these measures were transformed into "z" scores which in turn were interpreted as probabilities of successful performance. The use of probabilities for the prediction of skill retention can be useful in answering questions which deal with the degree of confidence that may be invested in the success of a particular mission, mission phase or individual task. Probability measures may be of value in identifying areas where remedial efforts are required, but they are of little value in determining the source of performance deficiencies. The use of probability values as a performance measure replaces a large amount of information about several performance dimensions with a single number. It appears that a probability measure technique is suitable as a final indicant of performance within the context of systems analysis, but is too global for use in initial skill retention analysis.

## Results

The experimental results which follow are presented as the effects of a number of independent variables. In view of the foregoing remarks, the following skill retention results should be interpreted in the light of that aspect of performance which was measured. Maintaining this distinction reduces many apparent inconsistencies and contradictions in the data.

Amount of Training. The amount of training has been found to be a most influential variable in skill retention. Several investigations have been carried out examining the effects of the amount of training and unanimously found that skill retention varied directly with amount of training (Trumbo et al, 1965; Naylor et al, 1968; Hammerton, 1963; Ammons et al, 1958; Naylor et al, 1962; Mengelkoch et al, 1967). All but one of the studies which examine the effects of amount of training used a tracking task. Two of the tracking investigations used temporal indicants of performance: elapsed time per trial for a compensatory tracking task (Ammons et al, 1958), and time to acquire the target in a pursuit tracking task (Hammerton, 1963). The remaining studies used an integrated error score which expresses absolute spatial displacement across trials. Essentially, these studies show that both final acquisition performance and initial retention performance vary positively with the amount of training.

The effect of amount of training on the magnitude of the retention loss has also received attention for both procedural (Ammons et al, 1958) and compensatory tracking tasks (Mengelkoch et al, 1960; Youngling et al, 1968). It was found that the absolute loss in performance using both spatial accuracy and temporal measures was not differentially affected by the amount of training. However, if retention loss is examined as a proportion of the performance level at the end of training it is seen that the lesser trained subjects suffer the greater retention decrement. This result necessarily follows from the fact that lesser trained subjects have lower final training scores. Thus, the absolute performance decrement, while equal to that suffered by subjects receiving more training, represents a larger portion of acquired skill for lesser trained subjects.

It was also found that retention decrements were much greater for procedural tasks than for tracking tasks. The finding that no difference in absolute skill loss occurs as a function of training over retention intervals up to two years (Ammons, 1958) reinforces the notion that final performance level is an excellent predictor of skill retention.

The training variable has been examined in another, qualitatively different way. The type rather than the amount of training has been examined (Fleischman and Parker, 1962; Swink et al, 1967). As in the case of amount of training, it was found that the higher the level of performance at the completion of training the higher was initial retention test performance. Therefore, it may be concluded that the type of training which produces the highest level of performance will also produce the best initial retention test performance.

Duration of Retention Interval. The duration of the retention interval has considerable validity as an influential variable. The durations which have been studied range from two years to less than one minute. The majority of the work investigating retention interval duration utilized tracking tasks (Ammons et al, 1958); Fleischman and Parker, 1962; Melton, 1964; Naylor et al, 1962; Naylor et al, 1968; Swink, 1967; Trumbo et al, 1965; Youngling et al, 1968). Unsurprisingly, the general finding is that the longer the retention interval the greater the skill loss and, consequently, the lower the absolute level of initial retention test performance. The amount of the retention decrement appears to be highly task specific and additionally is sensitive to other parameters which have been found to influence performance. The influence of additional factors can modify the effects of retention interval length. A two year retention interval has been found to produce a range of results, from no noticeable decrement (Fleishman and Parker, 1962) to a significant loss in performance (Ammons et al, 1958). In all cases, further retraining trials resulted in rapid improvement in skill levels. Test subjects typically reacquired their final training levels with the number of retraining trials fewer than 50 percent of the original training trials. In some cases, recovery is so rapid that as much as 75 percent of the retention loss can be regained in the first five minutes of retraining (Ammons et al, 1958). Recovery from retention loss is generally slower, the greater the retention interval, the more difficult the task, or the higher the original training level. Little retention loss is found in tracking tasks for retention intervals of one week or less. However, one day and one week intervals have produced statistically significant decrement in tracking performance (Melton, 1964). A retention increment in skill was in evidence for a 5 minute retention interval (Melton, 1964). This finding would seem to indicate that a type of distributed warm-up activity can meliorate retention test performance levels.

An examination of temporal measures of pursuit tracking (lead times and lag times) and integrated error scores (spatial accuracy) showed that the proportional loss within these two performance indices was substantially greater for the temporal measure (Trumbo et al, 1965). However, all measures evidenced a loss of performance proficiency with increasing retention interval lengths.

A few investigations of the effects of the length of the no-practice interval on procedural task performance have been conducted (Ammons et al, 1958; Naylor et al, 1962; Naylor et al, 1968; Neumann and Ammons, 1957). Using both elapsed time and accuracy (number correct or number of errors), it was found that increasing decrements in proficiency occurred as retention interval durations increased. Commissive errors rather than omissive errors were the more sensitive measure of a performance decrement on both absolute and difference scores. Greater sensitivity was found for measures which showed performance decrements for retention intervals as short as one minute to 24 hours. Furthermore, the time required to retrain subjects to their final training levels of procedural tasks is much greater than that required for continuous tracking tasks, after equivalent no-practice intervals.

Practice has been frequently considered as a possible procedure which might effectively mitigate the retention interval decrement. Investigative attempts dealing with practice and the retention of skill have been confined largely to the type of practice rather than amount or schedules of practice. The relative effect of whole-task, part-task and no-practice conditions have been explored for both tracking and procedural tasks. The effects of practice under tracking task conditions for retention intervals ranging from one week to one month are equivocal. Generally, some form of practice leads to superior retention test performance when compared with no practice conditions, but differences between practice groups were not significant, however (Brown et al, 1963; Naylor et al, 1963). Statistical significance of the differential effects of various types of practice was detected, depending on the performance measure chosen. When difference scores are employed, significance was found (Naylor et al, 1963). When absolute integrated error scores were employed no significant difference as a function of practice type was found (Trumbo et al, 1965).

Under procedural task conditions, commissive error data appears the most sensitive to practice techniques. Part-task practice was found to produce fewer errors than whole-task practice or no-practice (Naylor et al, 1963; Naylor and Briggs, 1963). Part-task practice appears to be effective when the temporal aspects of the task are practiced. However, it is ineffective if it is directed toward emphasizing the sequential aspects of the task or involves practicing a simplified version of the operational task. Some of the data suggest that with brief training periods, whole-task practice is best; with intermediate amounts of training, part-task practice appears superior; with extensive training, little difference between types of practice are found (Naylor et al, 1963). When the retention interval is increased from a week (as in the latter study) to two weeks, whole-task practice appears superior to other types of practice.

The conclusion that part-task practice is best was founded on an experiment involving both a procedural task and a tracking task on a time-shared basis. It should be noted that in that study part-task practice involved each of the two subtasks (procedural and tracking) on a sequential basis. Thus, the one aspect of the task which was not practiced, was the temporal factor of attending first to one task and then the other. In this case, the superiority of part-task practice in both the tracking and the procedural tasks may have been an artifact of labels. It appears that whole task practice is best when it refers to only a single task and part-task practice is best if it refers to whole-practice of one task within a context of time-shared tasks.

A task involving a unique motor response to each of several stimulus lights (the star discriminator apparatus) showed that the relevancy of the practice to the operational task was an important determiner of the skill retention decrement, viz. the greater the relevancy, the smaller the initial retention decrement. When the task was increased in complexity by the addition of more lights (thus requiring more responses), it was found that the effect of relevancy was still greater. Warm-up immediately before retention test resulted in better performance than no warm-up, but interim practice led to best performance (Macek et al, 1965). Since this study did not use other types of practice as rehearsal conditions, and since the star discriminator task is without much real world validity, generalization from the results is especially difficult.

Generally, the effects of rehearsal or warm-up are to mitigate the skill loss usually associated with the no-practice interval. Furthermore, the practice of a complete task rather than part of a task leads to superior performance even when these tasks are imbedded in an overall multi-task context. The importance of practice increases with the duration of the retention interval. Procedural tasks rather than tracking tasks appear to benefit the most from interim practice. The temporal aspects of the task can be beneficially practiced, but interim practice of spatial accuracy leads to little or no retention test improvement over no-practice.

Task Organization. Task organization was a variable identified by Naylor and Briggs (1961) as requiring considerable investigative attention. Several efforts have been made to determine the relationship between the level of task organization and subsequent retention of task performance skills over retention intervals of varying duration (Melton 1964; Naylor et al, 1962; Naylor et al, 1968; Swink et al, 1967; and Trumbo et al, 1967). These studies explored the level of task organization in a variety of ways: randomness of target motion, sequential randomness in procedures, and the location of the target. It was found that the effect of task organization was contingent upon the degree of training; lesser trained subjects had better retention if they performed on a procedural task with high organization (systematic occurrences stimulus events ) (Naylor et al, 1962). In a later study, procedural task retention performance was seen to be more proficient under low organization conditions when measured in terms of number of omissive errors. When commissive errors and response times were used, significant differences were not in evidence as a function of task organization (Naylor et al, 1968).

In a pursuit tracking task, it was found that the greater the predictability of the target location, the greater the amount of retention (Swink et al, 1967). Although initial retention test performance was superior for the subjects under the most predictable task conditions, the decrement occurring over the no-practice interval was also greater for these groups as measured both in integrated errors, and lead and lag frequencies in the pursuit task (Trumbo et al, 1967). The frequency of leads diminished and the frequency of lags increased during the no-practice interval for all groups, but subjects under the most predictable task conditions suffered the greatest decrement. Further efforts have been directed toward more operationally oriented task conditions.

Many of the investigations cited in the literature are concerned with a single task. Operationally, it is frequently found that human operators must handle at least two tasks concurrently. Some studies employed both a primary tracking task and a secondary procedural or verbal response task. It was found that the interference effects of the secondary task produced significant decrements in initial retention test performance on the primary tracking task; it was also found that the level of organization in the secondary task, was positively related to the retention test tracking performance level (Naylor et al, 1968; Trumbo et al, 1967). When difference scores of integrated errors are used as a performance measure, integrated error on a tracking task, no significant effects were found (Naylor et al, 1962; Naylor et al, 1968). These somewhat discrepant results can be resolved if the level of performance on the final acquisition trial is considered. It was seen that the subjects who trained under low organizational conditions produced significantly greater error. Thus, final acquisition performance is lower for subjects who trained under low organizational conditions, but the amount of performance decrement suffered during the no-practice interval remains constant. Again, as with other variables discussed above, the key factor in predicting skill retention for a given no-practice interval appears to be the final level of skill acquisition. Other variables were seen only to modify this level. Initial retention performance was affected by altering final training performance level rather than affecting the amount of skill loss during the no-practice interval. In one investigation in which the relative degrees of influence that amount of training and retention interval length were compared with degree of randomness of target motion (a level of organization) corroborates this conclusion. A maximum retention interval of one week was used. At a level of training which did not permit asymptotic training levels, no observable effects attributable to degree of randomness of target motion were found (Melton, 1964). Thus, the effect of organizational level on skill retention was to modify only slightly the skill levels established by the other two major variables.

Task Environment. The task environment has received considerable attention in the most recent literature. Factors such as display-control relationships, degree of fidelity in training devices, display specificity, augmented feedback and visual noise have been investigated. The effects of equipment fidelity showed that even an artist's reproduction of procedural task equipment was adequate to train subjects to a level of proficiency indistinguishable from that of subjects trained on operational equipment. Performance on a retention test after four weeks of no-practice was also undifferentiable for groups trained on equipment of different levels of fidelity (Grimsley, 1969 a, b).

The fidelity of training conditions with initial retention test condition has been examined for a tracking task. Interestingly, the results of this investigation showed that retention test performance was superior for subjects who had performed least well during training. One of the conditions operating during training was that one group of subjects trained under visual noise conditions while the other group of subjects did not. However, during retention testing visual noise was present in the displays for all subjects. Analysis of performance for both accuracy and timeliness indicated that those subjects who had experienced a noise condition earlier, performed significantly better than those who had not experienced the noise condition (but who had evidenced a higher level of performance on an apparently simpler task ) (Buckout et al, 1963).

Equipment characteristics have also been examined relative to skill retention. The effects of both display-control relationships and display specificity on skill retention in tracking tasks have been investigated. It was seen that display-control arrangements having relationships opposite to those usually encountered produced significantly poorer terminal training performance and significantly greater number of errors after no-practice intervals of one day or one week (Melton, 1964). The effects of display specificity (display specificity involved the use of transparent overlays on a CRT permitting several levels of target location cueing) was seen to be effective only during the initial stages of training (Trumbo et al, 1965) with final training performance equivalent between groups trained with different levels of display specificity. Retention testing failed to show significant differences between specificity levels.

Thus, equipment design does make a difference in skill performance. These differences may be produced during skill acquisition, and if present, can hasten training or increase the levels of proficiency attained during training. If retention test conditions are similar to training conditions differential skill loss as a function of equipment parameters is not to be expected. Again, as seen earlier, the final training level of performance appears to be the best predictor of initial retention proficiency. Equipment parameters are seen as modifying training effectiveness but not differentially affecting performance decrements occurring during no-practice intervals.

## Discussion

It seems clear that the literature has identified the level of performance on the final training period as the primary predictor of skill retention for any given retention interval duration. Inexplicably little attention has been given to the identification of those characteristics of individuals who achieve high performance. It would seem a reasonable hypothesis that individuals who either produce high levels of performance or train rapidly, or both, would perform at higher levels after a no-practice interval than individuals who do not exhibit those performance characteristics.

Some work along these lines has been performed by investigators in the course of skill retention study. A correlational analysis was performed on final training scores and initial retention test scores. The correlation ranged from .80 to .98 showing that very little change within experimental groups had occurred as a function of the no-practice interval (Fleischman and Parker, 1962). In another study utilizing a pursuit tracking task, poorest and best subjects were identified on the basis of retention test performance scores. The source of the difference between the scores was attributed to the temporal aspects of the task rather than a performance decrement in spatial accuracy aspects (Trumbo et al, 1965). When comparisons were made on the final training performance levels between these two groups of subjects no significant difference was found. The absence of significance during training may be a function of the selection procedure of the best and poorest subjects resulting in unequal representation of the other variables being investigated. It is clear that further work needs to be done in the area.

Additional performance measures employed during training may reveal differences between subjects on performance dimensions not usually considered relevant to the task. Because of the apparent breakdown in the retention of temporal skills, performance measures which emphasize this aspect of the task may be particularly helpful in predicting skill retention proficiency. A systematic investigation of individual differences would permit the assessment of the degree of influence of this variable. In addition, such a determination should aid in establishing the representativeness of subject populations frequently reported in the literature to populations found in operational settings.

Another area which may profit from future work, relative to skill retention, is performance measurement. The need for a broader approach to performance measurement has been stated previously. Response consistency was seen as an important aspect of both training and skill retention but has not been utilized as an independent variable in skill retention studies. A multi-dimensional approach to performance measurement should include several measures of temporal skill. Some literature suggests that skill acquisition in the temporal domain is the last aspect to be acquired during training and the first to be lost during the no-practice interval. Further work should establish the relationship of temporal measures to both tracking and procedural tasks. If the acquisition and retention of temporal aspects of skill performance is as tenuous as suggested, then performance measures designed to assess skill in this area should prove particularly sensitive to changes in proficiency. Sensitive performance measurement would be one way to detect proficiency changes so that a schedule of rehearsal could be established on grounds of objective need.

Skill retention remains to be examined under environmental or psychological stress conditions. In the context of space missions the performance of tasks which are known to affect the success of the mission, or the safety of the crew members, can be expected to have a stressful effect on the task performer. Stress is known to have enabling as well as disabling effects on performance depending upon intensity. Environmental stresses such as heat, noise, vibration, electrical shock (actual or potential), etc., have been shown to produce effects on performance. Since some element of stress can be expected to exist during the performance of a critical task, its effect on skill retention requires investigation.

Further difficulties arise when the utilization of retention data is attempted in the operational situation. Most of the tasks from which the literature derives its data are artificial. Investigators have attempted to forumlate the tasks so that they were representative of operational requirements. To date no comparative work between the complex operational tasks and the more simplified tasks found in the skill retention literature, has been reported. Full scale task simulation of operational situations yield the greatest confidence in the relevancy of the data, but such efforts can become prohibitive for economic reasons. Therefore, the identification of the essential elements necessary to be incorporated into simplified tasks has very practical implications for future work. The establishment of a relationship between simplified laboratory tasks and real world ones would permit the reliable and valid prediction of human performance in a wide variety of situations without the necessity of simulating each one individually.

A second advantage to be derived from the identification of essential task elements will be seen in the areas of training and rehearsal. During initial training special emphasis can be directed to those areas that have been identified as critical to the successful performance of the task. Additionally, attention could be given to minimum rehearsal requirements to produce substantial long-term savings in equipment, time and money.

Benefits to be derived during training lie in the identification of critical performance dimensions. Training which is designed to emphasize the acquisition of skill on critical dimensions can be expected to enhance the performance level at the termination of training. In the past, the performance measures which have been employed can be described as global, tending to render a single number or pair of numbers as an index of performance level. Under conditions which permit little performance variability, such as extended spaceflights, gross performance measures may be inadequate to indicate the needs for additional amounts of training, specialized training, or critical periods for appropriate rehearsal.

## 3. CROSS INDEX MATRIX

In order to provide a rapid comparison of some of the research covered by this review, relevant research parameters have been summarized for each of the reports abstracted in detail in the following section. A matrix of these parameters, along with study numbers cross-indexed to the bibliography at the end of this report, is depicted in Table I.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

