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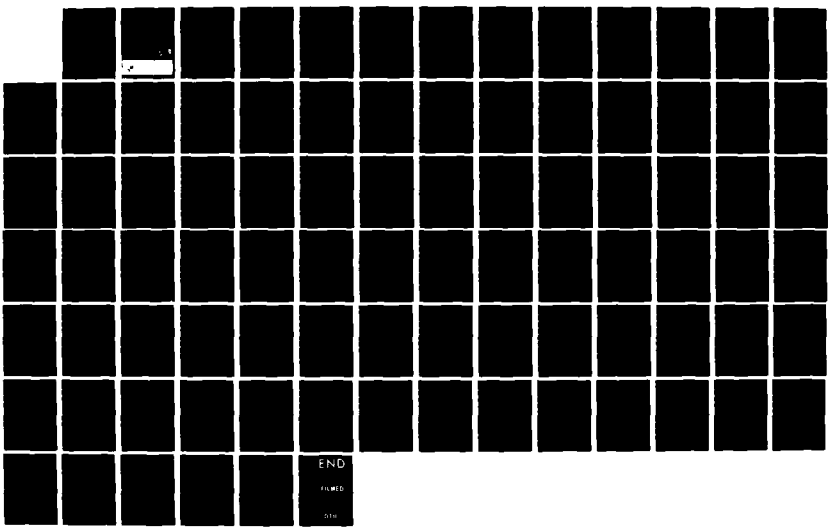

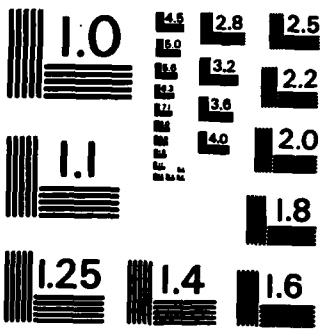

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SKILL LOSS: A REVIEW OF THE LITERATURE AND RECOMMENDATIONS FOR RESEARCH

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SKILL LOSS: A review of the literature and recommendations for research.

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SKILL LOSS: A REVIEW OF THE LITERATURE AND RECOMMENDATIONS FOR RESEARCH

(Summary Version)

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1. The rate at which skill is lost (or forgotten) during extended periods without practice and the ease with which unpractised skills may be refreshed by retraining are matters of consequence for those responsible for organising training. in industry. This review was carried out to find the answers to some of the key questions relating to skill loss and to identify areas where further research is needed.

2. The questions posed by the Directorate of the TSA were as follows:

   (i) What is the rate of performance decay in terms of terminal performance criteria of training over a wide range of skills and tasks ?

   (ii) Is skill loss in non-relevant employment greater than skill loss in unemployment ?

   (iii) What effect do different training techniques have on the retention of skills ?

   (iv) Is the rate of skill loss different for a trainee who remains unemployed after training compared with a person who has practised the skill and then become unemployed ?

   (v) Is the time to impart a new skill greater/less than the time to refresh an old skill?

   (vi) What is the value of output loss versus refresher training cost ?

   (vii) Does skill