## Table 1: CROSS INDEX MATRIX OF DETAILED ABSTRACTS

| RETENTION INTERVAL | STUDY NUMBER (FROM BIBLIOGRAPHY) | NUMBER OF SUBJECTS IN STUDY | TRAINING CONDITIONS: AMOUNT OF TRAINING | TRAINING CONDITIONS: TRAINING CRITERIA | TRAINING CONDITIONS: TASK TYPE | TRAINING CONDITIONS: TASK DESCRIPTION | TRAINING CONDITIONS: UNUSUAL PROCEDURES | RETENTION INTERVAL CONDITION: TYPE OF INTERPOLATED ACTIVITY | RETENTION INTERVAL CONDITION: AMOUNT OF INTERPOLATED ACTIVITY | TEST PROCEDURES AND RESULTS: FINDINGS | TEST PROCEDURES AND RESULTS: AMOUNT OF RETRAINING | TEST PROCEDURES AND RESULTS: LEVEL OF RETRAINING | TEST PROCEDURES AND RESULTS: CONFORMITY TO TRAINING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 MIN THRU 2 DAYS | | | | | | | | | | | | | |
| 1 MIN<br>1 DAY | 8<br>EXP 1 | 538 | 5 TRIALS, 30 TRIALS<br>1 SESSION | NA | CP | MANIPULATE ASSORTED CONTROLS FIXED SEQUENCE | | NONE | | SIGNIFICANTLY LESS TIME REQUIRED FOR LONGER TRAINED SUBJECT RETENTION INTERVAL EFFECT NOT SIGNIFICANT | 10 TRIALS | NR | IDENTICAL |
| 1 DAY | 8<br>EXP 2 | 465 | 1 HR & 8 HRS<br>1 TO 12 DAYS | NA | CP | CONTROL MODEL AIRPLANE ATTITUDE | | NONE | | SIGNIFICANTLY LESS TIME REQUIRED FOR LONGER TRAINED SUBJECT. (8 HR TRAINING NO EFFECT 1 HR TRAINING DECREMENT) | 2 HOURS | NR | IDENTICAL |
| 5 MIN<br>1 DAY | 68 | 330 | 20 TRIALS | NA | CP | SINGLE DIMENSION CRT TRACKING | | NONE | | SIGNIFICANT DECREMENT AFTER ONE DAY ON FIRST RETENTION TRIAL ONLY | 50 TRIALS | NR | IDENTICAL |
| 1 MIN<br>20 MIN<br>2 DAYS | 81 | 100 | | 2 SUCCESSIVE ERRORLESS TRIALS | I | OPERATE TOGGLE SWITCH IN SEQUENCE | | NONE | | 20 MIN AND 2 DAY RETENTION INTERVAL DECREMENT<br>TIME TO RELEARN POSITIVELY RELATED TO RETENTION INTERVAL LENGTH/ | 57 TRIALS AVG | TRAINING CRITERION | IDENTICAL |
| 3 DAYS THRU 3 DAYS | | | | | | | | | | | | | |
| 1 WEEK | 68 | 336 | 20 TRIALS | NA | CP | SINGLE DIMENSION CRT TRACKING | | NONE | | SIGNIFICANT DECREMENT ON FIRST RETENTION TRIAL ONLY | 50 TRIALS | NR | IDENTICAL |
| 1 WEEK | 78 | 128 | 2 WEEKS & 3 WEEKS | NA | P<br>CC | SEQUENTIAL BUTTON PRESSING<br>ATTITUDE CONTROL | | NONE<br>NONE | | LONGEST TRAINING BEST PERFORMANCE IN RESPONSE TIME<br>LONGEST TRAINING BEST PERFORMANCE | NONE | RETENTION TEST ONLY | IDENTICAL |
| 1 WEEK | 79 | 128 | 2 WEEKS & 3 WEEKS IN 10 15 SESSIONS | NA | P<br>CC | SEQUENTIAL BUTTON PRESSING<br>ATTITUDE CONTROL | | NONE<br>NONE | | DECREMENT COMMISSIVE ERRORS NO EFFECTS OTHER MEASURES<br>NO SIGNIFICANT DECREMENT | NONE | RETENTION TEST ONLY | IDENTICAL |
| 1 WEEK | 106 | 250 | 57 TRIALS, 107 TRIALS UP TO 5 SESSIONS | NA | CP | SINGLE DIMENSION CRT TRACKING | | NONE | | GREATEST TRAINING BEST PERFORMANCE RETENTION DECREMENT FOUND, PREDICTABILITY OF TARGET SEQUENCE SIGNIFICANT EFFECT | 15 TRIALS | NR | IDENTICAL |
| 1 WEEK | 108<br>EXP 1 | 54 | 15 40 60 TRIALS UP TO 3 SESSIONS | NA | CP | SINGLE DIMENSION CRT TRACKING | | NONE | | TASK PREDICTABILITY SIGNIFICANT EFFECT RETENTION INTERVAL DECREMENT SECONDARY TASK EFFECT SIGNIFICANT | 25 TRIALS | NR | IDENTICAL ON PRIMARY TASK CHANGES ON SECONDARY TASK |
| 1 WEEK | 108<br>EXP 2 | 48 | 15 55 TRIALS UP TO 3 SESSIONS | NA | CP | SINGLE DIMENSION CRT TRACKING | | NONE | | GREATER TRAINING FEWER ERRORS LARGE RETENTION DECREMENT SECONDARY TASK SIGNIFICANT EFFECT | 20 RETENTION TRIALS | NR | PRIMARY TASK IDENTICAL, SECONDARY TASK ASSIGNED |
| 2 WEEKS THRU 5 WEEKS | | | | | | | | | | | | | |
| 1 MONTH | 8<br>EXP 1 | 538 | 5 TRIALS, 30 TRIALS | NA | P | MANIPULATE ASSORTED CONTROLS FIXED SEQUENCE | | NONE | | 5 TRIAL TRAINED 53% LOSS OVER RETENTION INTERVAL<br>30 TRIAL TRAINED 23% LOSS OVER RETENTION INTERVAL | 10 TRIALS | NR | IDENTICAL |
| 1 MONTH | 8<br>EXP 2 | 465 | 1 HR, 8 HR | NA | CP | CONTROL MODEL AIRPLANE ATTITUDE | | NONE | | LONGER TRAINED GROUP BEST RETENTION, NO DECREMENT<br>1 HR TRAINING GROUP DECREMENT 1ST 15 MIN OF RETRAINING | 2 HOURS | NR | IDENTICAL |
| 14 DAYS<br>37 DAYS | 20 | 126 | 65 TRIALS OVER 8 SESSIONS | NA | P<br>CC | PANEL PUSHBUTTONS AND<br>NULL ERROR ON THREE METERS | | 1) SIMPLIFIED<br>2) OPERATIONAL<br>3) NO REHEARSAL | 50 TRIALS IN 4 SESSIONS 18 DAYS AFTER TRAINING | 1 REHEARSAL SUPERIOR TO NO REHEARSAL FOR TRACKING TASK NO DIFFERENCE BETWEEN TYPES OF REHEARSAL<br>2 PROCEDURAL TASK REHEARSAL TYPE SIGNIFICANT<br>3 OPERATIONAL REHEARSAL LEAST ERRORS | 10 TRIALS | NR | IDENTICAL |
| 1 MONTH | 21 | 142 | 1 28 TRIALS IN 4 SESSIONS<br>2 108 TRIALS IN 12 SESSIONS IN 3 WEEKS | NA | CC | NULL ERROR ON THREE METERS | | NONE | | 1 3WK TRAINING GREATEST RETENTION MOST EFFICIENT<br>2 VISUAL NOISE SIGNIFICANT DECREMENT | 4 TRIALS | NR | 1 VISUAL NOISE TRAINED VISUAL NOISE TESTED<br>2 TRAINED, VISUAL NOISE ABSENT TESTED VISUAL NOISE PRESENT |
| 1 MONTH | 33 | 2 GRPS | 1) 357 TRIALS OVER 6 WKS<br>2) 357 TRIALS OVER 6 WKS WITH CRITIQUES AND ASSISTANCE | NA | CC | PILOTING REQUIREMENTS OF A RADAR INTERCEPT MISSION | DATA OBTAINED FROM EARLIER WORKS | NONE | | 1) NO RETENTION INTERVAL DECREMENT<br>2) RETENTION PERFORMANCE CORRELATED WITH TRAINING PERFORMANCE<br>3) TYPE OF TRAINING NO EFFECT | 1) 4 SESSIONS CONTINUOUS<br>2) 4 SESSIONS DISTRIBUTED<br>3) 1 WK LATER ALL SET SESSION | NR | IDENTICAL TASK |
| 1 MONTH | 41 | 60 | 3 HRS OR CRITERION | 1 ERRORLESS TRAIL OR 3 HOURS | P | 92 STEP SEQUENCE ON NIKE HERCULES EQUIPMENT | | NONE | | 1) 16 RETENTION INTERVAL DECREMENT<br>2) SIMULATION FIDELITY NO EFFECT | NA | TO 90% CORRECT | IDENTICAL TASK |
| 1 MONTH | 42 | 123 | NA | 1 ERROR FREE TRIAL | P | 92 STEP SEQUENCE ON NIKE HERCULES EQUIPMENT | | NONE | | 1) EQUIPMENT FIDELITY NO EFFECT<br>2) REFAMILIARIZATION PROCEDURES SIGNIFICANT EFFECT<br>3) SIGNIFICANT RETENTION INTERVAL DECREMENT | NA | 1 ERRORLESS TRIAL | IDENTICAL TASK |
| 2 WEEKS | 66<br>PHASE II | 4 | 16 TRIALS IN 1 SESSION | NA | NP | ASTRONAUT STAR—SIGHTING | 3 VARIABLES<br>4 SUBJECTS | NONE | | 1) RETENTION INTERVAL INCONCLUSIVE RESULTS EXPERIENCED S BEST PERFORMER AND IMPROVED MOST RAPIDLY<br>2) PRACTICE IMMEDIATELY BEFORE TEST MODIFIES EFFECT OF EXPERIENCE | 4 TRIALS<br>6 TRIALS | NA | IDENTICAL OR NEW |
| 30 DAYS | 75 | 68 | 45 TRIALS OVER 5 SESSIONS | NA | P | PANEL PUSHBUTTONS AND LIGHTS | | PRACTICE<br>1) IDENTICAL TO TRAINING<br>2) SPATIAL<br>3) TEMPORAL | 45 TRIALS IN 5 SESSIONS 10 DAYS AFTER TRAINING | 1) INTERPOLATED PRACTICE EFFECTS IDENTICAL CONDITION TEST<br>2) COMMISSIVE ERRORS REDUCED BY INTERIM PRACTICE | 5 TRIALS | NR | IDENTICAL |
| 2 WEEKS | 76<br>EXP 1 | 50 | 4 DAYS PART TASK THEN 4 DAYS WHOLE TASK | NA | P<br>CC | PANEL PUSHBUTTONS AND LIGHTS<br>NULL ERROR ON 3 METERS | | PRACTICE<br>1) WHOLE TASK<br>2) PART TASK<br>3) SIMPLIFIED TASK<br>4) NO PRACTICE | 2 DAYS PRACTICE, 6 DAYS AFTER TRAINING | 1) TRACKING TASK INTERIM PRACTICE HAD NO PRACTICAL EFFECT<br>2) PROCEDURAL TASK INTERIM PRACTICE SIGNIFICANT FOR COMMISSIVE ERRORS AND RESPONSE TIME<br>3) GREATEST SKILL LOSS IN NO REHEARSAL GROUP | 1 SESSION | NR | IDENTICAL WITH FINAL TRAINING |
| 2 WEEKS | 76<br>EXP 2 | 84 | 1) 2 DAYS PART TASK THEN 3 DAYS WHOLE TASK<br>2) 2 DAYS PART TASK THEN 8 DAYS WHOLE TASK | NA | P<br>CC | PANEL PUSHBUTTONS AND LIGHTS<br>NULL ERROR ON 3 METERS | | PRACTICE<br>1) WHOLE TASK<br>2) PART TASK<br>3) NO PRACTICE | 2 DAYS PRACTICE 10 DAYS AFTER TRAINING | 1) TRACKING TASK SIGNIFICANT INTERIM PRACTICE EFFECTS SIGNIFICANT TRAINING EFFECT<br>2) PROCEDURAL TASK INTERIM PRACTICE NOT SIGNIFICANT FOR 5 DAY TRAINED S, TRAINING EFFECT SIGNIFICANT FOR COMMISSIVE ERRORS | 1 SESSION | NR | IDENTICAL WITH LAST TRAINING SESSION |
| 4 WEEKS | 78 | 128 | 2 WEEKS<br>3 WEEKS | NA | P<br>CC | PANEL PUSHBUTTONS AND LIGHTS<br>NULL ERROR ON 3 METERS | | NONE | | 1) 3 WEEK TRAINED S, BEST PERFORMANCE<br>2) RETENTION INTERVAL EFFECT SIGNIFICANT DECREMENT | 4 TRIALS IN 1 SESSION | NR | IDENTICAL |
| 4 WEEKS | 79 | 128 | 2 WEEKS AND 3 WEEKS IN 10 15 SESSIONS | NA | P<br>CC | SEQUENTIAL PUSHBUTTON PRESSING<br>ATTITUDE CONTROL | | NONE | | 1) SIGNIFICANT DECREMENT AS A FUNCTION OF RETENTION INTERVAL | NONE | RETENTION TEST ONLY | IDENTICAL |
| 1 MONTH | 106 | 250 | 1) 57 TRIALS<br>2) 107 TRIALS UP TO 5 SESSIONS | NA | CP | SINGLE DIMENSION CRT TRACKING | | NONE | | 1) RETENTION INTERVAL EFFECT DECREMENT | 15 TRIALS | NR | IDENTICAL |
| 31 DAYS | 107 | 120 | 115 TRIALS OVER 5 SESSIONS | NA | CP | SINGLE DIMENSION CRT TRACKING | | VERBAL REHEARSAL | 1 ERROR FREE REPETITION + 15 REPETITIONS | 1) RETENTION INTERVAL EFFECT LARGE AND SIGNIFICANT<br>2) VERBAL REHEARSAL NO EFFECT<br>3) VERBAL PRETRAINING SMALL SIGNIFICANT INCREMENT<br>4) DISPLAY SPECIFICITY SIGNIFICANT | 20 TRIALS | NR | IDENTICAL |
| 30 DAYS<br>(90 AND 200) | 115 | 32<br>196 TOTAL | 1) 60 TRIALS<br>2) 120 TRIALS | NA | CC | IMAGE MOTION COMPENSATION 2 AXIS PENCIL STICK CONTROLLER | | NONE | | 1) SOME DEGRADATION<br>2) LESS DEGRADATION WITH OVERTRAINING<br>3) MORE DEGRADATION WITH GREATER TASK DIFFICULTY<br>4) REACQUISITION FOR 30 DAY GROUP BETTER THAN 200 DAY GROUP | 25 TRIALS | NR | IDENTICAL |
| 6 WKS THRU 3 MOS | | | | | | | | | | | | | |
| 8 WEEKS<br>13 WEEKS | 23 | 12 | 6 WEEKS | SUCCESSFUL TASK SEQUENCE | AS | ASTRONAUT PILOTING TASKS | SIMULATION OF OPERATIONAL FLIGHT | NONE | | 1) RETENTION INTERVAL EFFECT - DECREMENT<br>2) OBSERVATION OF TASK PERFORMANCE BENEFICIAL EFFECT | 8 – 28 TRIALS LASTING 13 14 HOURS | NA | IDENTICAL BUT IN FAST TIME |

KEY

- AP AIRCRAFT PILOTING
- AS APOLLO SIMULATION
- CC CONTINUOUS COMPENSATORY TRACKING
- CP CONTINUOUS PURSUIT TRACKING
- NA NOT APPLICABLE
- NP NAVIGATIONAL OR PERCEPTUAL TYPE TASK
- NR NO REQUIREMENT
- P PROCEDURAL
- PS PROBLEM SOLVING TASK

Table 1: (CONTINUED) CROSS INDEX MATRIX OF DETAILED ABSTRACTS

| RETENTION INTERVAL | STUDY NUMBER (FROM BIBLIOGRAPHY) | TRAINING CONDITIONS: NUMBER OF SUBJECTS IN STUDY | TRAINING CONDITIONS: AMOUNT OF TRAINING | TRAINING CONDITIONS: TRAINING CRITERIA | TRAINING CONDITIONS: TASK TYPE | TRAINING CONDITIONS: TASK DESCRIPTION | TRAINING CONDITIONS: UNUSUAL PROCEDURES | RETENTION INTERVAL CONDITION: TYPE OF INTERPOLATED ACTIVITY | RETENTION INTERVAL CONDITION: AMOUNT OF INTERPOLATED ACTIVITY | TEST PROCEDURES AND RESULTS: FINDINGS | TEST PROCEDURES AND RESULTS: AMOUNT OF RETRAINING | TEST PROCEDURES AND RESULTS: LEVEL OF RETRAINING | TEST PROCEDURES AND RESULTS: CONFORMITY TO TRAINING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 WEEKS + 2 WEEKS<br>6 WEEKS | 42 | 123 | NA | 1 ERROR FREE TRIAL | P | 82 STEP SEQUENCE ON NIKE HERCULES EQUIPMENT | | NONE | | 1) RETENTION INTERVAL EFFECT SIGNIFICANT DECREMENT FROM TRAINING LEVEL; SIGNIFICANT DIFFERENCE BETWEEN INTERVALS<br>2) KNOWLEDGE OF FUTURE TEST OCCURRENCE NO EFFECT | NA | 1 ERROR FREE TRIAL | IDENTICAL TASK |
| 6 WEEKS | 66 PHASE I EXP NO 1 | 104 | 30 TRIALS IN 1 SESSION | NA | P | 6 SLOT STAR DISCRIMETER | UNIQUE PERFORMANCE MEASURE | ANALOG PRACTICE | WEEKLY PRACTICE SESSIONS | INITIAL RETENTION TEST DIFFERENTIAL ANALOG EFFECT FOR ADJUSTED SCORES AND ERRORS | 15 TRIALS IN 1 SESSION | NA | IDENTICAL |
| 6 WEEKS | 66 PHASE I EXP NO 2 | 104 | 30 TRIALS IN 1 SESSION | NA | P | 12 SLOT STAR DISCRIMETER | UNIQUE PERFORMANCE MEASURE | ANALOG PRACTICE | WEEKLY PRACTICE SESSIONS | 1) INITIAL RETENTION TEST DIFFERENTIAL ANALOG EFFECT FOR ADJUSTED SCORES AND ERRORS<br>2) DIFFERENTIAL PRACTICE EFFECT OBSERVED DURING INITIAL RETRAINING | 15 TRIALS IN 1 SESSION | NA | IDENTICAL |
| 6 WEEKS | 66 PHASE I EXP NO 3 | 104 | 30 TRIALS IN 1 SESSION | NA | P | 6 SLOT STAR DISCRIMETER | UNIQUE PERFORMANCE MEASURE | ANALOG PRACTICE IMMEDIATELY BEFORE TEST | PRACTICE SESSIONS | INCONCLUSIVE | 15 TRIALS IN 1 SESSION | NA | IDENTICAL |
| 7 WEEKS | 81 | 100 | | 2 SUCCESSIVE ERROR FREE TRIALS | P | OPERATE TOGGLE SWITCHES IN SEQUENCE | | NONE | | 1) RETENTION INTERVAL DECREMENT<br>2) GREATER RETRAINING REQUIRED THAN FOR SHORTER RETENTION INTERVALS | | TRAINING CRITERION | IDENTICAL |
| 3 MONTHS | 104 | 120 | 1) 100 TRIALS OVER 5 DAYS<br>2) EQUAL REPETITIONS | NA | CP | SINGLE DIMENSION CRT TRACKING | | NONE | | 1) PERFORMANCE IMPROVEMENT RESULTING FROM RETENTION INTERVAL (AUTHORS DISCREDIT FINDINGS)<br>2) SIGNIFICANT EFFECTS — SEQUENCE LENGTHS AND TASK PREDICTABILITY | 40 TRIALS IN 1 SESSION | NA | IDENTICAL |
| 30 DAYS<br>60 DAYS<br>(230) | 115 | 64<br>(96 TOTAL) | 1 60 TRIALS<br>2 120 TRIALS | NA | CC | IMAGE MOTION COMPENSATION — 2 AXIS PENCIL STICK CONTROLLER | | NONE | | 1) GREATER DEGRADATION AT 90 DAYS<br>2) LESS DEGRADATION WITH OVERTRAINING<br>3) RETENTION BETTER FOR MORE DIFFICULT TASK LEVELS | 25 TRIALS | NR | IDENTICAL |
| 4 MOS THRU 6 MOS<br>6 MONTHS | 8 EXP NO 1 | 538 | 5 TRIALS, 30 TRIALS OVER 1 SESSION | NA | P | MANIPULATE ASSORTED CONTROLS FIXED SEQUENCE | | NONE | | RETENTION INTERVAL — DECREMENT IN PERFORMANCE | 10 TRIALS | NR | IDENTICAL |
| 6 MONTHS | 8 EXP NO 2 | 465 | 1 HR, 8 HR UP TO 12 DAYS | NA | CP | CONTROL MODEL AIRPLANE ATTITUDE | | NONE | | 1) RETENTION INTERVAL — DECREMENT IN PERFORMANCE<br>2) LONGER TRAINED Ss PERFORMANCE ALWAYS SUPERIOR | 2 HOURS | NR | IDENTICAL |
| 5 MONTHS | 33 | 7 GROUPS | 1) 357 TRIALS OVER 6 WKS<br>2) 357 TRIALS OVER 6 WKS WITH E CRITIQUES AND ASSISTANCE | NA | CC | PILOTING REQUIREMENTS OF A RADAR INTERCEPT MISSION USING 5 OSCILLOGRAPHS | DATA OBTAINED FROM EARLIER WORK | NONE | | 1) NO PERFORMANCE DECREMENT<br>2) TYPE OF TRAINING — NO EFFECT | 1) 4 SESSIONS CONTINUOUS<br>2) 4 SESSIONS DISTRIBUTED<br>3) 1 WK LATER ALL Ss 1 SESSION | NR | IDENTICAL |
| 26 WEEKS | 48 | 18 | 5 TRIALS PER DAY UNTIL CRITERION | 1) 3 SUCCESSIVE SESSIONS LESS THAN 12 SECS NOT DIFFERING AT 5% LEVEL<br>2) AS ABOVE EXCEPT 1% LEVEL USED | CP | SECOND ORDER PURSUIT TRACKING OF CRT TARGET | | NONE | | 1) RETENTION INTERVAL EFFECT PERFORMANCE DECREMENT<br>2) RETRAINING TO CRITERION REQUIRED 1/2 LENGTH OF TRAINING<br>3) LONGEST TRAINED Ss BEST TEST PERFORMANCE | NA | TO TRAINING CRITERION | IDENTICAL |
| 4 MONTHS | 70 | 26 | 1) 5 DAYS<br>2) 10 DAYS | NA | AP | INSTRUMENT FLYING IN LINK TRAINER | | NONE | | 1) PROCEDURAL TASKS SIGNIFICANT RETENTION LOSS. LESSER TRAINED Ss SIGNIFICANTLY POORER PERFORMERS ON STATIC TASKS<br>2) TRACKING TASK SIGNIFICANT DECREMENT IN ALT BANK AND AIR SPEED | NA | TO TRAINING CRITERION | IDENTICAL |
| 5 MONTHS | 105 | 250 | 1) 57 TRIALS<br>2) 107 TRIALS UP TO 5 SESSIONS | NA | CP | SINGLE DIMENSION CRT TRACKING | | NONE | | 1) SIGNIFICANT RETENTION INTERVAL DECREMENT LARGE LOSS IN LEAD TIME PROFICIENCY | 15 TRIALS | NR | IDENTICAL |
| 30 DAYS<br>90 DAYS<br>200 DAYS | 115 | 96 | 1) 60 TRIALS<br>2) 120 TRIALS | NA | CC | IMAGE MOTION COMPENSATION 2 AXIS PENCIL STICK CONTROLLER | | NONE | | 1) APPROXIMATE LINEAR INCREASE IN DEGRADATION WITH LONGER INTERVALS<br>2) LESS DEGRADATION WITH OVERTRAINING<br>3) RETENTION BETTER FOR MORE DIFFICULT TASK LEVELS<br>4) REACQUISITION OF SKILLS FASTER FOR 30 AND 90 DAYS GROUPS | 25 TRIALS | NR | IDENTICAL |
| 7 MOS THRU 1 YEAR<br>1 YEAR | 8 EXP NO 1 | 538 | 5 TRIALS, 30 TRIALS OVER 1 SESSION | NA | P | MANIPULATE ASSORTED CONTROLS FIXED SEQUENCE | | NONE | | RETENTION INTERVAL EFFECT DECREMENT | 15 TRIALS | NR | IDENTICAL |
| 1 YEAR | 8 EXP NO 2 | 465 | 1 HR, 8 HR UP TO 12 DAYS | NA | CP | CONTROL MODEL AIRPLANE ATTITUDE | | NONE | | INITIAL RETENTION TEST 50-60% TIME ON TARGET | 2 HOURS | NR | IDENTICAL |
| 9 MONTHS | 33 | 7 GROUPS | 1) 357 TRIALS OVER 6 WKS<br>2) 357 TRIALS OVER 6 WKS WITH E CRITIQUES ASSISTANCE | NA | CC | PILOTING REQUIREMENTS OF A RADAR INTERCEPT MISSION USING 3 OSCILLOGRAPHS | DATA OBTAINED FROM EARLIER STUDIES | NONE | | RETENTION INTERVAL EFFECTS DECREMENTS FOR Ss NOT RECEIVING E AID ONLY | 1) 4 SESSIONS CONTINUOUS<br>2) 4 SESSIONS DISTRIBUTED<br>3) 1 WK LATER ALL Ss 1 SESSION | NR | IDENTICAL |
| 1 YEAR | 81 | 100 | NA | 2 SUCCESSIVE ERROR FREE TRIALS | P | OPERATE TOGGLE SWITCHES IN SEQUENCE | | NONE | | 1) SIGNIFICANT RETENTION INTERVAL DECREMENT<br>2) GREATEST NUMBER OF RETRAINING TRIALS | 57 TRIALS AVG | TRAINING CRITERION | IDENTICAL |
| 13 MOS THRU 2 YRS<br>2 YEARS | 8 EXP NO 1 | 538 | 5 TRIALS 30 TRIALS OVER 1 SESSION | NA | P | MANIPULATE ASSORTED CONTROLS FIXED SEQUENCE | | NONE | | 1) LESSER TRAINED Ss RETENTION TEST TIME 3 TIMES FINAL TRAINING TIME<br>2) LONGER TRAINED Ss RETENTION TEST TIME OVER TWICE FINAL TRAINING | 15 TRIALS | NR | IDENTICAL |
| 2 YEARS | 8 EXP NO 2 | 465 | 1 HOUR, 8 HRS UP TO 12 A DAYS | NA | CP | CONTROL MODEL AIRPLANE ATTITUDE | | NONE | | 1) RETENTION TEST SIGNIFICANT DECREMENT<br>2) LONGER TRAINED Ss RETRAINING PERFORMANCE IMPROVEMENT NOTED FOR UP TO 48 MIN | 2 HOURS | NR | IDENTICAL |
| 14 MONTHS<br>24 MONTHS | 33 | 7 GROUPS | 1) 357 TRIALS OVER 6 WKS<br>2) 357 TRIALS OVER 6 WKS WITH E CRITIQUES & ASSISTANCE | NA | CC | PILOTING REQUIREMENTS OF A RADAR INTERCEPT MISSION USING 3 OSCILLOGRAPHS | DATA OBTAINED FROM EARLIER STUDIES | NONE | | 1) RETENTION INTERVAL EFFECT LARGE INITIAL DECREMENT AT 24 MONTHS FOR E UNAIDED Ss<br>2) NO RETENTION INTERVAL EFFECT FOR E AIDED Ss | 1) 4 SESSIONS CONTINUOUS<br>2) 4 SESSIONS DISTRIBUTED<br>3) 1 WK LATER ALL Ss 1 SESSION | NR | IDENTICAL |

KEY

AP AIRCRAFT PILOTING
AS APOLLO SIMULATION
CC CONTINUOUS COMPENSATORY TRACKING
CP CONTINUOUS PURSUIT TRACKING
NA NOT APPLICABLE
NP NAVIGATIONAL OR PERCEPTUAL TYPE TASK
NR NO REQUIREMENT
P PROCEDURAL
PS PROBLEM SOLVING TASK

# 4. SELECTED ABSTRACTS

## Approach

During the course of the literature search, a number of research reports were identified as having particular relevance to the problem of the retention of learned skills. While the selection of these works was somewhat arbitrary due to the availability of the documents and the bias of the authors, it was believed that all provided information which deserved more than passing mention in the overview section. Each of these reports had one or more of the following characteristics in common:

1) investigation of operational or near operational flight tasks,

2) use of test subjects which were closely representative of the pilot or astronaut population,

3) parametric evaluation of the factors affecting skill retention or degradation,

4) particularly complete experimental or theoretical evaluation of skill retention research methodology, technique, problems, and interpretations,

5) integrative review or assessment of the variables affecting the retention of skilled performance.

Detailed abstracts were prepared for 21 of the selected reports and short summaries were prepared or obtained for the remaining 25 reports. Differences in the magnitude of the abstracts should not be construed as indicating differences in quality or significance of the reports. Short summary abstracts were prepared for those significant reports of primarily a theoretical, supportive, or review nature. In addition, where reports of similar content or coverage were obtained, the first acquired was often given preference for detailed abstracting due to time constraints.

## Detailed Abstracts

To facilitate the location and cross referencing of the detailed abstracts with the Bibliography and Cross Index Matrix (Table I), a list of the detailed abstracts is provided in Table II. The following outline is representative of the form used to draft the detailed abstracts.

Author(s), Title, and Source

PURPOSE

METHOD

Subjects:

Equipment:

Procedure:

Independent Variable(s)

Dependent Variable(s)

RESULTS

CONCLUSIONS

REVIEWER'S COMMENT

Table II. Detailed Abstract List

Ammons, R. B.; Farr, R. P.; Bloch, Edith; Neumann, Eva; Day, Mukul; Marion, Ralph; Ammons, C. H.. Long-Term Retention of Perceptual-Motor Skills, J. of Exp. Psychol., 1958, 55, 318-328.

## Experiment 1

### PURPOSE

To examine the effects of different amounts of initial training and no-practice intervals upon retention of a procedural perceptual-motor skill.

### METHOD

Subjects:
538 unpaid male university students from various college departments, courses and living groups were used.

Equipment:
17 control units (e.g., light switch, toggle switch, automobile turn indicator, rotary switch, doorbell buzzer and a sliding door latch) were mounted on a vertical panel and so arranged to permit easy access by a seated S. A schematic chart was hung on the panel indicating the correct sequence. A large red signal light was mounted at the top center of the panel and remained on as long as the sequence was being correctly performed by S.

Procedure:
Each S was trained in one of three sequences. Each sequence contained 15 of the 17 control units. A trial consisted of S manipulating control units as indicated on the schematic chart until the sequence was complete. In the event of a manipulative or sequential error, the red signal light went out and the S was required to turn it on and correct his error and complete the sequence as rapidly as possible. A 2 x 6 factorial design was utilized.

Independent Variables:

1. Degree of learning
   a. 5 trials
   b. 30 trials
2. No-Practice Intervals
   a. one minute
   b. one day
   c. one month
   d. 6 months
   e. 1 year
   f. 2 years

### RESULTS

The data were derived from matched groups. The procedure used to match groups of subjects was such that Ss who were extreme in mean or variance relative to their own group were eliminated. The discard technique tended to bring mean or variance of the group more nearly to those values attained by other groups.

A. <u>Effects of Amount of Training</u> -
Task completion time was reduced during the first five trials from a mean time of 1.75 minutes to approximately .04 minutes. Mean completion time after 30 training trials were reduced to 0.2+ minutes. After a no-practice interval, mean performance time rose by approximately an amount equivalent for each of the two training conditions. The mean number of retraining trials required to reach the final training performance level was 3.2 for the 5 trial group and mean performance time for the 5 trial group across all no-practice intervals was 0.372 minutes; for the 30 trial group the mean performance time was 0.203 minutes.

B. <u>Effects of No-Practice Interval</u> -
The effects of the length of the no-practice interval was similar for Ss trained under the 5 trial condition or the 30 trial condition. A 2 year no-practice interval for 5 trial group gave rise to performance time of 1.294 minutes as contrasted with 0.406 minutes for the same subjects at their last training trial. For 30 trial trained subjects, mean performance time was 0.4866 minutes as contrasted with 0.202 minutes for the last training trial. No-practice intervals of 1 minute and 24 hours do produce absolute decrements of very small magnitude. As the no-practice interval lengthens, the decrement increases.

C. <u>Percent Performance Loss</u> -
The number of trials required to relearn the task to the originally trained performance level was found to be significantly influenced by both the amount of training and duration of the no-practice interval in the expected directions.

CONCLUSIONS

A. The greater both the amount of original training and the duration of the no-practice interval, the more retraining trials are required to regain the performance level achieved before the occurrence of the no-practice interval.

B. Proportionally fewer trials are required by subjects having a greater training period to achieve former acquisition performance levels.

C. When both, less practice and greater durations of the no-practice interval, are given the lower the absolute performance level immediately following the no-practice interval.

## Experiment 2

PURPOSE

To determine the effects of amount of practice and the duration of the no-practice interval on the performance of a compensatory pursuit task.

METHOD

Subjects:
465 male university students were paid to participate.

Equipment:
A model airplane was mounted on a shaft above a box; a cam and pulley arrangement caused the aircraft to bank, climb and turn before the seated Ss. Compensatory pedal and stick controls were also incorporated into the apparatus.

Procedure:
Ss were instructed to compensate for movement of the aircraft model by the use of hand and foot controls to maintain the airplane in level straight ahead flight. This condition was verified by the illumination of a small red light. Individual trials lasted about one minute. Ss received differential training and were given retention tests at various intervals (see below).

Independent Variables:

1. Degree of training
   a. one hour
   b. 8 hours

2. Duration of no-practice interval
   a. one day
   b. one month
   c. six months
   d. one year
   e. two years

Dependent Variable:

Time on target

RESULTS

A. Effects of Practice -
During the first 15 minutes of training Ss were on target about 40% of the time. After one hour, 70% performance was achieved; and after 8 hours, Ss were on target 90% of the time. After a two year no-practice period, retention loss for the one hour trained group was about the same as the 8 hour trained group. The level of performance for the 8 hour group remained superior to the one hour group at every no-practice interval duration. The difference in percent time on target between the two training groups for the first retraining trial was approximately 10% while on

the last retraining trial this difference was reduced to 2% with most practiced group performing best.

B. Effects of Duration of No-Practice Interval -
The initial performance for the one hour trained group after no-practice intervals of either one or two years is between 50 and 60% time on target. Improvement continued throughout one hour of retraining. For the 8 hour trained group, performance for all no-practice intervals appears to have stabilized after the first 5 minutes of retraining; however, very slight gains were still realized for the two year no-practice interval as long as 48 minutes after beginning retraining. The amount of skill retention was a negative function of the length of the no-practice interval.

CONCLUSIONS

A. The longer the no-practice interval, the greater the loss in performance at the start of retraining.

B. The greater the amount of practice, the more retraining trials will be required to attain the performance set during the final training trials.

C. Proficiency is reinstated very rapidly with as much as 75% of the loss regained in the first 5 minutes of retraining.

D. The absolute loss in performance is the same irrespective of amount of training, but the proportional loss is greater for the one hour trained group.

E. Greater skill loss occurs on procedural than on tracking tasks as a function of duration of the no-practice interval.

REVIEWER'S COMMENT

1. The above two experiments appear to have been carefully run investigations. It is important to note that the tasks used contained a large motor element and a relatively small cognitive aspect. Attempts to generalize these tasks to space systems tasks should take this factor into account.

2. Some Ss groups having shorter no-practice intervals evidenced a performance increment on initial retention test.

Brown, D. R., Briggs, G. E., and Naylor, J. C. The Retention of Discrete and Continuous Tasks as a Function of Interim Practice with Modified Task Requirements. Technical Documentary Report, AMRL-TDR-63-35, Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio, May 1963. (Clearing House Assession No. AD 408 780)

PURPOSE

To examine the effects of simplified, operational, and no-rehearsal conditions on the retention of procedural and tracking task skills.

METHOD

Subjects:
126 naive male undergraduates volunteered to serve as paid participants.

Equipment:
For the procedural task a display-control panel consisting of 9 pairs of lights and 3 pushbuttons associated with each light pair was used. The light pairs consisted of a red and amber light. The three pushbuttons associated with the light pairs were labelled "emergency," "O.K.", and "check", respectively.

A three-dimensional display-control device was utilized for the tracking task. This device consisted of three center-null-position meters. Each indicating one of three types of attitude error. The device simulated a vehicle in free flights and input rates of 0.025 Hertz and 0.050 Hertz were used. A three-dimensional control stick was provided for Ss responses. The three-dimensions of attitude were roll, pitch, and yaw.

Procedure:
At the first session both tasks were carefully explained. During the first three daily sessions all Ss received part-task training; half the subjects were trained on the procedural tasks followed by training on the tracking-task; the remaining half subjects received training in the opposite order. Each trial was 70 seconds long. A session consisted of 5 trials on each task. On Session 4 through 8, whole training was given; each session was composed of 10 trials on both tasks simultaneously.

Rehearsal training was given 18 days following final training trials (Session 8). Ss were matched and assigned to 9 groups on the basis of their tracking scores derived from training sessions 4 through 8. The rehearsal conditions are given in the table below.

| GROUP | TRACKING TASK | PROCEDURAL TASK Temporal Sequence | Spatial Sequence |
|---|---|---|---|
| 1 | Simplified | Operational | Operational |
| 2 | Simplified | Operational | Simplified |
| 3 | Simplified | Simplified | Operational |
| 4 | Simplified | Simplified | Simplified |
| 5 | Operational | Operational | Operational |
| 6 | Operational | Operational | Simplified |
| 7 | Operational | Simplified | Operational |
| 8 | Operational | Simplified | Simplified |
| 9 | No Rehearsal | No Rehearsal | No Rehearsal |

All groups were trained on the operational task and were retention tested on the operational task. The simplified version of the tracking task involved substituting the 0.025 Hertz signal for the 0.050 Hertz input of the operational task. Simplification for the procedural task was attained in both the temporal and spatial aspects. The simplified temporal condition consisted of a constant 7 second interval between each stimulus event rather than the operational one (i.e., a temporal order sequence of 4, 8, 10, 4, 10, 6, 6, 8 second intervals). The simplified spatial condition was achieved by producing a stimulus event sequence in the order 1, 2, 3, .... 9 with 1 referring to the top pair of lights and 9 to the bottom most pair rather than the operational sequence (i.e., spatial order sequence was 1, 5, 2, 9, 8, 3, 6, 7, 4 in the operational condition). Fourteen Ss were in each group.

After the four daily rehearsal sessions, one retention test session was given. Fifteen days after the final rehearsal session consisting of 10 trials identical with those given during original training.

Independent Variables:

Rehearsal Type

a) Simplified
b) Operational
c) No Rehearsal

Dependent Variables:

1. Procedural Task

   a) Commissive errors
   b) Omissive errors
   c) Total response time (total for the 9 stimulus light events)

2. Tracking Task - Integrated absolute error summed across the roll, pitch and yaw dimensions (error in terms of linear extent).

RESULTS

A. Effects on Tracking Task -
Initial rehearsal performance produced error scores which would be predicted from a linear extrapolation of earlier training (i.e., no decrement in evidence) for all groups. Analysis of variance of retention scores failed to show significant differences between the rehearsal groups (Groups 1-8), but significantly greater error was found for the no-rehearsal groups.

B. Effects on Procedural Task Performance -
No significant differences were found in an analysis of variance of difference scores. Analysis of variance of retention test scores revealed a significant effect on the rehearsal type on both commissive errors and response time. Further analysis showed that significantly fewer commissive errors occurred under operational type rehearsal. Significantly longer response time was required by Ss receiving simplified temporal rehearsal than operational task rehearsal. Comparing the experimental groups with the no-rehearsal group showed that Groups 1 and 5 had significantly fewer commissive errors; significantly fewer omissive errors were found for Groups 1, 5, 6 and 8; no differences in response time were found. Generally, it was found that modifying the tracking type parameters was of little significance in procedural task performance.

CONCLUSIONS

A. Rehearsal of tracking skill led to superior retention performance over no rehearsal.

B. Differences in rehearsal conditions did not lead to significant differences in task performance (tracking).

C. Operational rehearsal was more effective under procedural task conditions than no-rehearsal relative to commissive errors.

D. Most rehearsal conditions produced significantly fewer omissive errors than no rehearsal conditions on the procedural task.

E. The amount of original training, if sufficiently long, can eclipse any positive effects of rehearsal.

F. Under limited training conditions interim practice on the more difficult portions of the tasks can be expected to lead to superior skill retention.

Buckout, R., Naylor, J.C., and Briggs, G.E. Effects of Modified Task Feedback during Training on Performance of a Simulated Attitude Control Task after 30 Days. Technical Documentary Report AMRL-TDR-63-125, Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio, Dec. 1963.

PURPOSE

To examine the effects of modifications in task feedback during training on skill retention.

METHOD

Subjects:
142 undergraduates volunteered to serve as paid participants.

Equipment:
A procedural task device consisted of a display-control consisting of 9 rows of amber and red lights. On each row, the light pair consisted of one red and one amber. Associated with that light pair was a set of three buttons. The buttons were labeled "Emergency", "O.K.", and "Check", respectively.

The tracking task device simulated the attitude of a vehicle in free flight and was similar to the apparatus described elsewhere by Naylor and associates (see AMRL-TDR-63-33). A tracking control stick was utilized to null readings which deviated from the optimal attitude in roll, pitch and yaw.

Visual noise was introduced into the display so as to cause the meter needles to flutter while being driven by a forcing function. Capability was present for E to turn the visual noise on or off according to experimental conditions. Additionally, auditory noise was delivered to Ss by means of padded earphones. The auditory noise intensity level was caused to vary between 80 and 95 db as a function of the amount of tracking error (the poorer the performance the greater the noise level). The amount of error tolerance permitted before the sound level would change could be adjusted by E.

Associated with each dimension was a fuel gauge which simulated the amount of fuel remaining in the "fuel tank" for that dimension (attitude). This permitted Ss to attempt to optimize their attitude control (i.e., consume the least amount of fuel and still maintain precise attitude control).

Procedure:
Ss were oriented to the two tasks on the first session and then on the second day received part-task training first on the procedural task, and then the tracking task.

Eight groups of subjects were formed with 16 to 20 Ss in each group. Four of the groups received 3 weeks of training and the other four groups received one week of training. In accordance with the factorial design, half the subjects were exposed to visual noise and half were not; half had the high tolerance condition for auditory noise, while the other half of the subjects had the low tolerance condition.

Ss who trained for one week had 28 trials in 4 sessions; the 3 week trained group had 12 sessions of 108 trials. Thirty days after his last training trial, each S was retention tested in a session consisting of 4 trials under the visual noise, low tolerance condition (small error produces large intensity changes). The retention task involved a simultaneous performance of both the procedural and tracking tasks.

Independent Variables:

1. Length of Training
   a) one week
   b) 3 weeks
2. Visual Noise
   a) present
   b) absent
3. Condition of Augmented Feedback
   a) High (large amount of error triggered greatest sound intensity level)
   b) Low (small amount of error required to trigger greatest intensity level)

Dependent Variables:

1. Tracking Task
   a) Integrated absolute error (summed across the three dimensions)
   b) Fuel scores

RESULTS

A. Effects of Training -
An analysis of variance of the absolute retention scores showed that final training scores for the 3 week group were significantly superior to the one week trained group. The scores at retention tests showed that significantly fewer errors were committed by the group receiving 3 weeks training.

An analysis of variance of the fuel scores showed that Ss trained for only one week used significantly more fuel at the end of training than did Ss who received 3 weeks of training. At retention test no significant differences in fuel scores were in evidence as a function of the training variables.

B. Effects of Visual Noise -
An analysis of variance of absolute tracking scores showed that visual noise produced significant differences both from the last day of training and on the retention tests. On the final day of training, the presence of visual noise produced significantly greater tracking error scores than lack of visual noise.

On the retention test, Ss trained with visual noise produced significantly fewer errors than Ss trained without visual noise (the displays contained visual noise retention tests for all Ss).

An analysis of variance was performed on the fuel scores and showed that significant differences both on the last day of training and on the retention test could be attributed to the visual noise variable. On the final day of training, Ss who trained with the visual noise present had significantly higher fuel usage scores than those trained without visual noise. At retention test, less fuel was consumed by Ss trained with visual noise than Ss trained without visual noise.

C. Effects of Auditory Augmented Feedback -

No significant effects were found.

CONCLUSIONS

A. The significance of the amount of initial training is of extreme importance in determining skill retention following an extended no-practice interval.

B. Training with the presence of visual noise is best if noisy displays will be utilized at retention tests for extended periods without practice.

C. The use of auditory augmented feedback as an influential variable in skill retention is discouraged.

REVIEWERS COMMENT

The lack of data for procedural task performance is unfortunate since the possibility of transfer effects (as has been shown on other investigations) must be ignored. If would seem that effects from the presence or absence of visual noise on the primary task could affect performance both during training and during retention test on the procedural task.

Cotterman, Theodore E., and M. E. Wood. Retention of Simulated Lunar Landing Mission Skill: A Test of Pilot Reliability, Aerospace Medical Research Laboratories, Report No. AMRL-TR-66-222, Wright-Patterson AFB, Ohio, April, 1967.

PURPOSE

To determine the effects of no-practice intervals up to 3 months in duration on the retention of lunar landing mission skills.

METHOD

Subjects:
12 graduates of the Aerospace Research Pilots School at Edwards AFB, active in flying and having considerable military flying experience participated.

Equipment:
A full size mockup of the Apollo Command Module (CM) and the Lunar Excursion Module (LEM). The CM rested in a sound-damped cradle and had high fidelity outside and inside with a real Apollo CM. Three operator stations were provided: pilot, navigator and engineer.

The pilot position contained the main controls and instruments for controlling the vehicle. The controls and displays were primarily associated with translatory accelerations and attitude changes (pitch, roll and yaw). The LEM crew compartment was simulated. External to the LEM was a 3-axis, hydraulically operated, gimbal system which permitted attitude changes in response to computer signals. This system was utilized in simulating docking with the CM.

The LEM stations (side-by-side seating arrangement for two occupants) contained controls and displays for both translation and attitude. Controls consisted of two control sticks and an engine throttle. Displays included a Delta V counter, cross range, and cross range rate meter, attitude and attitude rate meter, range meter, range rate meter and down range and cross range displacement from landing site presented by means of CRT. Additionally, a down range rate meter was provided.

External to the simulated LEM compartment was a projected star field which moved appropriately in response to computer signals to give realistic indications of pitch, roll and yaw. In general, the highest fidelity simulation was achieved in the area of instrumentation. The continuous confinement aspect of the Apollo mission was not simulated nor were the variations in gravitational forces. The lunar landing was achieved by instruments only, and habitability aspects of theCM were not included in the simulation during retention testing but it was an aspect of training.

Procedure:
Crews were trained over a six-week period. Initially 3 to 5 days were devoted to indoctrination of the mission, vehicle systems and familiarization with displays and controls. Additionally, study time was given for various written materials regarding the overall mission. Customized checklists were developed. Next Ss were introduced to the simulator and various mission phases

were practiced. Each phase consisted of a sequence of tasks. During the last 5 to 7 days, mission phases were practiced in order. Finally, the entire mission was simulated in real time lasting through a 169 hour period.

Crews designated to have 8 week and 13 week no-practice intervals received substantially more training than the two crews having 4 to 9 week no-practice intervals. Critical mission phases were identified as trans-lunar insertion, transition (an arrangement of the CM, Service Module, and LEM), position determinations and midcourse corrections, lunar orbiter insertion, lunar landing, lunar ascent, trans-earth orbit insertion and earth entry.

Retention testing took place for the 4 week and 9 week retention crews by repeating 3 times within the mission, the mission phases. For crews having 8 week and 13 week retention periods, retention testing was accomplished by repeating the mission times in succession. Retesting was always accomplished in fast time (the long coast periods eliminated permitting the entire testing to be achieved in an elapsed time of 13 to 14 hours). Retesting permitted each crew member to assume pilot duties on each of the mission phases. After the fast time mission testing, subsequent testing was done on selected mission phases. Tasks within each mission phase necessary for the successful completion of that phase are best categorized as flight control tasks and procedural tasks (switching and information handling).

Independent Variables:

1. No-practice interval
   a) 4 weeks
   b) 8 weeks
   c) 9 weeks
   d) 13 weeks

Dependent Variables:

From one to four parameters were identified as critical to successful mission phase completion. Criterion values were established for each of these parameters. Performance was measured on each of the parameters and transformed into probabilities of successful performance respect to criterion values.

## RESULTS

The findings are given in terms of five probabilities of meeting criterion performance: (1) in a measured parameter of a given mission phase, (2) in all measured parameters of a given mission phase, (3) in a measured parameter of the complete mission, (4) in all measured parameters in a phase of the complete mission, and (5) in all measured parameters of all phases of the complete mission.

Skill acquisition in the crews designated for 4 week and 9 week no-practice intervals as indicated by the probability indexes showed that the probability of meeting criterion performance across the entire mission was never greater than .002. The probability of a particular parameter across the whole mission (i.e., the probability of meeting criterion on any parameter selected at random) never exceeded .845 and the probability of a meeting criterion for a mission phase across the complete mission never exceeded .619. For the purposes of examining the effects of retention, the authors state that insufficient training nullified the data resulting from these two crews.

For the 8 week and 13 week no-practice interval crews, the probability of meeting the criterion for a particular parameter across the mission ranged from .932 to .990 and for a phase across the complete mission, the values ranged from .9077 to .978 and probability of meeting criterion across the entire mission ranged from .294 to .817.

A. Mission Retention Performance Tests -
The effect of the 8 week and 13 week retention intervals was generally to lower the probabilities associated with performance on various mission phases in all parameters, for all phases of the entire mission. The greatest decrease occurred for the first pilot in each crew (it appears that there is less retention loss in individuals who have an opportunity to observe task performance prior to engaging in task performance). Differential effects of 8 weeks, 13 weeks of no-practice were not discernible. Certain pilots showed performance gains in certain phases, but these are without explanation.

The probability of meeting criterion in any parameter for the entire mission after a retention interval of 8 to 13 weeks averaged about .95. The probability of meeting criterion for any phase in the mission averaged about .91 after a retention interval. The probability of meeting criterion in all parameters in all of the phases across the mission averaged about .41. (These figures contrast with those determined for end of training as follows: .96, .94, and .57 respectively).

B. Retraining -
Additional training of 8 to 28 trials was performed on each of the mission phases. After retention test, the best block of four trials was used to find the probability of meeting criterion on any parameter in the mission. The averages taken across the 8 week and 13 week retention crews equaled .99+. A probability of meeting criterion in all parameters in all phases for the entire mission, again averaging across crews, was found to equal .93.

CONCLUSIONS

A. A retention interval of 8 to 13 weeks produced a significant decrement in performance level. This decrement was ameliorated in large part by observation of the task performance by Ss who were to be subsequently tested.

B. The effects of retraining (post retention test) showed that a high probability of meeting criterion in all parameters for all phases for the whole mission existed. Performance on the best retraining trials failed to meet or exceed the performance exhibited on the final four training trials indicating a need for additional training. Special attention should be given to training and re-familiarization procedures for the maintenance of skilled performance.

REVIEWERS NOTE:

Data assessment should include the following:

A) The probability values used in this report were based on a sample size of four for the training and retraining trials. For the retention test trials, a sample size of one was used (with assumptions that the variance of the training trials equalled that of the retention trial necessarily being made which makes it difficult to assess the data).

B. The effect of the type of data analysis presented here is to eliminate a considerable amount of information. The reader can not know whether failure to meet criteria during the retention test was a result of the same performance deficiencies as were failures during training and retraining.

C. All Ss were military pilots having active assignments there can be little doubt that intervening activity between training and retention testing influencing retention test performance.

D. The selection of criterial values (which in effect determined the probability of success in meeting criteria) were established after data collection.

Fleischman, Edwin A. and Parker, James F. Factors in the Retention and Relearning of Perceptual-Motor Skills. J. of Exper. Psychol, 1962, 64(3), 215-226.

PURPOSE

To determine the effects of no-practice intervals, degree of initial proficiency, type of initial training and type of retraining on skill retention.

METHOD

Subjects:
Information on Group I subjects can be obtained from Parker and Fleischman "Prediction of Advanced Levels of Proficiency in a Complete Tracking Task", USAF WADC Tech. Report, 1959, No. 59-255; and Group II subjects information can be obtained from: Parker, J. F., and Fleischman, E. A. "Ability Factors and Component Performance Measures as Predictors of Complex Tracking Behavior", Psychological Monographs, 1960, 74(16) Whole No. 503.

Equipment:
Three identical tracking devices were constructed for the study. Each device consisted of an oscillograph which presented a target pip. Initially, a zero-centered voltmeter used as a "sideslip" indicator supplemented the oscillograph presentation. Completing the apparatus was an aircraft control system comprised of a control stick and rudder pedals. These controls were so constructed as to produce realistic aircraft compensatory movements by the target pip on the oscillograph. The target pip was caused to move in accordance with a 6 Hz damped sine wave.

Procedure:
The data utilized in this study was collected in the course of two other investigations which are cited above in the section on "Subjects". Group I subjects learned the tracking task without the benefit of formal instruction with the exception that Ss questions were answered. Seventeen training sessions, distributed over six weeks. Each session comprised 21 one-minute trials.

Group II subjects also learned the tracking task with the benefit of an initial explanation, a demonstration of the tracking device, critiques after sessions 7, 11 and 15 and the initial three training sessions monitored and assisted by E. The tracking task required each S to maintain the target dot at the center of the oscillograph display, and nulling the sideslip indicator by means of the aircraft type controls. Groups then experienced varying amounts of no-practice intervals. Group I subjects experienced either 9, 14, or 24 month intervals. Group II subjects experienced either 1, 5, 9 or 14 month no-practice intervals. After the passage of the retention interval, each group of subjects was divided in half. One-half from each group received retraining according to a massed schedule and the other half of each group to receive retraining according to a distributed practice schedule. One week after the final retraining sessions, all Ss were tested in a final session. Since Group II subjects were more proficient at the end of training than were Group I subjects, a matching procedure was followed to assure comparability between groups.

Independent Variables:

1. Length of Retention Interval
   a) 1 month
   b) 5 months
   c) 9 months
   d) 14 months
   e) 24 months (not for all groups)

2. Training Type
   a) formal
   b) informal

3. Original Learning Level

4. Type of Retraining Schedule
   a) massed practice
   b) distributed practice

Dependent Variables:

An integrated absolute error score was calculated from absolute errors measured on the controls in terms of azimuth, elevation, and sideslip. Calculations were based on equation T = 1/2X + 1/2Y + 1/2Z. Where T equals integrated absolute error score, X equals absolute aximuth error, Y equals absolute elevation error and Z equals sideslip error.

RESULTS

A. Effects of Retention Interval Length -
Group I produced an obvious but slow decrement in performance following a 24 month no-practice interval. At the two shorter retention intervals, no decrement in performance from the final learning trial level was apparent. Earlier performance levels achieved during initial training appears to have been regained in the first two or three minutes of retraining. The most marked improvement is in the 24 month retention interval group, whose initial error level was nearly double that of the other two groups. This difference appears to have vanished at the end of the first minute of retraining.

Group II demonstrated virtually no decrement in performance as a function of any of its retention intervals. There are virtually no differences between performance levels of any of the retention groups within Group II.

B. Effects of Original Learning Level -
A correlational analysis was performed between the average score for the last 44 minutes of original practice and final 18 minutes of the first retraining session. The obtained values were all extremely high ranging from .80 to .98 and all statistically significant beyond the .01 level indicating very little change in the ordering of subjects within any group with respect to relative performance as a function of any of the retention intervals.

C. Effects of Type of Training -
It was found that Group I subjects during the first 21 minutes (first session) of retraining were consistently inferior to that of Group II (this comparison made of retention interval subgroups in common, viz., 9 months and 14 months). Using matched subjects it was found that no significant difference was obtained between first session retention scores between Groups I and II.

D. Effects of Type of Retraining -
The massed practice subgroup (receiving four 21-minute sessions with 10 minute intermission between sessions) performed significantly poorer than the distributed practice subgroup (receiving four 21-minute sessions with one-day intervals between sessions). When both groups were retested one week after their own final retraining session, this difference disappeared. The final performance score was superior to that obtained by either group during initial training, the scores were significant for the distributed practice group only.

RESULTS

A. Retention of complex continuous tracking is extremely great for no-practice intervals up to 24 months.

B. The length of retention intervals up to 14 months are unrelated to skill retention. A skill retention decrement can be expected when the retention interval increases to 24 months.

C. The level of initial proficiency rather than the type of training is the determiner of skill retention level when retention interval is held constant.

D. Distributed rather than massed practice produces superior performance at the end of the 4 sessions of retraining. However, scores obtained one week after retraining indicated no observable differences between the two types of retraining schedules.

REVIEWERS COMMENT

Failure to obtain significant differences relative to the types of training must be considered specific to this investigation, since only two training types were attempted.

Grimsley, Douglas L., Acquisition, Retention and Retraining: Effects of High and Low Fidelity in Training Devices. Human Resources Research Office, Technical Report 69-1, Feb. 1969 ( Clearing House Accession No. AD 685 074).

PURPOSE

To determine the effects of simulation equipment fidelity on the acquisition, retention and retraining of procedural task performance.

METHOD

Subjects:
60 traines in Advanced Individual Training from the U.S. Army Training Center at Fort Ord, California acted as participants. All Ss had AFQT scores 30 or above.

Equipment:
The basic apparatus was a section control indicator (SCI) (a panel used during preparation and firing status in the Nike-Hercules Guided Missile System). Three variations of this panel were utilized: (1) a hot panel in which every switch light meter and piece of communication equipment was functional, (2) a cold panel which was identical to the hot panel with the exception that no electrical power was supplied, and (3) a reproduced panel which consisted of an artist's reproduction of the hot panel and painted to illustrate that the panel is illuminated. The panel contained toggle switches, pushbuttons, rotary switches, rheostat controls, a banana plug, communication equipment, light meters, and auditory display.

Procedure:
Each S was train individually on 92 step procedural task on the SCI. Training was initiated with an orientation in the Nike-Hercules equipment functions, and physical site layout. Next, the instructor presented a "talk thru" demonstration of the procedural task. Each step of the task was cued by some stimulus presentation from the panel. Training continued until S achieved one errorless trial or consumed 3 hours of training time. Ss were randomly divided into five groups. Each group was subjected to different experimental conditions as shown below.

| | Training Panel | Proficiency Test | Retest 1 | Retest 2 |
|---|---|---|---|---|
| Group 1 | Hot | Hot | Hot | Hot |
| Group 2 | Cold | Hot | Hot | Hot |
| Group 3 | Cold | Cold | Hot | Hot |
| Group 4 | Repro | Hot | Hot | Hot |
| Group 5 | Repro | Repro | Hot | Hot |

Five minutes after training was completed, a proficiency test was administered according to the above conditions. After the test, all Ss returned at approximately a 4 week interval (26 to 30 days) and all were tested on the hot panel.

14 to 18 days later all subjects again returned and were tested on the hot panel. After the test, further test trials were administered until S had reached a criterion of 90% correct.

Independent Variables:

1. Level of Simulation
   a) hot
   b) cold
   c) repro.

Dependent Variables:

1. Number correct
2. Time to train
3. Time to retrain after the second retention test

RESULTS

A. No differences in performances were found as a function of simulation fidelity.

B. The 4 week retention interval produced an average decrement in performance of 16% across all experimental groups. No significant differences between groups at retention test was found. The average loss in performance at the second retention interval test as compared with final training performance was approximately 7%

CONCLUSIONS

A. Very simple low fidelity training equipment is sufficient to produce performance on a procedural task equivalent to that produced by Ss trained with high fidelity devices. The retention loss is equivalent between groups trained differentially on relative high and low fidelity devices.

B. There were no significant differences between groups relative to high and low fidelity training devices with respect to amount of retraining to restore original performance.

Grimsley, Douglas L., Acquisition, Retention and Retraining: Group Studies on Using Low Fidelity Training Devices. Human Resources Research Office, Technical Report 6904, March 1969. (Clearing House Accession No. AD 686741)

PURPOSE

To determine the effects of group training procedures under various levels of simulation equipment fidelity on the acquisition, retention and retraining of procedural task performance. In the absence of significant effects, four additional objectives were to be examined.

1) To examine the effects of low fidelity equipment trained Ss of exposure to high fidelity equipment by demonstration or by practice.

2) To examine various aspects of retraining.

3) To examine the magnitude of the skill decrement over 4 and 6 week periods.

4) To determine the effects of the knowledge that retention testing will occur.

METHOD

Subjects:
123 trainees having AFQT scores of 30 or above in Advanced Individual Training at the Ft. Ord, California, U.S. Army Training Center participated.

Equipment:
The section control indicator (SCI) (see abstract: Grimsley, Feb. 1969) in its three variations: (1) Hot - a real panel with power supplied, (2) Cold - a panel with no power, and (3) A reproduced panel - full size carboard facsimile.

Procedure:
Ss were trained on the 92 step procedural task utilizing one of the three forms of the SCI. Training was administered to groups of four subjects. All errors were immediately corrected and some verbal reinforcement was given periodically for correct responses. As each S performed the procedural task, the other three members of his group observed. After group practice, individual training was administered until the 92 correct criterion was achieved. Approximately 5 minutes after training, each S was given a proficiency test on the hot panel. Initially, three larger groups of 12 Ss were each trained (not simultaneously) under one of the three panel conditions prior to the proficiency test. Two of these groups were given differential exposure to the hot panel: one group of Ss observed a demonstration of the entire procedural task sequence on the hot panel, and then 5 minutes later were given the proficiency test on the hot panel; the second group of subjects trained on the reproduction panel but were allowed one practice trial on the hot panel.

Three more groups of 12 Ss each received differential instructions after having been first trained on the hot panel:

1). One of these groups received a written list of instructions, and Ss were permitted to study it for 15 minutes then rest for 5 minutes, and then participated in the 4 week retention test. They returned again 2 weeks later for participation in the 6 weeks retention test which was also preceded by the opportunity to study the list for 15 minutes.

2) The second group of subjects received the list of instructions and a drawing of the hot panel. The Ss in this group were permitted 15 minutes of practice, 5 minutes of rest and then were retention tested on the hot panel.

3) The last group received a demonstration of the correct procedure on the hot panel just before retention testing. Another group of 12 Ss who had been trained on the reproduction panel were given a retention test after a 6 week no-practice interval without the intervention of the 4 week test.

Independent Variables:

1) Fidelity of Simulation Equipment
   a) Hot
   b) Cold
   c) Reproduction

2) Method of Exposure to
   a) Demonstration
   b) Actual practice

3) Method of Retraining
   a) Instruction alone
   b) Instruction with a reproduction panel
   c) Demonstration on a hot panel

4) Retention Interval
   a) 4 weeks
   b) 4 weeks plus 2 weeks
   c) 6 weeks

5) Knowledge of Retention Testing
   a) No knowledge
   b) Informed

Dependent Variables:

1) Number of correct responses

2) Time to train

3) Time to retrain

RESULTS

A. Effect of Equipment Fidelity -
No significant differences were found between groups trained on the hot panel, the cold panel and the reproduced panel for either initial proficiency test, retention test, time to train or time to retrain.

B. Effects of Method of Hot Panel Introduction -
A group having actual practice with the hot panel prior to proficiency testing produced significantly superior performance over the "demonstration only" group.

C. Effects of Differential Preparation on Retention Performance -
The group having written instructions plus a full size drawing of the panel and the group receiving a demonstration, both performed superior to the instructions only group. Their time-to-train scores and retest scores were significantly superior at the .05 level. Their second retest score, number of trials to retrain, and time to retrain were significantly superior at the .01 level.

D. Effects of Retention Interval of 4 Weeks, 4 Weeks plus 2 Weeks, and 6 Weeks
No significant difference was found between 4 weeks and 6 weeks retention performance scores. The difference between the 4 week plus 2 weeks score and the full 6 week performance score was found to be significantly different at .01 level, with the full 6 week score having the fewer correct responses. (85.3 correct as opposed to 75.8 correct).

E. Effect of Knowledge of Future Retention Testing -
No significant differences between the two groups were found.

CONCLUSIONS

A. Low fidelity training equipment for procedural tasks can be equally effective as high fidelity equipment relative to training time, level of proficiency, amount of skill retained and time-to-retrain.

B. Type of training (individual vs group) - does not interact with fidelity of training equipment.

C. Low fidelity equipment in addition to written instructions is an effective means of achieving retraining.

Hammerton, M., Retention of Learning in a Difficult Tracking Task. J. of Exper. Psychol., 1963, 66(1), 108-110.

PURPOSE

To examine the effects of extensive practice on the retention of second order control skill.

METHOD

Subjects:
16 male and 2 female colleagues of the author acted as volunteers.

Equipment:
A display control device presented to the S a short, vertical line and a spot of light by means of a CRT. The spot location was controlled by means of a thumb joy stick whose deflection was proportional to the acceleration of the spot across the screen.

Procedure:
Ss were instructed to activate the thumb joystick control so as to move the spot on the CRT to the vertical line target. Ss received 5 trials each day until they both had 3 successive daily mean scores less than 12 seconds and 3 successive day's scores which did not differ significantly at the 5% level. After this training, half of the subjects (extensive learning group) then received 10 trials per day until they attained 3 successive day's scores which did not differ significantly at the 1% level.

Retention testing began 26 weeks after the final training trial for all subjects. Retraining trials continued until all Ss reached the initial two criteria. Each S received immediate feedback.

Independent Variable:

1. The amount of training
    a) Criterion learned to 5% level of statistical significance.
    b) Criterion learned to 1% level of statistical significance.

Dependent Variable:

1. Elapsed time to acquire the target

RESULTS

A. Performance during Training -
Both groups of subjects reduced target acquisition times from initial highs of 46 secs to lows at the end of the common training period of 10 secs. Variability in performance also decreased quite markedly during this period. The extended learning group continued to decrease performance variability and acquisition time. Similar small decreases in variability were also noted for other learning groups.

B. Performance after No-Practice Interval -
The initial testing after a six month retention interval resulted in retention performance decrements which are significant over final training performance. For the standard trained group on the initial retention test was approx. 40 secs and for the extended learning group, the target acquisition time was approx. 19 sec of the same test period. Retraining to criterion level required one-half as much training time per subject as did initial training.

CONCLUSIONS

A. A significant decrement in performance occurs after a 6 month retention interval (no-practice interval) on complex tracking tasks in spite of extensive training.

B. Initial performance at the end of a retention interval is significantly superior in Ss receiving extensive training.

REVIEWERS COMMENTS

The "extensive Training" group was required to achieve a more statistically significant criterion than the group receiving lesser training. It can be argued that since more stringent training conditions were imposed on the former group they achieved substantially superior performance in performance areas other than the time dimension studied here.

Macek, A. J., Vilter, P. F., and Stubbs, D. W. Rehearsal and Warm-Up in Skill Retention Final Report. NASA Contract No. NAS9-3649, Final Report No. 20153-FR-1, Oct. 1965, Honeywell Inc., Research Dept., Systems and Research Division, Minneapolis, Minnesota.

PHASE I

PURPOSE

To examine the effectiveness of warmup and rehearsal in perceptual-motor paired-associate tasks:

Experiment 1 - to determine the relative effectiveness of two verbal analog rehearsal on skill retention.

Experiment 2 - to examine the effects of verbal analog rehearsal on the skill retention of a task of greater complexity than Experiment 1.

Experiment 3 - to determine the relative effectiveness of verbal analog and manipulative warming-up on skill retention of the simpler perceptual motor task in Experiment 1.

METHOD

Subjects:
104 University of Minnesota graduate and undergraduate students were recruited.

Equipment:
Two variations of the Star Discrimeter were used. This device consists of a stimulus unit, a response unit and an experimenter's readout unit. The stimulus unit was positioned a few feet ahead of S at eye level. It presented one of six colors. The color presentation was turned off by use of the response unit. This unit consists of a stick protruding through a hole from which six slots radiate; when the stick is pushed all the way into the appropriate slot, the color was turned off. (In the case of Experiment 2, a 12 slot arrangement was utilized; in the arrangement, the illuminated color was turned off by placing the stick into two slots in the appropriate 1, 2 sequence.) Each color always has the same associative pairing with the response unit. The experimenter's readout unit consisted of four counters, each recording one of four types of responses: (1) shallow error, when the S pushes the stick only part way into an incorrect slot; (2) deep error, when the S pushes the stick all the way into an incorrect slot; (3) shallow correct, when the S pushes the stick part way into the correct slot; and (4) deep correct, when the S pushes the stick all the way into the correct slot.

Procedure

Experiment 1: At the first session, Ss practiced on the Star Discrimeter for 30, one-minute trials. On the basis of initial session performance, the Ss were divided into four matched groups. One group acted as a control group, and spent the time (from the second through the sixth week) taking mechanical comprehension or spatial relation standard tests as rehearsal task activity (irrelevant rehearsal). The other three groups practiced on a memory drum. Each group learned to associate the stimulus colors with either clock hours, months of the year or adjectives. Additionally, during the third week of rehearsal pictorial representations of a response unit were introduced. These showed clock hours or months of the year (as would be appropriate to the two groups involved) arranged in a circular array permitting the slots to be designated by even clock hours or by the names of the even numbered months of the year. During the second through the sixth week, the experimental groups worked with the memory drum and completed 8 runs of the six paired associates. An additional run was given if Ss failed to complete two trials perfectly. Finally, during the seventh week Ss returned for 15 trials on the Star Discrimeter.

Experiment 2: The procedure was exactly the same as given above with the exception of the modifications necessary to accommodate the more complex task. The S responded to each of the stimuli by entering two slots in proper sequence. Under Experiment 2 conditions, the Star Discrimeter device had 12 rather than 6 slots. Each experimental group now had 12 labels (one for each slot) with which to work. The memory drum was employed again with the two labels following each color name. Exposure duration was doubled to permit the same viewing time per label.

Experiment 3: The procedure for this experiment was essentially the same as in Experiment 1; subjects practiced for 30 trials on the 6 slot Star Discrimeter task and were then divided into matched groups according to their performance. After two weeks of no practice, Ss returned and first underwent warmup procedures according to group membership and then participated in 15 retention test trials. Details on the amount of warmup were not stated.

Independent Variables:

Experiment 1

Type of Verbal Analog:

a) Clock hours to correspond with the even hours on the face of a clock.

b) Months of the year arrayed as in (a)

c) Adjectives descriptive of behavior

d) No verbal analog

Experiment 2

Three types of verbal analogs as in (a) above were used but in the case of Experiment 2, twelve labels in each analog category were necessary rather than six as above.

Experiment 3

Warmup Conditions

(a) Cognitive warmup (utilizing the clock rehearsal treatment as in Experiment 1).

(b) Perceptual-motor warmup (utilizes an established stick manipulation routine and color observation).

(c) Combination warmup (utilizes (a) and (b) above).

(d) No warmup (control group).

Dependent Variables:

Six indices of performance were acquired in all three experiments:

(a) Shallow errors
(b) Deep errors
(c) Shallow-correct
(d) Deep-correct
(d) Adjusted score, computed by the expression $(1 - T_e/T_a)C$

where C equals number of correct responses per trial; $T_a$ equals number of responses for the first five retention trials, $T_e$ equals the total number of errors made in the first five retention trials.

(f) Mean errors
(Calculated as the mean number of total errors made by the four groups during the first five trials).

RESULTS

Experiment 1:

Performance as measured by adjusted scores attained the final acquisition level in only one group, the clock group, by the fifth retention trial. By the 15th retention trial all groups had surpassed final acquisition performance level. Initial performance by the clock group was 95% of its final acquisition performance trial. Initial group performance by the other three groups averaged a little more than 80% of the final acquisition level. Correct response scores showed that the clock group was again superior, achieving a final acquisition performance level by the second retention trial. The month group achieved this same level by the third retention trial, while the control group and adjective groups reached this level on the 4th and 5th trials, respectively. Recovery for all groups, except the clock group, was very rapid from 1st to 2nd trials. The clock group initiated its retention performance at nearly its final acquisition level.

The mean number of total errors (averaged over first five retention trials) failed to decline for any group to that level attained during acquisition. Total errors computed on a trial-by-trial basis showed the clock group with the lowest number of errors on the initial retention trial. The adjective group had approximately 80% more errors, and the month group 90% more errors than the clock group. The control group had over 100% more errors. The differences between groups, however, failed to achieve statistical significance. Final retention performance (Trial 15) attained the same freedom from error as final acquisition performance, with the control group slightly surpassing that level. The control group after the third retention trial consistently remained superior to the other groups, although not statistically significantly so.

Further analysis of error shows little change for shallow-errors. False starts change very little over the 15 retention trials. Deep errors showed large changes from final acquisition performance levels on the initial retention trials: the control group producing nearly 9 times as many deep errors, the month group with about 6 times as many, the clock group about 5 times as many errors. The clock group was significantly superior to any of the other three groups with approximately a 40% increase in deep errors as on the first retention trials.

Experiment 2:

A. Adjusted Scores: The clock group performed on the initial retention trial at 74% of the level attained on the final acquisition trial. The month group evidenced a 56% initial retention score. The adjective group showed 54% retention and the control group, 44%. Analysis of variance of the first 5 retention trials showed a significant difference between groups contrary to the findings in Experiment 1. Performance on the 15th and final retention trial surpassed the final acquisition performance level for all groups (using adjusted scores).

B. Correct Response Data: During the first five retention trials, the clock group achieves final acquisition performance by the third trial and improves performance from there on. The month group achieves final acquisition performance by the 5th trial. The remaining two groups do not achieve the former level within the first five retention trials. By the end of the 15 retention trials all groups have surpassed the acquisition performance level. An analysis of variance on the correct scores on the first five trials shows a significant difference between groups indicating that the more difficult task gives rise to more persistent group differences than in Experiment 1. These group differences, however, disappear by the end of retention testing.

C. Error Scores: The mean number of total errors over the first five trials showed that the clock and month groups achieved final acquisition performance by the fifth retention trial. The differences in number of errors was statistically significant at the .01 level (Kruskal-Wallis Test). Initial retention trial performance showed a large decrement (over 5 times) over final acquisition performance for the control group. The clock group showed the least performance decrement with approximately twice the final acquisition trial error. Intermediate between these groups were the month and adjective groups, initially performing quite similarly.

Deep error data for the four groups were quite similar. The total error scores, shallow error and false start data remained unchanged across acquisition trials and was essentially the same for all groups. The error levels were the same as that on final acquisition performance. While more absolute errors were made in Experiment 2, the proportionate increase over acquisition final level was less than in Experiment 1.

Error reduction during acquisition trials failed to reach asymptote explaining the difference in proportionate performance decrements between Experiment 1 and 2.

Experiment 3:

Adjusted score data revealed little retention decrement. Correct response data shows more of a retention decrement on the initial retention test trial. But by Trial 5 all groups had surpassed the final acquisition performance level. Shallow error scores show the only potentially important group differences. Here the three experimental groups tend to demonstrate fewer errors than the control group. No significant differences were found between groups for any of the performance indices.

CONCLUSIONS:

A. The greater the rehearsal relevancy to the task, the smaller the initial retention decrement with respect to correct responses and errors.

B. In a more complex task the effect of type of rehearsal is more persistent than on a simple task. The superiority of the most relevant rehearsal type (clock group) was demonstrated and the effect was greater than in the simple task (Experiment 1).

C. Warmup after a two week retention interval was not as effective as weekly rehearsal over a 6 week retention period with respect to overall performance. The data suggests that warmup may be an effective deterrent for motor errors (i.e., the finger-slip variety).

# PHASE II

## PURPOSE

To assess the amount of skill retention and the effects of relevant practice on an astronaut star-sighting task.

## METHOD

Subjects:
Four subjects participated in the experiment; One S was highly experienced both in conceptualizing the task and in operating the rotational controller; two Ss were familiar with the problems but had less experience than the first subject; the fourth S was familar with the task concept but lacked experience in working the problem.

Equipment:
A display-control device was utilized which designated the star pair on a CRT that could be aligned by means of an Apollo rotational controller. Simulation of control dynamics and display vehicular motion was achieved by means of a PBP-1 computer, a PACE computer, and 3 REAC analog computers.

Procedure:
Two problems were run in each of three sessions. The sessions were run two weeks apart. The third session presented a similar but unpracticed problem. In Session 1, the first three subjects worked Problem A first, then Problem B. The fourth subject was presented the opposite order. In Session 2, the first three subjects worked Problem B first, then Problem A. The fourth subject worked the opposite order. In Session 3, the first three subjects worked the new and unpracticed Problem C. On entering the experimental setting, S was read instructions by the experimenter and was given time to familiarize himself with the equipment. The S started a timer when he was ready to begin the problem and stopped the timer when he was satisfied that his alignment was accurate. Computer output provided performance measures to the experimenter.

Session 1 consisted of 8 trials on Problem A and 8 trials on Problem B; Session 2 provided 4 trials on each problem A and B; Session 3 provided 6 trials on Problem C.

Independent Variables:

1. Number of trials
2. Retention interval (2 weeks) parameter
3. Level of experience
   a) high
   b) low

Dependent Variables:

1 Fuel consumption (computer simulation values from Apollo spacecraft profile)

2. Elapsed time per problem

RESULTS

A very brief summary of the data is given below since a statistical analysis was precluded with so few Ss.

Data for First and Final Trials

of Phase II Experiment

| | | Session I | | Session II | | Session III |
|---|---|---|---|---|---|---|
| | Ss | Prob. A | Prob. B | Prob. B | Prob. A | Prob. C |
| Fuel Consumption Scores in Pounds | 1 | 10.0/1.4* | 2.6/2.3 | 2.7/1.7 | 1.2/1.0 | 2.8/1.2 |
| | 2 | 10.8/2.9 | 7.1/3.9 | 7.9/2.7 | 4.3/2.5 | 4.8/3.9 |
| | 3 | 2.4/1.6 | 2.9/2.4 | 14.4/6.2 | 2.0/1.6 | 2.7/2.3 |
| | 4 | **6.5/3.7 | **6.6/3.0 | **3.8/4.5 | **7.4/3.4 | NA |
| Elapsed Time in Seconds | 1 | 635/101 | 97/98 | 99/65 | 56/56 | 95/55 |
| | 2 | 210/60 | 185/115 | 210/110 | 215/115 | 122/100 |
| | 3 | 315/85 | 315/120 | 326/140 | 110/50 | 120/77 |
| | 4 | **247/88 | **198/80 | **111/103 | **215/79 | NA |

* Measures before the / mark obtained on first trial, and the following number obtained on final trial.

** These values were obtained for each problem in the reverse order indicated.

NA = not available

CONCLUSIONS:

A. The effects of experience on initial retention performance is modest, but rapidly asserts itself in superior performance after performing the task for a little while. With continued warmup, the relative superiority of the more experienced Ss is diminished; therefore, initial warmup is most important.

B. Initial efforts to conceptualize the problem by the experienced S resulted in greatly extended performance times with very small fuel savings indicating that manipulative activity was central to task handling adequacy.

C. Data suggests positive transfer between problems in a single task (of the type described here).

D. Experienced Ss' performance on fuel consumption was less variable, therefore the effects of training appear to enhance prediction reliability.

## PHASE III

PURPOSE

To evaluate retention performance and establish tentative criteria for a retention performance aid relative to the Apollo "Flight Director Attitude Indicator" (FDAI).

METHOD

Subjects:
Three development engineers at Honeywell, thoroughly familar with the FDAI, acted as subjects with only one giving a complete set of data.

Equipment:
The apparatus consisted of a FDAI display and associated analog computer. The display equipment responded to the movement of an Apollo Rotational Control Stick and simulated Apollo vehicle response rates and fuel consumption. The control stick could be manipulated under two modes of operations: (1) open loop, where no visual display was provided; and (2) closed loop, wherein the results of control movement were displayed on the FDAI.

Procedure:
Ss were required to initiate a gross attitude change utilizing the FDAI and associated apparatus. Performance of the task was preceded by the following warmup schedule; 30 secs warmup, 30 secs rest, 30 secs warmup, 30 secs rest, 30 secs warmup. Following this procedure Ss were instructed to "think through" a change of attitude so as to arrive at a designated setting and to make the appropriate control motions (this trial lasted 60 secs). After this final warmup procedure an actual attitude change was simulated (Test I).

Test 2 - Subjects 1 and 2 from Test 1 received 20 secs warmup practice in moving the controls under either closed loop or open loop conditions before applying rates to certain attitude change conditions: (1) pitch up, (2) yaw left, (3) roll right, (4) a combination condition - pitch-down, yaw-left, roll-right, Whenever Subject 1 had open loop conditions, Subject 2 had closed loop conditions and vice versa.

Independent Variables:

1. Warmup Procedure Type

   Open Loop
   Closed Loop

2. Retention Interval

   One week
   4 weeks
   5 weeks

Dependent Variables:

Fuel consumption (computer simulated fuel utilization to achieve attitude change)

RESULTS:

Closed loop warmup conditions led to less fuel consumption than did open loop warmup. The effects of the retention interval are confounded with the warmup condition permitting no results.

CONCLUSIONS:

A. Warmup was effective early in performance but did not influence later performance.

B. The task was found to be composed of two sub-tasks for which warmup was appropriate for the first subtask but not the second.

REVIEWERS COMMENT:

Phase I - It is implied that the tasks in the three experiments were self-paced without total activity comparisons between subjects; the data presented may require conservative interpretation. Both Phase II and III lack detail in descriptions of the apparatus and subjects' tasks. These operational tasks are no doubt quite complex and composed of many smaller tasks. A better picture of skill retention might be constructed if performance measures on the subtasks could be analyzed as well as the more gross measures of elapsed time and fuel consumption.

Melton, Arthur W. Retention of Tracking Skill, Final Report. Department of Psychology, University of Michigan ORA Project 02855, Sept. 1964. (Clearing House Accession Number AD 606 236).

PURPOSE

To determine the effects of: (1) type of display-control relationship, (2) type of target motion, and (3) duration of retention interval on skilled performance.

METHOD

Subjects:
Male, University of Michigan students were paid to participate in the investigation. Of the subjects originally engaged, the data of 336 Ss qualified for inclusion in the study.

Equipment:
The display-control device presented a vertical line target just above the horizontal mid-line of a 21-inch oscilloscope. The target moved along the horizontal axis in either a random or repeating pattern (the spatial-temporal pattern repeated every two seconds). A vertical control stick capable of being moved left and right caused left and right movement of the cursor presented on the oscilloscope. The display-control relationship could be changed to conform or contrast with the population stereotype. Integrated error score was displayed to the experimenter.

Procedure:
The pursuit task and equipment were explained to Ss. A 2 x 2 x 3 factorial design utilized 28 Ss per cell. Ss assigned to the 5-minute retention condition received 20 trials then a 5 minute rest, then 40 trials and a 5 minute rest, and then a final 10 trials. Ss in the one day and one week retention conditions received 20 trials on Day 1 then returned after retention interval for an additional 40 trials followed by a 5 minute rest and a final 10 trials. During the training an obvious trend toward dissimilarity between groups occurred and was corrected by the assignment of new subjects to various groups in an effort to equate final performance levels.

Independent Variables:

1. Target Movement Pattern
   a) Random
   b) Nonrandom
2. Display Control Relationships
   a) Normal
   b) Reverse
3. Retention Intervals
   a) 5 minutes
   b) 1 day
   c) 1 week

Dependent Variables:

1. Integrated Error Score

RESULTS

A. Effects of Display- Control Relationship - The first 20 trials which preceded the retention interval evidenced a significant differential skill acquisition between groups. Ss using the display-control population stereotype were significantly superior for both the normal and reverse display-control groups. Continued reduction in error scores was a general trend across trials 1 through 70. The relative superiority of the normal display-control groups Ss was maintained under both target motion conditions or retention intervals.

B. Effects of Target Motion - During initial training trials the random motion pattern gave rise to lower error scores. By Trial 10, however, both the normal and reverse display-control group subjects had begun to perform better under the nonrandom target motion condition. Post retention interval trials ( Trials 21-60) showed consistently improving performance for the groups having the nonrandom target pattern; for those Ss having the random target pattern virtually no improvement was in evidence. The lack of improvement in acquisition performance at the 20th trial for groups under the random target movement condition suggests inadequate skill acquisition.

C. Effects of Retention Interval - For subjects under the normal display-control condition and the nonrandom movement condition, differential retention effects were in evidence. Both the 1 day and 1 week retention groups suffered a significant loss in proficiency while the 5 minute retention group evidenced an improvement in performance on initial retention test. The improvement effect is expected theoretically due to the dissipation of retroactive inhibition. The second 5 minute interval, over all groups, produced no marked change in performance trends.

Ss working with the reverse display-control relationship under nonrandom movement conditions produced similar trends after the retention interval as the above Ss. The absolute effect, however, was much greater i.e., the one week and one day retention groups both showed marked losses in proficiency with the greater loss associated with the one week retention group. A rather persistent beneficial effect was associated with the 5 minute retention group and was reflected in the first ten retention trials. Recovery for the one week and one day interval groups was very rapid. The one day retention interval group attained the extrapolated performance level (the graphical extrapolation of acquisition performance trends across the retention interval) on the second retention trial and the one week group attained it on the third retention trial.

Groups working under the random movement condition show little consistent retention interval effects. Of the 4 groups involved, only one (the one day retention interval, normal display-control relationship) evidenced poorer performance after the retention interval. Ss under the normal display-control relationship but random target movement showed a moderate retention effect with the one week and 5 minute groups both producing about a 10% error reduction. The 1 day retention group increased errors on the initial retention trial, but reduced error below that of the final training trial by the second retention trial.

## CONCLUSIONS

A. Superior performance is attained when the normal display-control relationship is employed.

B. Random target motion conditions generally failed to support notions of the effects of retention intervals. This observation may largely be due to insufficient learning to produce the effect.

C. Retention loss for the one day and one week groups under nonrandom movement conditions appears generally greater for the reverse display-control relationship group than for the normal relationship group. This confirms initial hypotheses. For the 5 minute group, however, the 5 minute retention interval appears to have a positive effect with the reverse display-control group deriving the greatest benefit.

D. Recovery from retention loss occurred during the second or third retention trial.

## REVIEWERS COMMENT

This research effort attempts to relate theory (in this case the interference theory of forgetting) to applied data. While the effort was not 100% successful, the data generally support the theoretical notions. The specific difficulties in this study appear to be: (1) lack of a statistical tool to deal with the data, (2) lack of a challenging psychomotor task, and (3) retention intervals which were too brief. The findings of two pilot experiments, reported in the document, were incorporated in the main study. (The findings of the two preliminary experiments led to the choice of the pursuit task over compensatory task and indicated support for the hypothesis regarding normal and reverse display-control relationships.)

Mengelkoch, Robert F., Adams, Jack A. and Gainer, Charles A. The Forgetting of Instrument Flying Skills as a Function of the Level of Initial Proficiency. Technical Report: NAVTRADEVCEN 71-16-18, U.S. Naval Device Training Center, Port Washington, N. Y. (NASA Accession No. N66 39860), 1960.

PURPOSE

To determine the effects of amount of initial level of flying proficiency and a four-month no practice interval on instrument flying skills.

METHOD

Subjects:
26 male undergraduates at the University of Illinois volunteered to participate as paid subjects.

Equipment:
A Link 1-CA-2 Trainer was employed to simulate a SNJ aircraft. The trainer was modified with respect to rudder control and instrument panel to emphasize those instruments required for the flight regime to be utilized in the study. The trainer canopy was visually restricted to prevent Ss from obtaining any out-of-canopy cues.

Procedure:
Ss received two-part training. Initially four hours of classroom training involving principles of flight with the SNJ aircraft were completed in two 2-hour sessions. The classroom training involved the presentation of general flight principles and specific information about the location of controls, displays, and the use of checklists, etc.

Next, Ss were divided into two groups and received one 50 minute daily trial of practice in the trainer for 5 or 10 days depending on group membership. For the 5-day practice group, the retention interval averaged 121.2 days, and for the 10-day practice group the retention interval averaged 121.5 days. Each training trial consisted of an identical mission involving common maneuvers and procedures found in instrument flying and compatible with the apparatus used

Independent Variables:

1. Amount of training

   a) 5 trials
   b) 10 trials

Dependent Variables:

1. Error deviations from each of various flight parameters from optimal values. (The primary flight parameters were: altitude, air speed, bank and heading. Measures on the primary flight parameters were taken at 10 second intervals.)

2. Error-No Error scoring occurred for procedural tasks (sequential acts which had been a specific part of the training procedure). An exception to the above was that minimum airspeed, minimum altitude and time to complete the sequence were measured and certain emergency procedures.

RESULTS

A. Procedural Tasks: The error data is reflected as percent retention loss which is computed as the difference between the mean errors on the first retention trial and the final training trial divided by the total number of possible errors and multiplied by 100. Mean Percent Retention Loss across all procedures was 16.5 for the 10-trial group, and 20.1 for the 5-trial group.

1) Static Procedures (those procedural tasks not requiring simultaneous flight control)

The 10-trial group showed 20.9% retention loss while the 5-trial group showed 28.2% retention loss. These values are significantly different from each other at the .02 level. Within the 10-trial group the mean difference in errors between the first retention trial and the final training trial was 7.8 and the similar value for the 5-trial group was 15.9. Both values significant at less than the .02 level.

2) Dynamic Procedures (those procedural tasks during which simultaneous flight control was necessary)

Mean percent retention loss for the 10-trial group was 11.1 and for the 5-trial group was 10.2. These values not being statistically significant. Within each training group, however, the differences in first retention trial error and last training trial error was statistically different at the .02 level.

3) Emergency Procedures (procedural tasks requiring concurrent flight control and emergency cues presented without warning)

Mean percent retention loss for the 10-trial group was 16.7 and for the 5-trial group was 20.0. The differences between these groups failed to reach statistical significance. Within the 10-trial group the difference in errors between the first retraining trial and the last training trial was 3.5 and significant; for the 5-trial group the value was 4.2 and significant.

B. Tracking Tasks: None of the mean retention loss values between the 10-trial group and 5-trial group was found to be significant. Differences between the first retraining trial and the last training trial was found to be significant for the parameters: altitude, bank and airspeed, for the 5-trial group; and the parameter, airspeed, for the 10-trial group. The number of trials required to re-learn the tracking skill to the performance level set at the final training trial was in no case less than 2 trials for either group, and in no case more than 4 trials for either group.

## CONCLUSIONS

A. Greater retention loss occurs for procedural tasks than for tracking tasks.

B. Performance retention loss for procedural tasks of the dynamic type showed less loss than for other categories of procedures.

C. The amount of training did not influence the absolute amount of retention loss but the performance level of the more highly trained group was always superior to that of the lesser trained groups for both final training trial and retraining trials.

D. The number of retraining trials to attain the performance level found on the final training trial after a no-practice interval in excess of 120 days is greater for the group receiving the greater amount of initial training, in absolute number of trials but is generally less in relative number of trials.

E. Immediate performance after the no-practice interval is always superior for the greater trained group.

Naylor, James C., Briggs, George E. Effective Rehearsal of Temporal and Spatial Aspects on Long-Term Retention of a Procedural Skill. J. of Appl. Psychol., 1963, 47(2), 120-126.

PURPOSE

To examine the effects of temporal and spatial rehearsal on the retention of a procedural task skill.

METHOD

Subjects:
68 undergraduate volunteers participated as paid subjects.

Equipment:
A display-response panel was employed which had a column of 9 pairs of lights. Each light pair consisted of a red and a amber light. Associated with each light pair was a row of 3 buttons, labelled "o.k.", "emergency", and "check".

Procedure:
The experimental period lasted 30 consecutive days. During the first 5 days, all Ss received initial training. Their task was to respond to stimulus events with an appropriate button pressing response. This response was designed to "lock in" the amber lights. The order of presentation by rows was 1, 5, 2, 9, 8, 3, 6, 7, 4 and the temporal interval between events was 4, 8, 19, 4, 10, 6, 6, 8 secs, respectively. There were three possible conditions of simulus events: (1) Amber light, to which the correct response was to press the "o.k" button; (2) Red light, to which the correct sequence of button pressing was first the pressing of the emergency button (to eliminate the red light) and then pressing the o.k. button to lock in the amber light; (3) No light occurring during the proper temporal interval to which the correct response was: press a check button to activate either a red or amber light whichever occurred the subject was to respond as above.

Ten days after the final training session (day 15) of the experiment, 3 of the 4 groups of Ss received differential rehearsal. One group merely repeated the same task as encountered during initial training for the 4 day rehearsal period. The second group also rehearsed the task for a 4 day period with the exception that all stimulus events occurred 7 secs apart. The third group of Ss rehearsed for 4 days using the same temporal spacing as in the initial task, but the order of occurrence of the stimulus events of the display-response panel was top to bottom in order. The 4th group of Ss receive no-rehearsal training. On Day 30 of the experiment retention testing took place.

Independent Variables:

1. Rehearsal condition
    a) whole task rehearsal
    b) temporal rehearsal
    c) spatial rehearsal
    d) no rehearsal

Dependent Variables:

1. Errors of Commission
2. Errors of Omission
3. Reaction Time (the temporal interval between the onset of a stimulus event and the occurrence of the button response)

RESULTS

A. Effect of Rehearsal Condition on Omissive Errors - On the initial retention trial the groups receiving no rehearsal, temporal rehearsal only, and spatial rehearsal only, all produced nearly twice as many errors as the group who had received rehearsal identical with initial training. For the 5 retention trials, improvement was rapid and performance on the final retention trials being superior to performance on the terminal initial training trial for all groups except the group receiving spatial rehearsal. The differences between rehearsal groups, however, failed to be statistically significant.

B. Effects of Rehearsal on Commissive Errors - While rehearsal techniques did not differentially affect the performance during rehearsal performance, there were significant differences between groups after the retention period. (This period is 11 days after the rehearsal for 3 groups, and 25 days for the no-rehearsal group.) Significantly greater losses at retention test were exhibited by the no-rehearsal and the spatial rehearsal groups. Retention test performance was inferior to performance exhibited on the last training trial (final rehearsal trial for three groups and final initial training trial for a no-rehearsal group).

C. Effects of Rehearsal Conditions on Reaction Time - Time data were completely insensitive to the experimental conditions.

CONCLUSIONS

A. The beneficial effects of rehearsal was demonstrated only by the reduction of commissive errors.

B. Whole task rehearsal was found to be superior to other rehearsal conditions; nearly as effective was temporal rehearsal.

C. An additional correlational analysis between error scores showed that Ss were able to drastically reduce omissive errors by making a few commissive ones. This phenomenon occurred during initial training. This tendency is not seen during the rehearsal trial, but recurred again in the retention trials. The authors point out that emphasizing the omissive error aspect of performance permitted Ss to utilize immediate feedback conditions, i.e., the red light "locked on" whenever an error of this type occurred.

Naylor, J.C., Brigge, G.E., Brown, E. R. and Reed, W.G. The Effect of Rehearsal on the Retention of a Time-Shared Task. Technical Documentary Report No. AMRL-TDR-63-33, Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio, April 1963.

## Experiment 1

### PURPOSE

To determine the relative effects of three types of rehearsal on the retention of a task requiring time-sharing skills.

### METHOD

Subjects:
60 undergraduate males volunteered to serve as paid subjects.

Equipment:
The procedural task equipment consisted of a display-control panel containing nine pair of stimulus lights (each pair was composed of an amber and red light). The light pairs were arranged in a vertical column. To the left of each light pair were 3 response buttons labelled "emergency", "o. k. ", and "check". A tracking task display panel contained three pair of center-null-position meters mounted in two rows. The top row gave attitude error, and the lower row gave rate error. The meters responded to the movements of a three-dimensional control stick. The input signal was 0. 1. Control stick movement left to right influenced roll, front to back controlled pitch, and rotational movement affected yaw.

Procedure:
The procedural task required Ss to depress the "o. k. " button if an amber light occurred; to press first the "emergency" and then the "o. k. " button in response to a red light; and to press first the "check", next the "emergency" and, finally, the "o. k. " buttons in the event that no light at all was presented.

The tracking task simulated three attitude control dimensions of a vehicle in free flight; Ss were required to keep meters in the null position. On the first session each S had four 70-second trials on each of the two tasks (the two tasks were trained individually and sequentially, rather than simultaneously. Twelve trials per session of part-task training continued through the 4th session, with procedural task training preceding tracking task training. Session 5 initiated whole-task training and continued through Session 8.

Six days after the termination of training, 3 or 4 subject groups received rehearsal. Each group received a different rehearsal type. Rehearsal lasted two days, and then a 7-day retention interval was followed by retention testing. Rehearsal consisted of either part-task training, whole-task training, or simplified task training. Ss in the first condition consisted of 6 procedural trials followed by 6 tracking trials per session (one session per day was implied). The latter two rehearsal conditions consisted of 6 whole-task trials per session. The 4th group of subjects had no rehearsal.

Independent Variables:

1. Type of Rehearsal

   a) Whole task training (both tasks requiring simultaneous attention)

   b) Part-task training (tasks handled separately)

   c) Simplified task training (tracking tasks requiring nulling of attitude meters, rather than attitude and rate meters)

   d) No task rehearsal

Dependent Variables:

1. Procedural Task Measures

   a) Total response time per trial

   b) Number of commissive errors (number of excessive button presses over the required number of or incorrect presses)

   c) Omissive errors (failure to respond)

2. Tracking Task Measure - integrated absolute error on each dimension was summed for each S.

RESULTS

A. Effects of Rehearsal on Tracking Performance - Using absolute scores an analysis of variance failed to show significant differences between the groups. Analysis of variance was also applied to difference scores (final training session minus retention session means) and revealed significant differences between rehearsal groups. Although statistical significance was obtained, the difference never exceeded 0.034 inches (retention test producing the greater error scores). The relationship of this difference to the final mean training session score was approximately a 25% increase in error for groups under whole rehearsal and no rehearsal conditions. Differences for the other two rehearsal conditions were found to be less than 5% of the final mean training session value. When another difference measure was used (last training session mean score minus the first retest trial) no significant differences between groups were found

B. Effects on Procedural Task Performance - An analysis of variance using absolute retention test scores showed that both commissive errors and response time showed significant differences as a function of rehearsal type. When difference scores were used in an analysis of variance, no significant differences were found for either number of commissive or omissive errors. Whole rehearsal produced the fewest number of errors at retention tests (mean of six trials). The part rehearsal group evidenced a reduction in both types of errors at retention tests over final training session. Only the response time measure gave consistent retention decrement findings; no significant differences in either the absolute retention scores or the difference scores as a function of rehearsal. In general, there was a tendency in terms of difference scores to see that greatest skill retention was in evidence for the part rehearsal group. The next best performance was given by the simplified rehearsal group, followed by the whole rehearsal group. Greatest skill loss was evidenced in the no rehearsal group. This general trend was also in evidence for the tracking task.

CONCLUSIONS

Under the training conditions of Experiment 1, the effectiveness of the four rehearsal conditions appears as follows in descending order of effectiveness.

(1) Part rehearsal
(2) Simplified rehearsal
(3) Whole rehearsal
(4) No rehearsal

## Experiment 2

PURPOSE

To examine the effects of four rehearsal procedures and two levels of training on skilled performance retention.

METHOD

Subjects:
84 undergraduate males volunteered to act as paid participants. All Ss had prior experience in a study involving a three-dimensional tracking task.

Equipment:

As in Experiment 1

Procedure:
All Ss experienced either 5 or 10 days of training depending upon group assignment. Each group was matched on the basis of Ss performances in a prior study. Initially two days of part-task training was administered. This was followed by either 3 days or 8 days of whole-task training. The training period was followed by a 10 day no-practice interval. This interval was followed by 2 days of rehearsal. Each of the three groups in the 5 day training period received differential rehearsal. One group whole task rehearsal, one group part task rehearsal and the third group no rehearsal. The three groups in the 10 day training period were exposed to similar rehearsal training. Nine-day retention period followed the rehearsal. Retention testing took place on the day following the 9-day retention interval.

Independent Variables:

1. Amount of Training
   a) 5 days
   b) 10 days

2. Type of Rehearsal
   a) Whole rehearsal
   b) Part-task rehearsal
   c) No rehearsal

Dependent Variables:

1. Procedural Task Measures
   a) Commissive errors
   b) Omissive errors
   c) Response time

2. Tracking Task Measure - integrated error (summed across dimensions)

RESULTS

A. Effects on Tracking Task Performance - At the end of training both the one week and two week groups performed to reduce error with the 10 day training group having about half the errors as the 5 day training group on the final training session. No evidence of asymptotic performance is indicated. Performance during rehearsal clearly indicated superior results by the part-rehearsal group over the whole rehearsal group. Using difference scores at retention test and analysis of variance indicated significant differences as a function of amount of training and rehearsal type; whole rehearsal produced superior performance followed by part rehearsal, and poorest performance produced by the no rehearsal group.

   The integrated error was significantly less for the two week trained group than for the group receiving one week training. The one week trained group evidenced skill increase during the retention interval whereas the two week trained group showed little change in skill during the retention interval.

B. Effects on Procedural Task Performance - An analysis of variance on the difference scores showed that only commissive errors were found to be significantly different as a function of amount of training. No significant differences as a function of type of rehearsal was found for any of the three performance measures (final training performance levels were found to be significantly different in terms of both commissive and omissive errors; this effect is noted for the group receiving one week training; this finding emphasizes the need to use difference scores). The difference scores showed that the effects of type of rehearsal are extremely small for Ss receiving two weeks training. Using difference scores on the first retention trial showed whole rehearsal to be significantly superior to other rehearsal types for groups having one week training. No significant differences were found between groups having two weeks training. The effects of type of rehearsal tended to disappear when performance was averaged over the retention test session.

CONCLUSIONS:

A. In tracking performance whole task rehearsal is superior to part-task or no rehearsal. The effects of rehearsal decrease the greater the amount of original training.

B. The initial retention trial scores for the procedural task showed: that whole rehearsal was a more effective rehearsal type; that differences between rehearsal groups tended to disappear as training increased; that differences between rehearsal groups disappeared as the number of retention trials increases.

C. Integrating the results of Experiments 1 and 2, it was concluded that whole rehearsal was superior up to 5 days of training; part rehearsal superior after 8 days of training; and after 10 days of training no appreciable rehearsal effect was observed.

D. Groups receiving different amount of training in the two experiments also received differing proportions of their total training in whole task and part task conditions. The relative effects of rehearsal may depend on the method of original training as well as amount of original training.

Naylor, James C., Briggs, George E. and Reed, Walter, G. The Effects of Task Organization, Training Time and Retention Interval on the Retention of Skill. Technical Documentary Report No. AMRL-TDR-62-107, Sept. 1962, Behavioral Sciences Laboratory, Aerospace Medical Division, Wright-Patterson AFB.

PURPOSE

To investigate the effects of task organization and its interaction with amount of original training and length of retention interval on skill retention.

METHOD

Subjects:
128 male undergraduate volunteers were paid for experimental participation.

Equipment:
A procedural task panel was developed which contained 9 pairs of lights. Each pair contained an amber light and a red light and associated with each light pair were three buttons labelled "o. k.", "emergency", and "check", respectively. A tracking task panel was developed which contained 6 meters. Meter pairs were labelled "roll", "pitch", and "yaw". Each pair member indicated attitude error, or rate error. A three-dimensional control stick was also provided.

Procedure:
Ss were trained to press buttons in appropriate sequence in response to the presence of, or absence of, a light on the procedural task panel. The tracking task required Ss to null meter-displayed error by appropriate control stick manipulation. Initially, Ss were trained on both the tracking task and the procedural task in an alternating fashion. Later training was switched to whole-task training. Ss assigned to groups on the basis of their performance on first six days of training so as to minimize random error between groups.

Independent Variables:

1. Amount of Training
   a) two weeks
   b) three weeks
2. Retention Interval
   a) one week
   b) four weeks
3. Task Organization
   a) high
   b) low (High organization meant that the light pairs were systematically illuminated in order; Low organization, a fixed but unsystematic sequence was used.)

Dependent Variables:

1. Integrated absolute error for each dimension

2. Procedural task measures

   a) Response time
   b) Number of commissive errors
   c) Number of omissive errors

RESULTS

A. Tracking Task

1. Training Effects: As expected superior acquisition performance was attained by the group receiving the greater amount of training. Testing after the no-practice interval revealed that statistically significant superior performance was produced by the 3 week practice group.

2. Organization Effects - Using difference scores (last training session minus retention test score) significance was not obtained. Interaction significance was obtained between organization and amount of training. A very significant difference under the two week training condition was in evidence between the low organization group and the high organization groups.

3. Duration of Retention Interval: A decrement in performance was in evidence for the 4 week retention interval over performance levels for the one week retention interval. Difference scores failed to show significance in an analysis of variance but the absolute scores did indicate that the retention interval was a significant variable.

B. Procedural Tasks

1. Training Effects: This was found to be a significant variable in an analysis of variance of difference scores as well as in an analysis of variance of absolute scores using the omissive error measurement. Significance was obtained using the response time measure for absolute scores only.

2. Task Organization: Significance was obtained only in the absolute scores of omissive errors.

3. Retention Interval: Significance for both difference and absolute scores when using the commissive error measurements was obtained.

4. Interactions: Interactions between the amount of training and task organization was found to be significant using omissive error measurement for both difference scores and absolute scores. Thus, the importance of organization is reflected in this task as relative to low levels of training.

CONCLUSIONS

A. Training is a major significant variable in skill retention performance.

B. Task organization has a differential effect depending upon the amount of task training. It has greater influence the less the amount of training.

C. Within the interval studied, retention duration appears to have little influence.

D. The similarity in performance found between the two dissimilar tasks indicate that the effects noted here generally hold across both continuous and discrete tasks relative to skill retention behavior.

REVIEWER'S COMMENT

Several factors should be considered when utilizing the above data:.

1. Different performance measures were used for the two tasks.

2. Task organization was a different experimental variable in the two tasks.

3. The procedural task may have been too simple to permit behavioral changes under the experimental conditions. Authors' indicate that commissive errors and response time were unknown to the subject until the end of the day's session. Omissive error information had immediate feedback to the S.

Naylor, James C., Briggs, George E., and Reed, Walter G. Task Coherence, Training Time and Retention Interval Effects on Skill Retention. J. of Appl. Psychol., 1968, 52(5), 386-393.

PURPOSE

To examine the effects of "....two levels of secondary task coherence on primary (tracking) task performance during both learning and retention."

METHOD

Subjects:
128 male undergraduates volunteered to participate and were paid $1 per session for services.

Equipment:
A compensatory display control device was utilized which presented three center-reading voltmeters to the S. Each voltmeter represented system error information in a separate dimension. Each meter received an input signal of .6 cpm which required nulling by the manipulation of a single control having left-right, fore-aft and rotational control motions. A secondary procedural display control task was also employed. This device has red and amber light pairs arranged in a column consisting of 9 rows. Associated with each light pair on the row was a series of 3 response buttons labelled "o. k.", "emergency," and "check".

Procedures:
All Ss received identical part-task training through the first five training sessions except for a brief initial session; subsequent sessions consisted of twelve, 70-second trials per session. The tracking task was always practiced as a complete task.

The procedural task was administered so as to increase in complexity across the first five training sessions. The procedural tasks required the Ss to respond differentially depending upon the type of stimulus event, i.e., he was to respond to an amber light by depressing the "o. k." button. In the event of a red light he was to depress the "emergency" button first, causing the red light to be extinguished and the amber light to turn on, and then to depress the "o. k." button which "locked on" the amber light. If no light appeared during the event interval, the S was to first press the "check" button which activated the red light, then to depress the "emergency" button which extinguished the red light and lit the amber light, and finally to depress the "o. k." button which locked on the amber light.

The increasing complexity of the task training involved the type of stimulus events presented. During the first two trials only red or amber lights occurred. During the third session, S was presented with one non-light event, and later in that same session, two no-light events occurred. In the fourth session, three no-light events occurred, later shifting to 4 no-light events and finally during the fifth session, each S encountered four no-light events in each trial. After the 5th session whole-task training was given. On the basis of 6-session total tracking task performance, Ss were assigned to groups, each group totalling 16 Ss. Training then continued depending on group membership for either two or three weeks. Groups were then tested after appropriate retention intervals.

Independent Variables:

1. Training Time
   a) 2 weeks
   b) 3 weeks

2. Retention Interval
   a) 1 week
   b) 4 weeks

3. Task Coherence (refers to the order of light events on the procedural task)
   a) High (sequence was 1, 2, 3, .....9)
   b) Low (sequence was 1, 5, 2, 9, 8, 3, 6, 7, 4)

Dependent Variables:

1. Tracking error (measured during the same time that the procedural task events occurred) was taken as integrated absolute error and transformed into inches of deviations.

2. Monitoring Task Performance
   a) Total response time
   b) Number of omissive errors
   c) Commissive errors

RESULTS

A. Tracking Performance

1. Effects of Task Coherence on Integrated Error - During training integrated error was significantly greater for low coherence groups. After the no-practice interval, error difference scores (last training score minus retention test performance) failed to show significance as a function of task coherence. Significance was obtained relative to absolute skill level; high task coherence group (on the procedural task) produced superior retention performance on the tracking task regardless of amount of training or length of retention interval.

2. Effects of Training on Integrated Error - Groups trained for the longer period produced significantly superior performance at the end of their training period to that of the final training performance of the two week group. Significance was also obtained ( $p < .01$) in terms of difference scores, i.e., the losses after the retention interval were significantly less for the groups receiving 3 weeks training.

Retention performance for the group receiving 3 weeks training was found significantly superior, regardless of retention interval, to the performance of the group receiving two weeks training.

3. Effects of Retention Interval in Integrated Error - Losses (final training score minus initial retention) failed to produce significance as a function of the duration of the no-practice interval. Absolute retention scores, however, did reveal statistically significant differences at the .01 level. These differences showed that significantly greater retention losses occurred at the 4 week retention interval.

B. Procedural Task Performance

1. Effects of Task Coherence - The only significant effect occurred with omissive errors (in absolute scores). Training by coherence interactions were found significant both for the relative retention scores and absolute retention scores, showing that within the two week training group retention losses, both relative and absolute, were greater for the Ss having low coherence sequences.

2. Effects of Amount of Training - Only omissive errors as measured by relative retention loss showed significance ( p  .01). Absolute retention scores showed significant effects, the 3 week group showed significantly fewer omissive errors, significantly fewer commissive errors, and significantly briefer response times.

3. Effects of the Length of the Retention Interval - The only performance measure on which a significant performance decrement was produced was commissive errors, occurring at the longer retention interval (four weeks).

CONCLUSIONS

A. Predictably, superior performance was achieved after 3 weeks of practice compared to 2 weeks of training.

B. Superior compensatory tracking was achieved during training by groups concurrently engaged in a more coherent than less coherent secondary procedural task.

C. Significantly superior retention performance was achieved by groups having 3 weeks rather than 2 weeks of training.

D. Superior retention performance was achieved by Ss having the more predictable secondary task.

E. Significantly superior performance was evidenced by groups having a one week retention interval rather than a four week retention interval when measured in absolute scores.

F. The amount of loss in performance between final training and retention testing was found to be significantly less for the Ss having greater original training; least tracking performance loss occurred when Ss experienced both the predictable procedural task and two weeks of original training.

G. The training variable was the most influential variable investigated and can ameilorate the effects of low task coherence if a sufficient amount is possible.

Neumann, Eva and R. B. Ammons, Acquisition and Long-Term Retention of a Simple, Serial, Perceptual-Motor Skill. J. of Exper. Psychol. 53(3), 1957, 1599161.

PURPOSE

To examine acquisition and retention performance on a serial perceptual-motor task.

METHOD

Subjects:
Twenty male college students.

Equipment:
The device consisted of toggle switches arranged in two circles one inside the other. There were 8 toggle switches in each circle.

Procedure:
The task consisted in turning the switches in the inner circle to the "on" position in a clockwise order. After activating each switch in the inner circle, S then attempted to activate a "matched" switch in the outer circle. Correct matchings were signaled by a buzzer. The matching pattern was held constant throughout the experiment. S attempted to secure a matching at the rate of about 1 every 3 secs. Training continued until S achieved two successive errorless trials.

Independent Variables:

1. Length of the retention interval

   a) 1 minute
   b) 20 minutes
   c) 2 days
   d) 7 weeks
   e) 1 year

Dependent Variables

1. Number of correct responses.

RESULTS

1. Performance during Training - Ss were divided into retention groups and no significant differences between these groups were in evidence during the training. Approx. 57 trials were required to attain the criterion (averaging across subjects)

B. Retention Interval Effects - Performance on the first trial after the retention interval was significantly different between groups. A consistently increasing decrement in performance was associated with progressively longer retention intervals.

Retraining after the retention interval required more trials to regain the training criterion, the greater the retention interval duration. The one year retention interval group initially performed after the no-practice interval at the same level as they did at the beginning of training. At the end of 36 retraining trials they had regained criterion performance. Additionally, serial position curves were constructed for each of the retention groups. Marked serial position effect was noted; the poorest performance occurring at the 4th and 5th positions (typical of findings on serial position learning).

C. Ss reported on methods used to learn the positions permitting the formation of categories on the basis of amount of verbalization. No significant difference in serial position learning was found as a function of these categories.

CONCLUSIONS

A. Initial retention test performance becomes progressively worse as the retention interval increases.

B. The amount of retraining required to achieve final training performance levels is greater the longer the no-practice interval.

Swink, Jay, Trumbo, Don and Noble, Merrill. On the Length-Difficulty Relation in Skill Performance. J. of Exper. Psychol. 1967, 74(3), 356-362.

PURPOSE

To examine the effects of the length of a sequence for target location, task predictability, and training criteria on the retention of pursuit tracking skills.

METHOD

Subjects:
120 right-handed male undergraduate students aged between 17 and 24 years participated. Ss either received course credit or were paid for their services.

Equipment:
A pursuit tracking apparatus was utilized which displayed a one-half inch vertical hairline target on a CRT at any one of 15 equi-distant positions on the horizontal axis. A cursor line, displayed below the target and having an overlap of one-eight inch, was movable by means of a lateral arm controller. Various sequences of target appearances were accomplished by means of a punched tape program.

Procedure:
A four-way (5 x 5 x 2 x 2) factorial design was employed with six Ss randomly assigned to each of the 20 training conditions. Each group was later halved, permitting 3 Ss in each of the 40 retention conditions. Ss were all trained initially by giving detailed instruction describing the task and explaining the method of performance scoring as well as identifying principle sources of errors. Intermittent knowledge of results was also provided Ss.

Independent variables:

1. Sequence Length - The number of targets in a basic positional sequence was either 8, 12, 16, 24 or 48.

2. Task Predictability - Two Levels

   a) 100% condition wherein targets appeared in the same order and position on each repetition.

   b) 75% condition wherein every 4th target position was selected at random during each sequence repetition

3. Training Criteria

   a) Equal practice time - each S received 20 trials per day for 5 consecutive days.

   b) Equal Repetition - each S was presented 360 repetitions of a given sequence (exception - 48 target sequences received only 180 repetitions).

4. Retention Interval

   a) 3 month no-practice interval
   b) 5 month no-practice interval

Dependent Variables:

1. Absolute error integrated across each trial.

2. Temporal Index (an algebraic sum of lead and lag times scored to the nearest 50 millisecond and then divided by the number of targets in a trial.

RESULTS

A. Effects of Sequence Length - The effects of sequence length on integrated error show positive correlation with length of sequence when subjects are run under the equal practice time criterion. However, when Ss were run under the equal repetitions criteria, differences in performance relative to sequence length as measured by integrated error disappear. Within the variable task condition, sequence length is seen to be a significant variable with performance on the 12 target sequence significantly superior to that on the 8 target sequence regardless of the training criteria.

B. Effects of Task Predictability - Statistical significance was found at the .01 level with predictable sequences as low as 24 producing superior performance to any of the variable predictability sequence length. Even the 48 target sequence yielded terminal performance for the predictable task group superior to both the 24 and 48 sequence length variable group. (This finding for the equal practice time criteria.) In general, 24 and 48 target sequences gave rise to poor performance regardless of other conditions. The predictable task gave rise to significantly superior performance for both equal repetitions conditions and equal practice time condition. The equal repetitions criteria produced the best performance.

C. Effects of Training Criteria - No significant effects were found.

D. Effects of Retention Interval - The data collected indicated a constant improvement in performance positively correlated with the length of the no-practice interval. The authors rejected these data on the ground of equipment malfunction; they find the data beyond explanation or belief. It was seen that both task predictability and sequence length were the only two statistically significant factors affecting retention. No other variable or interaction was found to be significant.

## CONCLUSIONS

A. Sequence length has no effect on skill acquisition if each item within the sequence is presented an equal number of times.

B. Superior performance was obtained under the most predictable task conditions. Temporal measures of performance indicates a very marked increase in lead time for Ss trained under predictable task conditions.

C. The effects of two levels of training on performance were not significantly different after the no-practice intervals.

## REVIEWER'S COMMENTS

The attempt to investigate four independent variables utilizing a factorial design with so few Ss appears to have precluded well defined results. However, confirmation of the importance of the temporal factor during skill training is an important finding.

Trumbo, Don, Noble, Merrill, Cross, Kenneth and Ulrich, Lynn. Task Predictability in the Organization, Acquisition, and Retention of Tracking Skills. J. of Exper. Psychol., 1965, 70(3), 252-263.

PURPOSE

To examine the effects of task predictability on the temporal-spatial organization, acquisition and retention of tracking skill.

METHOD

Subjects:
250 righthanded male students aged between 17 and 26 years acted as paid participants.

Equipment:
A tracking apparatus was used which displayed a one-inch vertical hairline on a CRT. Also displayed was a vertical line cursor whose position on the CRT is controlled by a lateral arm controller. The tracking apparatus was constructed to integrate the difference between the target and cursor (momentary absolute error) across each trial. Furthermore, input, output and momentary error were automatically recorded; integrated error was recorded by E.

Procedure:
All Ss were first given seven 60-second trials followed on the next day by 20 trials. Initial training was followed by additional amounts of training depending on group (training-level) membership. Initial training included detailed instruction including various sources of tracking error. After the initial training Ss were given only feedback on their error scores after every fifth trial. The Ss specific task was to superimpose a cursor on the target hairline which could appear at any one of 15 equi-distance positions along the horizontal axis of the CRT.

Independent Variables:

1. Task Predictability

    a) Predictable - 12 targets appearing in the same order and repeated five times per trial for all trials.

    b) First Intermediate Predictability - every second target was selected at random using the predictable target sequence.

    c) Second Intermediate Predictability - every third target was selected at random from the original predictability sequence.

    d) Random Predictability - each target was selected at random each trial

2. Training Levels

   a) Low - additional 30 trials after initial training

   b) High - additional 80 trials after initial training over the next 3 days

3. Retention Intervals

   a) one week
   b) one month
   c) five months

Dependent Variables:

1. Integrated absolute error

2. For Ss in the high training, five month retention group, additional measures were taken:

   a) Indices of temporal accuracy viz. mean lag time, mean lead time and beneficial anticipation

   b) Indices of spatial accuracy viz. number of overshoots, number of undershoots, and number of accurate anticipations.

RESULTS

A. Effects of Task Predictability - Final training performance for both the high and low training groups was significantly superior to those Ss who had the predictable task target sequence. After the no-practice interval, Ss trained with the predictable sequence performed superior to Ss trained on other levels of task predictability. Performance on the initial recall trial for Ss receiving high training and the predictable task target sequence, after a five month retention interval, was superior to the performance of subjects receiving high training and random or intermediate task predictability, with a one week retention interval. Error after passage of the retention interval ranged from approximately 80% to 100% of the predictable group for the intermediate and random predictability groups. Little practical difference was seen between the random and intermediate prediction groups in either training or retention loss.

B. Effects of Level of Training - High level of training resulted in superior performance at all retention intervals.

C. Effects of Retention Intervals - In both the low and high training groups, a one week retention interval produced little, if any, decrement in performance With continued retraining, performance continued to improve, generally surpassing that of the final trials of initial learning. A slight decrement in performance is in evidence at a one week retention interval for the "predictable task" group. Retention intervals of one month and five months produced progressively larger decrements in performance, but with retraining, quick recovery is in evidence (although final performance at the end of the retraining did not reach initial training proficiency levels).

D. Special Results for the High Level 5-Month Retention Subjects

1. Temporal Accuracy: Lag time generally decreased throughout training and increased by about approx. 50% after the retention interval. Subjects in the more predictable task group were significantly different from other groups. Within group comparisons revealed that best subjects had fewer lags and shorter mean lag times than poorest subjects. (Provision had been made to compare the best 3 and poorest 3 subjects within each group; Ss were identified on the basis of integrated error for last block of training trials.)

   Groups with the most predictable task had significantly greater lead time than all the other groups; they also suffered the greatest losses between trials. After the retention interval, initial retesting showed almost a complete loss in lead time proficiency, but as in other performance, recovery was rapid. Ss in the intermediate predictability group appear to have suffered the largest loss of leading responses. Their counterparts in the random predictability group showed nearly twice the percentage of leads for best subjects. All groups increased in the percentage of beneficial anticipations during training. The percentage gained was statistically significant for all but the first intermediate predictability group. A great deal of variability is in evidence between training sessions. Less retention loss is seen on this measure than with either lead or lag time measures.

2. Spatial Accuracy: Only the predictable task group Ss reduced the percentage of overshoot errors during training. After the no-practice interval, performance had regressed for the predictable task group to the level at initial training. For other groups, performance level was worse than at any time through any part of the training. There is little evidence of change in performance data for undershoots. Performance stayed somewhat the same across training trials whish showed very little improvement; data after retention interval indicates little change from that during the training trials.

CONCLUSIONS

A. The level of uncertainity in a tracking task can have a profound beneficial effect on performance.

B. Retention losses are substantial over no-practice intervals for this type of tracking skill and appear to be positively correlated with interval length.

C. Both initial retraining performance and final retraining performance was superior for the high learning group over other groups.

D. The analysis of the temporal and spatial scores revealed that best subjects emphasized temporal accuracy over spatial accuracy; retention performance confirmed the prudence of this strategy. Temporal rather than spatial accuracy appears the more crucial aspect of skill retention and the most easily lost. The notion that temporal training rather than spatial training is the more effective in maintaining skill performance was seriously advanced

Trumbo, Don, Ulrich, Lynn, and Noble, Merrill E. Verbal Coding and Display Coding in the Acquisition and Retention of Tracking Skill. J. of Appl. Psychol., 1965, 49(5), 368-375.

PURPOSE

To examine the role of cue specificity on the acquisition and retention of tracking skills.

METHOD

Subjects:
120 right-handed male, undergraduates aged 17-26 years received course credit and/or money in return for their participation.

Equipment:
A display-control device was utilized to establish a pursuit tracking task. The device displayed on a CRT a 1/2 inch,vertical, hairline target on the horizontal axis at any one of 8 possible equi-distant positions. Additionally, a second line, the cursor, was displayed below the target line and overlapping it by 1/8 inch. The cursor was controllable by a lateral arm controller pivoted at Ss elbow.

Procedure:
All Ss received identical instructions on the task (positioning cursor on target) during the initial training trial, a demonstration of the equipment and an opportunity to control cursor. After initial familiarization, each S received 15 trials on the task. Each S was informed that the sequence of target appearance was fixed and that it was 12 events in length. On each of the 4 succeeding days, each S received 25 trials for a total of 115 training trials. All Ss returned after 31 days (plus or minus 2 days) for 20 retention test trials. Ss who were members of pretraining and rehearsal groups learned a sequence of 12 digits (the digits were between 1 and 8); each sequence was learned to a criterion of one errorless repetition. After meeting this criterion, each S made 15 additional repetitions. Immediately after pretraining or rehearsal S was taken to the tracking apparatus. Ss in the pretraining and rehearsal groups were also informed that the sequence they had been learning corresponded to the sequence of target appearance that would be displayed to them.

Independent Variables:

1. Training - 2 levels
   a) pretraining
   b) no pretraining
2. Rehearsal - 2 levels
   a) rehearsal
   b) no rehearsal

3. Displayed Specificity (Varied by means of transparent overlays)

   a) Low - no marking

   b) Intermediate - 8 one-inch vertical hairlines corresponding to possible target position

   c) High - 8 one-inch vertical hairlines, corresponding to possible target position, and numerals ranging from 1 to 8 engraved above the 8 hairlines.

Dependent Variables:

1. Integrated absolute error (an index of spatial displacement, integrated over a trial)

2. Paper and pencil test (to determine the degree to which Ss could reproduce the sequence of target positions by marking a booklet of diagrams while not present in the tracking situation)

3. 12 indices of continuous tracking performance were obtained.

RESULTS

A. Effects of the independent variables on integrated error performance. Both pretraining and display specificity produced small but nonetheless significant difference during training. By the end of training, however, performance for all groups was much the same. The effect of the one month no-practice interval was the same for all groups; a marked retention loss was in evidence, this difference between the initial retention trial and the final block of training trials was found to be significant at less than .001 level (t test). No significant difference in retention losses as a function of differential effects of display specificity, rehearsal, or pretraining was found.

B. Paper and pencil tests given immediately after the last training trial and before either retention or rehearsal began showed marked loss in retention after the no-practice interval. This difference was found to be statistically significant regardless of pretraining or no pretraining. Ss who used the numbered display performed better than their counterparts having either the grid or the blank display. While paper and pen test scores within each of the acquisition groups were not significantly correlated to integrated error scores at the close of training, it was found for the no pretraining, no rehearsal groups having the numbered displays, that a significant correlation existed with performance after the no-practice interval.

C. 24 Ss having best retention scores across groups and 24 having poorest retention scores across groups were compared. These Ss did not differ at the end of training. Retention loss, measured on the 12 indices of performance, showed 0% for best Ss, and 40% for poorer Ss in original gain. At retention test, best Ss showed 2% loss in lead time, maintained proficiency on frequency on target, and evidenced a slight increase in beneficial anticipations. Poorer Ss at retention showed a 14% loss in lead time, a 17% loss in beneficial anticipations, and a 30% decrease in the number of "on target" scores.

CONCLUSIONS

A. Pretraining and display coding are of value early in training but produce interfering effects later (possibly due to Ss shift of attention from perceptual to motor aspects of the task).

B. After a retention onterval of one month, no differential loss in performance as a function of pretraining or display specificity was seen. There remains the possibility that with longer retention periods, significant effects might arise.

C. Analyses between best and poorest subjects showed that the predominant source of integrated error was contributed by temporal factors rather than spatial inaccuracy.

REVIEWER'S COMMENTS

Rehearsal consisted of part-task practice (verbally repeating the target location sequence in terms of numbers). The effectiveness of whole task rehearsal on retention over a one month interval was not answered.

Trumbo, Don, Noble, Merrill, and Jay, Swink. Secondary Task Interference in the Performance of Tracking Tasks. J. of Exper. Psychol., 1967, 73(2), 232-240.

GENERAL OBJECTIVE

The following three experiments were an investigative attempt to examine the effects of secondary verbal tasks on skill retention of tracking performance.

## Experiment 1

PURPOSE

To examine the effects of primary task predictability and secondary task uncertainty on retention of tracking skill.

METHOD

Subjects:
54 male right-handed students aged 17-35 years were engaged as paid participants.

Equipment:
A display-control device was utilized which presented a 1/2 inch, vertical, hairline and a cursor hairline on a CRT. The cursor hairline appeared below the target line and overlapped it by 1/8 inch. Cursor position was determined by the position of an arm control which consisted of an armrest, pivoted at the elbow and a handgrip. Punched paper tape programs were used to control the position of the target line. The device permitted scoring to be achieved as integrated absolute error which relates the difference between target location and cursor position, and absolute integrated acceleration of control output. In addition, oscillographic recordings were made to permit the scoring of temporal and spatial accuracy.

Procedure:
Ss were instructed in the primary tracking task and sources of error were illustrated. During training on the primary task 48 targets were presented in each trial. A sequence of 12 targets were constructed by randomly drawing from 15 possible locations on the X-axis of a CRT display. This sequence of 12 was thus repeated 4 times in a trial and remained constant throughout all trials. Two other sequences were also constructed, I-3 sequence consisted of a sequence of 12 targets with every 4th target position drawn randomly from the 15 possible target locations, and I-5 consisted of a sequence of 12 targets in which every 6th target location was drawn at random from the 15 possible target locations.

One-third of the Ss were randomly assigned to each of the three target sequence conditions, viz. predictable (P), I-3 and I-5. In an attempt to attain equal performance levels at the end of training, the group assigned to the predictable condition received 15 trials in one session. The group assigned to the I-5 condition received 40 trials in two daily sessions, and the group assigned to I-3 received 65 trials in 3 daily sessions. After 7 days, Ss returned for 25 retention trials. Each of the 3 groups of Ss described above was divided into thirds; each subgroup being assigned to one of three secondary task conditions: (1) "no task" condition, (2) Secondary Task I, and (3) Secondary Task II. The latter two tasks involved the presentation of a series of numbers using the digits 1 to 5 via audio tape. These were presented in the last 39 seconds of the retention trial at the rate of 1 digit every 3 seconds. Both tasks required verbal anticipation of each digit in the series.

Secondary Task I used the probabilities .50, .25, .125, .0625 and .0625 for the digits 1 to 5 respectively.

Secondary Task II had equal first order probabilities but unequal second order (diagram). In this way each of the digits 1 to 5 was followed by one or two numbers which had probabilities of .9 and .1. The subject's task remained the same in both of these secondary tasks.

<u>Independent Variables:</u>

1. Primary Task Predictability

    a) P
    b) I-5
    c) I-3

2. Secondary Task Uncertainty

    a) No task
    b) Secondary Task
    c) Secondary Task II

<u>Dependent Variables:</u>

1. Integrated absolute error (interpretable in inches)

2. Absolute integrated acceleration

3. Temporal accuracy - lead and lag times scored to the nearest 50 milliseconds (msec)

4. Spatial accuracy - overshoots and undershoots scored to the nearest millimeter.

RESULTS

A. Effects of Predictability on Performance

At the end of training an F test failed to show significant difference between the training groups. The Predictable Task group did perform with approx. 15% fewer errors than the other two groups and the plot of errors versus trials indicate a sharp decrease in errors within increasing trials (steep slope) with no evidence of an asymptote having been reached.

After the retention interval, primary task predictability was found to be a significant variable at the .05 level. The most predictable primary task group evidenced approx. 30% increase in errors but rapidly regained former proficiency and continued to improve with further retention trials finally achieving performance superior to that achieved in initial training.

The I-3 group performed better than the I-5 group and continued to show improvement with increasing retraining trials, with final performance superior to that gained on initial training. The I-5 group showed little change in performance with further retraining trials (a probable anomalous effect according to authors).

Differences between last training and first retention trial in frequencies of leads and lags showed the predictable group with a mean decrease in frequency of leads equaling to 15.5, while the I-5 had 3.7 and the I-3 had .7. Increases in lags were noted with differences equaling 7.0, 1.7 and 1.0 respectively for the group having no secondary task.

B. Effects of Secondary Task

The effect of this variable on retention as measured by error scores was found to be significant at the .01 level. Decrements in performance were large enough to produce initial retention performance equivalent to that found at initial training. Improvement in performance with additional retraining trials was still significantly less than the improvement shown by the no secondary task groups.

Lead and lag differences between last training trial and the first retention trial, averaging across primary task conditions, showed decreased in lead frequency under either Task 1 and Task II conditions. These decreases in frequency were approx. 2.5 and 2 times as great as the decrease under the no secondary task conditions respectively. Increases in lag frequency also occurred under Task I and Task II conditions. These increases were on the average nearly 5 times as large as the increase observed under the no secondary task condition.

## Experiment 2

### PURPOSE

To determine the source of the secondary task interference producing performance decrements in Experiment 1.

### METHOD

Subjects:
48 high school males, aged 15-16 years, acted as paid participants.

Equipment:

The same as used in Experiment 1.

Procedure:
Ss were divided into two equal sized groups. One group received one day's training (i.e., 15 trials), and the other received 3 day training (i.e., 55 trials) on the tracking task. All Ss returned in one week for retention testing. Each of the two training groups was then divided into four subgroups on the basis of performance during the final block of training trials so that Ss were matched within each training level. The four subgroups corresponded to four secondary task conditions. One condition (ST) was identical to the Task II condition in Experiment 1. The second condition (the stimulus (s) of Experiment 1) was presented to Ss but they were told that they need not do anything about it and go on tracking, performing as well as possible. In the third, response (R) condition, a succession of relay clicks was presented to Ss. They were instructed to respond to each click by calling out a number between 1 and 5 without repeating numbers and to do the best job possible on tracking. The fourth secondary task condition was "no task", similar to that used in Experiment 1.

Independent Variables:

1. Training Level

   a) high
   b) low

2. Secondary Task Condition

   a) ST
   b) S
   c) R
   d) No task

Dependent Variables:

The same as in Experiment 1.

RESULTS

A. Effects of Training - During skill acquisition (training) the lesser trained Ss had approx. 16% more errors at the end of training than did the longer trained group. Retention loss was very marked on initial testing after the no-practice interval. The longer trained subjects showed an average initial retention loss at initial test which very nearly equaled performance for lesser trained subjects at the end of 20 retraining trials.

B. Effect of Secondary Task Condition - After the no-practice interval, Ss in the ST group and the R group performed very similarly to each other and to the Ss in Experiment 1 under Task 1 and Task 2 conditions. These same Ss gave consistently inferior performances to those Ss in groups S and No-Task. Performances by Ss in the latter two groups were quite similar to each other. The increase in lag frequencies for the ST and R groups was nearly 3 times that of the increase for the S and No-Task groups under the longer training conditions after the retention interval.

## Experiment 3

PURPOSE

To determine the effects of retention interval and secondary task interaction on skill retention.

METHOD

Subjects:
24 male university students participated as subjects.

Equipment:

Same as in Experiments 1 and 2.

Procedure:
All Ss received training identical to that in Experiment 2 for the first 2 days for a total of 35 trials. Ss were randomly assigned to three equal sized groups; A, B, and C. On Day 3, Groups B and C continued as before with an additional 20 trials on the primary task. Group A received 5 additional trials on the primary task and then 15 trials on the secondary task. After an 8 day no practice interval, Groups B and C returned for 20 additional trials. For Group B the secondary task (ST) as in Experiment 2 was introduced. For Group C no secondary task was used.

Independent Variables:

1. Period of secondary task introduction

    a) Before retention interval
    b) Immediately after retention interval
    c) No task

Dependent Variables:

As in Experiment 2.

## RESULTS

The introduction of the secondary task produced sharp decrements in performance. Secondary task introduction produced a performance level equal to that seen very early in training. The differences in absolute decrement between Group A and Group B (i.e., difference in size of decrement before or after the retention interval) is equal to the decrement suffered by Group C upon initial test after the retention interval.

## GENERAL CONCLUSIONS

A. Retention of skill performance after a no-practice interval is significantly less when a secondary task is introduced than when no secondary task is presented.

B. The effects of training are independent of the effects produced by the introduction of a secondary task introduced at the end of the retention interval.

C. The decrement in performance attributable to the introduction of a secondary task is independent of the decrement produced by an 8-day retention interval.

D. The decrement produced by the introduction of a secondary task arising from the response interference between primary and secondary tasks, that are introduced during training, are independent of retention interval effects.

## REVIEWER'S COMMENTS

Clearly there are significant implications of this investigation to applied settings with time-shared tasks. In operational situations time-shared task performance may not always be of secondary importance. The absence of performance data on the secondary task in the present investigation is unfortunate since an appraisal of overall performance cannot be made without these data.

Youngling, E. W.; Sharpe, E. N.; Ricketson, B. S.; McGee, D. W. Crew Skill Retention for Space Missions Up to 200 Hundred Days. McDonnel-Douglas Astronautics Co., Eastern Division, Report F7666, Dec. 15, 1968.

PURPOSE

To determine the effects of: (1) amount of training, (2) visual obstruction, (3) control difficulty levels, and (4) duration of the retention interval on the retention and image motion compensation skill.

METHOD

Subjects:
Ninety-six male volunteers from the engineering and computer staffs at McDonnel-Douglas Corp. participated.

Equipment:
A device was utilized which simulated the visual dynamics of an earth orbital flyby at 100 nautical miles. The dynamic portion of the apparatus permitted a pencil stick controller to produce image motion compensation (IMC) of a photographic mosaic depicting an earth target area. Disturbances in the simulated motion of the mosaic were introduced into the optical system (simulated thruster firings). The equipment was calibrated daily and revealed no systematic shifts.

Procedure:
Initially subjects were divided into two equal groups. Each group received training on the IMC task; one group for 60 trials, the second group received 120 trials. In all of the trials the subjects task was to null the motion of the displayed photo mosaic by means of a pencil stick controller. After training the subjects were randomly assigned to retention intervals of either 30, 90 or 200 days. On the day of retesting, 25 retraining trials were administered and were identical to those given during training.

Independent Variables:

1. Amount of Training
   - a. 60 trials
   - b. 120 trials
2. Retention Intervals
   - a. 30 days
   - b. 90 days
   - c. 120 days
3. Atmospheric Degradation (simulated clouds)
   - a. 0% cloud cover
   - b. 50% cloud cover

4. Difficulty Level

(4 performance tolerance levels were imposed on all subjects: 40, 60, 80 and 100 microradians per second; i.e., these were the maximally tolerated smear rates)

Dependent Variables:

Performance was measured in terms of the number of the seconds during a 40 second trial during which the subject successfully nulled image motion within the constraints of the four levels of difficulty. (Skill loss was indicated by subtracting the duration of time that motion was nulled during the first retention trial from the mean time that motion was nulled during the final 15 training trials.)

RESULTS

A. Effects of Amount of Training

1. An analysis of variance showed that this variable is significant ($p < .01$) on the amount of skill retention. This variable was not significant with respect to retraining.

2. The performance loss for the 60 trials group was twice as large as that for the 120 trial group (viz. 5.46 seconds compared with 2.41 seconds, respectively).

B. Effects of the Duration of the Retention Interval

1. An analysis of variance showed a significant effect on skill retention. A nearly linear relationship was found between the length of the retention and performance loss. Skill loss amounted to 1.33 seconds after 30 days, 3.28 seconds after 90 days, and 7.19 seconds loss after 200 days without practice. The difference between the 30 day group and 200 day group was significant at the .01 level.

2. A significant difference in the rate of reacquisition of skill was found between the 30 and the 200 day retention interval groups. There was virtually no difference between the 30 and 90 day groups. For the 30 day group there was a mean improvement in IMC skill 0.2 sec, while the 200 day group evidenced a 2.8 sec skill loss.

C. Effects of Atmospheric Degradation

Significance was not obtained for this variable for either the first retest trial or for reacquisition performance.

D. Difficulty Levels

1. Performance loss ranged from 3.31 sec at the most difficult level (40 microradians/sec) to 4.38 sec at the easiest level (100 microradians/sec). The fact that performance at the more difficult level was retained better than performance at the easier level was unexpected; when the relative skill loss is considered (% of skill retained) greater loss was found to have been incurred at the more difficult levels.

2. No significant effect was found on IMC skill reacquisition.

CONCLUSIONS

A. The greater the amount of training the greater the degree of skill retention.

B. Skill loss was found to increase linearly with the duration of the retention interval.

C. Reacquisition of skill was more rapid by the 30 day retention interval group than the 200 day group.

D. Interactions of significance were found between atmospheric degradation and amount of training, and difficulty levels for both skill retention performance and reacquisition performance indicating that the dependencies between these variables require further clarification.

## Summary Abstracts

The following are short abstracts of significant reports of primarily a theoretical or review nature. In addition, research reports providing data which support the understanding of the variables impacting the skill degradation process are included. Table III lists the summary abstracts by author's name, bibliographic number, and page.

Table III. Summary Abstract List

Bahrick, Harry P. Retention Curves: Facts or Artifacts? Psychological Bulletin, 1964, 61(3), 188-194.

Retention curves based on recognition scores may be comparable in slope and amount of retention to curves based on recall and anticipation performance. Previous contrary conclusions are over generalized. They are the result of the selection of easy recognition tests and failure to control the variable of overlearning. Measures of recognition, re-recall and anticipation are dichotomous, and slopes of curves based on such measures are artifacts of the changing sensitivity of the measure. The curves can, therefore, not provide the basis for general conclusions regarding forgetting over different periods.

(Author Abstract)

Bahrick, H. P. The Ebb of Retention. Psychological Review, 1965, 72, 69-63.

Initially a critique is presented of the methods of representing retention: dichotomous scores and savings scores. Both of these conventional techniques are shown to have limited utility since they both produce confounded measurement values. The author proposes a new method for retention representation which utilizes variance units. He terms these units "ebbs" and shows that it is necessary to use them as measures of the change in the mean of the associative strength distribution. This permits observation of the rate of weakening of associations during different temporal intervals. Assumptions underlying the new method and indirect evidence for its support are presented.

Battig, W.F., Nagle, E.H., Voss, J.F., and Brogden, W.J. Transfer and Retention of Bi-dimensional Compensatory Tracking after Extended Practice. American Journal of Psychology, 1957, 70, 75-80.

An experiment was performed to determine if the acquisition of skill at high levels of performance influences the retention of that skill after 8 months of no practice. Ss were required to keep a target circle (driven by a target course generator) within 1/2 inch square on a CRT. Four Ss were given 100 practice sessions. Asymptotic skill acquisition was seen at the 80th session. On session 101 and 102 the target sourse was reversed. Sessions 103 and 106 provided standard practice. On sessions 107 to 110 the direction of the control movement was reversed. Sessions 111 to 114 provided standard practice. Analysis of variance failed to show significantly different retention test scores from final acquisition scores. The results further indicated that positive transfer was seen for target course reversal, but large negative transfer was seen under control movement reversal. Under this latter condition performance was so poor that the unattended target display produces scores superior to those when Ss attempted tracking (very serious distruption of performance was observed).

Bilodeau, Edward A. Retention. In E. A. Bilodeau (Ed.) Acquisition of Skill, N. Y.: Academic Press, 1966, 315-350.

A discussion of both verbal and motor tasks is presented. In both cases the need to measure response consistency is advanced. It was suggested that statistics of change such as variance and correlation may prove to be valuable tools in the measurement of forgetting. The argument was advanced that a simple tally of events is inadequate to fully describe response changes. A novel idea that forgetting could be a process different from learning was discussed.

Brelsford, John W. and Atkinson, Richard C. Recall of Paired-Associated as a Function of Overt and Covert Rehearsal Procedures. Technical Report No. 114, Institute for Mathematical Studies in the Social Sciences, Stanford University, Stanford, California. NASA Accession No. N67 34286, July 21, 1967.

The effect of memory of the mode of studying paired-associates was investigated using a continuous presentation technique. Overt rehearsal was found to be superior to covert study for all Ss. Furthermore, the form of the forgetting curve was qualitatively different for the two study procedures. The overt-rehearsal curve dropped slowly at first then very rapidly defining an S-shaped function, whereas the curve for the covert study decayed exponentially. A mathematical model employing a short-term rehearsal buffer and a long-term memory state accurately predicted the data obtained under the two study conditions.

(Author Abstract)

Duncan, Carl P., and Underwood, Benton J. Retention of Transfer in Motor Learning After 24 Hours, and After 14 Months. J. of Exper. Psychol., 1953, 46 (6), 445-452.

The acquisition and retention of perceptual motor task transfer was examined as a function of amount of training and amount of similarity between tasks. Two tasks were learned. The tasks required a control stick to be pushed into an appropriate one of six radially arranged slots in response to stimulus lights. The difference between tasks was that a different pairing of lights and slots was used. The transfer task was relearned after a 24 hour inverbal and again after a mean interval of 14 months. The results included the finding that performance after a 14-month interval was initially poorer than performance on the first acquisition trial. Retention performance was independent of degree of learning or amount of task similarity. Relearning after the 14 month no-practice interval was rapid and after completion of 10 trials was positively related to the degree of initial learning.

Ginsberg, Rose, McCullers, John C., Merryman, John J., Thomson, Calvin W. and Witte, Robert S. A Review of Efforts to Organize Information about Human Learning, Transfer, and Retention. Aerospace Research Medical Laboratory, March 1966, Technical Report No. AMRL-TR-66-23, Wright-Patterson, AFB, Ohio. (Clearinghouse Accession No. AD 635 491)

In this report, fourteen efforts pertaining to organizing available information on human learning, transfer, and retention are summarized and evaluated on six criteria: behavioral significance of category, scope, objectivity and reliability of categories, prognosis for the system, logical structure, and heuristic value of the system. Attention is also given several other sources of guidance for organizing information on human learning. The review indicates at least six major approaches to a taxonomy of human learning. The bases for these different approaches are: (1) general or limited theoretical factors, (2) conditions of learning including the learner, (3) individual differences, (4) physical characteristics of learning tasks, (5) task characteristics in relation to empirical variables, and (6) task charàcteristics in relation to learning principles. In some cases the approaches are combined. The major conclusion is that although some cintributions have been made to a general organization of information on human learning, intense and detailed efforts toward a comprehensive taxonomy are only in a preliminary formative phase. An empirically grounded and logically sound taxonomy of a wide range of learning situations will contribute substantially to the use of existing informa tion and to the guidance of future research.

(Author's Abstract)

Grimsley, Douglas L. Acquisition, Retention and Retraining: Training Category IV Personnel with Low Fidelity Devices. Human Resources Research Office, Technical Report 69-12, June 1969. (Clearinghouse Accession No. AD 692 115).

Armed forces personnel having AFQT scores under 30 were trained on simulation devices have three different levels of fidelity. The findings indicated that the low aptitude Ss learned the procedural task (involving an SCI in a Nike-Hercules system see abstracts on Grimsley 1969 a and b) with no practical differences in training time, initial proficiency level, or retention loss after an interval of 4 weeks and two additional weeks. (While low AFQT Ss required approx. 50 more minutes to train than did high AFQT Ss, the author discounts these data as of no practical importance.)

Grodsky, Milton A., and Flaherty, T. M. and Moore, Heber G. Crew Reliability During Simulated Space Flight. American Institute for Aeronautics and Astronautics, AIAA Paper No. 65-275, AIAA/AFLC/ASD Support for Manned Flight Conference, April 21-23, 1965, Dayton, Ohio

This paper presents a description of a simulation experiment involving a 7-day space mission. A large number of task variables and performance measures were investigated with the general finding that little degradation in performance was in evidence as a result of the 7-day continuous duration of the mission task. An exception to the general finding was that switching performance (establishing and returning the system to the proper state to accomplish certain functions) was found to degrade during certain portions of the mission.

Grodsky, Milton A. and Glazer, David L. Analysis of Crew Performance in the Apollo Command Module Phase II - Vol. I, Engineering Report No. ER 14396, The Martin Company, Jan. 1967. NASA Report No. N67 38806.

The effects of (1) checklists, (2) communication blackout periods, (3) control response to changing spacecraft inertia, (4) isometric exercise, (5) diurnal cycle variations, and (6) mission-to-baseline correlates were investigated relative to system and mission performance. Results include the general finding that high performance on all types of tasks were maintained throughout the duration of the mission. In addition, design and programmatic suggestions were derived from this study for incorporation into the Apollo program.

Grodsky, Milton A., Glazer, David L., and Hopkins, Albert R. Jr. Analysis of Crew Performance in The Apollo Command Module. Engineering Report No. ER-14264, The Martin Company, Baltimore, Md., June 1966.

A 7-day lunar landing simulation was performed utilizing 15 test pilots. Tasks performed during the mission were classified as flight control, switchings, and guidance and navigation. Errors arising during task performance were analyzed relative to nature, magnitude, direction and cause. Findings showed that, in general, performance was maintained at a high level throughout the entire mission. One exception was that variability in switching performance increased with mission time.

Grodsky, Milton A., and Lutman, C. C. Pilot Reliability and Skill Retention for Spaceflight Missions. Air University Review, May-June 1965, 22-32.

This article presents a discussion of recent studies concerned with pilot reliability under long duration spaceflight mission conditions. Performance tasks fell into one of the following categories: flight control, switching, information handling, procedural tasks, and navigation. Performance was examined after training during a 7-day simulated flight, after a no-practice interval of 30 days, and after a no-practice interval of 60 days. Only the 60 day retention condition gave evidence of any significant decrement in performance.

Grose, Joel E. Inter-, Intra-Variability of Motor Performance. The Research Quarterly, 1967, 38(4), 570-575.

The analysis of the variability in three motor tasks by conventional methods (i.e., examination of the observed scores distribution) indicates no significant change in the first third to the last third of the trials. It is found that practice does not cause individuals to become more alike or less alike, but does make the individual less variable, (more consistent) in coincidence timing.

Practice failed to cause any change in the variability among subjects, but it did cause the variability within subjects to decrease 14% in finger response, and 27% in the arm and whole body response.

(From Author's Summary)

Hornby, R.C. and Wilson, R. The Effects of Extended Practice on Performance in a Tracking Task. C.P. No. 1030, Dept. of Aeronautical Engineering, The Queens College of Belfast, Dec. 1967. (NASA Accession No. N69-25756)

Experimental measurements of human controller performance have been made during extended periods of practice in visual sine wave tracking tasks. It has been found that, irrespective of task difficulty, rms error scores decreased to such small magnitude that differences in scores due to different task variables would have no practical significance. Thus, the average values of steady scores when tasks are well learned are meaningless for subject or task comparison. It has been shown that performance scores vary in an exponential manner with the number of task repetitions and it is proposed that an empirical constant related to the rate of decrease of scores be used as a measure of relative task difficulty.

(Author Summary)

Jahnke, John C., and Elkin, Carl P. Reminiscence and Forgetting in Motor Learning After Extended Rest Intervals. J. of Exper. Psychol., 1956, 52(5) 273-282.

An investigation was carried out to determine the dissipation of reactive inhibition over long periods utilizing massed and distributed practice training techniques and retention intervals of 10 minutes, 1 day, 1 week, 2 weeks, 3 weeks and 4 weeks, Training on a pursuit rotor was given to 22 groups of 20 men each.

Findings included: when initial retention test was averaged over the 1 to 4 week period, the massed practice group performed poorest; Ss trained under a distributed practice schedule of 10 sec work/20 sec rest performed best and maintained their superiority throughout the retraining trials; distributed practice trained subjects showed superior performance during training compared to massed practice Ss. After 10 retraining trials, distributed practice Ss trained on a 5 sec work/25 sec rest schedule performed significantly poorer than the massed practice subjects.

The performance increase from the first retention trial to the 5th was seen as accruing to warmup. With most groups the need to warmup increases up to the first two weeks of the no-practice interval. After this period the need decreases for all groups except the distributed practice group having the 10/20 schedule. For this group after a slight decrease at the 2 week period, a sharp increase followed at the 4th week. The residual traces of reactive inhibition appear to have trace presence after a one-day retention period, but dissipation appears complete after one week.

Lavery, J. J. Retention of a Skill as a Function of Display/Hand Movement Ratio During Training. Perceptual and Motor Skill, 1964, 19, 626.

An experiment was performed to determine the effects of amount of information contained in knowledge of results (KR) and the cues inherent in a task on skill retention. The position of a lever control was displayed by means of an oscilloscope utilizing display/hand movement ratios of 0.5:1, 1:1, and 2:1. Ss were 36 housewives aged 21 to 35 years and were trained for 120 trials on lever positioning under one of the three display/hand movement ratios. Next, 80 retention trials were given on Day 1 and 120 trials one week later. No differences between groups were found for the first set of retention trials, but on the final set both the 2:1 and 1:1 ratio groups were superior to the 0.5:1 ratio graoup, showing that KR can influence retention if suffucient information in the task is available.

McDonald, R. D. Retention of Military Skill Acquired in Basic Combat Training. Technical Report 67-13. Human Resources Research Office, Dec. 1967 (Clearinghouse Accession No. AD 663 785)

The retention of skills in three areas of military training was examined as a function of a one year retention interval. Finally, training performance was assessed on the basis of scores attained on standard tests used in performance evaluation during basic training. The three tests which were given were:

(1) The basic rifle markmanship test which involves proficiency at firing a rifle at pop-up targets.

(2) The end-of-cycle test which is composed of eight sub-tests. Military courtesy and general subjects, military justice and code of conduct are both paper and pencil tests. The remaining six, drill and ceremony, first aid and individual protective measures, guard duty and reporting, individual tactical training, hand-to-hand combat, and baynoted, are tests of motor performance.

(3) The physical combat proficiency test is composed of sub-tests for the one mile run, the 40 yard low crawl, the horizontal ladder, the dodge run and jump, and the grenade throw.

A general decrement in rifle markmanship was observed but it failed to reach statistical significance. A slight decrement in performance as a function of no practice was observed for the physical combat proficiency test. The end-of-cycle test showed the greatest retention decrement, with retention test having 50% of the score of tests administered during basic training.

Reviewers Note: The above findings must be utilized carefully since details of the experimental method are incomplete (i.e., there is some indication that warmup was permitted prior to retention testing).

Naylor, James G. and Briggs, George E. Long-Term Retention of Learned Skills: A Review of the Literature. ASD Technical Report 61-390, Behavioral Sciences Laboratory, Aeronautical Systems Division, Wright-Patterson AFB Ohio, August 1961. (DDC No. AD 267 043).

The review classifies variables of potential importance in the investigation of long-term retention of learned motor behavior as: (1) those dealing with the type of task, (2) those concerned with learning parameters, (3) those concerned with retention interval parameters, and (4) those concerned with recall parameters. The general findings of the review are that: (1) the retention problem has not been very thoroughly explored, (2) that only limited research has been conducted on any one of the potentially large number of important variables, and (3) that certain variables such as organization and methods, such as scoring, should be considered of key importance in any research program investigating skill retention.

Noble, Merrill, and Trumbo, Don The Organization of Skilled Response. Organizational Behavior and Human Performance, 1967, 2, 1-25.

A number of experiments performed by the authors and their associates were reviewed relative to task coherence and skill acquisition, long-term retention and task coherency, task variables (e.g., target velocity, task coding, and secondary task effects) and response strategies. Retention loss is discussed in terms of spatial uncertainty and temporal uncertainty. In general, it was found that Ss performing under the least uncertain task conditions had the greatest retention losses. It was found that Ss response strategies vary with the degree of uncertainty present in the task. Other task variables were also identified and discussed.

Pepper, Ross L. and Herman, Louis M. Decay and Interference Effects in the Short-Term Retention of a Discrete Motor Act. J. of Exper. Psychology, Monograph Supplement, 1970, 83-No. 2, Part 2).

A series of four studies were reported which examined the effects of: (1) the length of the retention interval, (2) rehearsal opportunity during the retention interval, (3) the application of various magnitudes of interpolative forces applied in the same or opposite direction to a criterion force, and (4) the number of repetitions of the force response occurring prior to the retention interval. On the short-term retention of applied force, results showed that over retention intervals ranging from 4 to 60 seconds, a performance decrement was not found. Under conditions of filling the retention interval with unrelated verbal counting activity, it was found that errors decreased with increasing retention interval. However, error scores decreased for control subjects also. The performance of the control group was found to be significantly superior to that of the experimental group. Under conditions of an interpolative force during the retention period and active verbal counting during a fixed retention interval of 20 seconds, consistently larger errors occurred with the counting activity. Recall response occurred in the direction of the relative magnitude of the interpolative force to the criterion force. The effects of successive repetitions of the criterion force under the conditions of a 20 second retention interval was found to yield increasing errors. Experimental results are all characterized by overshooting responses during recall. The results are interpreted in terms of advanced dual process theory of motor short-term memory.

Riveness, Richard S. and Mawhinney, Martha M. Retention of Perceptual Motor Skill: An Analysis of New Methods. The Research Quarterly, 1968 39(3), 684 - 689.

New methods for determining the amount and type of forgetting pioneered by Bilodeau, Sulzer and Levy were applied to gross perceptual motor skill retention. The changing interdependencies in time of the learned response, recalled knowledge of results after an interpolated rest interval, and post test performance were studied. No evidence of forgetting occurred except for the recalled knowledge of results measure which deteriorated in accuracy over a 21 to 23 day rest interval. Limitation of the new paradigm were discussed.

(from Author Abstract)

Roehrig, Wm. C. Psychomotor Tasks with Perfect Recall After 50 Weeks of No Practice. Perceptual and Motor Skills, 1964, 19, 547-550.

A study is reported which employed a balancing device. This device required Ss to stand on a board supported by a laterally movable fulcrum. Ss received various amount of extensive practice and then after 50 weeks without practice received retention testing. Their curves of skill acquisition show a continuation in training without loss or gain after the retention interval. The author offers high motivation and intelligence on the part of the Ss (staff members at N. Y. State Psychiatric Institute) as a possible explanation of the unusual results.

Silver, R. J. Effect of Amount and Distribution of Warming-Up Activity on Retention in Motor Learning. J. of Exper. Psychol., 1952, 44, 88-95.

An investigation was undertaken to determine: (1) the relationship between amount of warmup and amount of training, (2) the relationship between massed warmup and retention loss, and (3) the relationship between distributed warmup and retention loss. Ss were trained in a task requiring alphabetical letters to be written upside down from right to left. The retention interval was ten minutes.

The authors summarized results and conclusions are:

(1) The Ss who received warming-up activity were significantly superior in performance on the trial following rest to those who had rest only, with no warming up activity.

(2) The amount of warming up activity necessary to reinstate the set was found to be an increasing function of the amount of pre-rest practice. This was interpreted as indicating that the number of perceptual-motor adjustment acquired during learning increased with increasing amounts of pre-rest practice.

(3) With increasing amounts of massed warming-up activity there was a tendency for retention to increase up to a point and then decline. This decrease indicates that $I_R$ (reactive inhibition-Reviewer) built up during the practice on the warming-up activity summated with the $I_R$ accumulated during the practice on the main learning task.

(4) Increasing amounts of massed warming-up activity beyond a certain point did not result in a further increase in performance. It was suggested that beyond a certain amount of warming-up activity, the ration between the amount of set reinstated and the amount of $I_R$ accumulated becomes constant.

(5) Because the accumulation of additional $I_R$ was prevented, distributed warming up activity resulted in greater increments in performance than did massed warming-up activity.

(6) Increasing amounts of distributed warming-up activity resulted in progressively greater increments in performance. The possibility was considered that the adoption of a particular set may have been facilitated by constant shifting from working to resting with the distributed warming-up activity.

Stebbins, Richard J. A Comparison of the Effects of Physical and Mental Practice in Learning a Motor Skill. The Research Quarterly, 1968, 39(3), 714-720.

This study sought to determine the relative effectiveness of mental and physical practice upon the learning of a selected motor skill and the possible differential effects of mental practice during different stages of the learning period.

93 male volunteers were used as subjects. They were randomly assigned to the following five treatment conditions: controlled, mental practice, physical practice, mental-physical practice, and physical-mental practice. Practice consisted of throwing rubber balls at targets from a distance of 15 feet. The practice periods lasted for 18 days.

Initial and final tests were administered to determine the increase in skill. Data, which consisted of game scores, were analyzed using analysis of variance. The results indicated that the only significant improvement occurred in the combination type treatment conditions. Trend analyses were used to evaluate changes in the daily practice scores. The results showed that either mental or physical practice was equally effective during the first half of the skill development period.

(Author's Abstract)

Underwood, Benton J. Motor-Skills Learning and Verbal Learning: Some Observations. in Acquisition of Skill, Edward A. Bilodeau (ed.), 1966, Academic Press, N. Y.

The author ends a discussion on retention of skills with the following remarks. "Our general conclusion is that an increase in the variance as a measure of forgetting can be a very meaningful measure in certain situations. However, we will expect this increase to be accompanied by substantial correlation between original learning and retention and those correlations will decrease substantially with time. If they do, and if decrease can not be attributed to an artifact, such as many subjects fall into a zero level of performance, we are faced with a very difficult interpretative problem. On the basis of previous evidence it seems unlikely that we will have to face the problem."

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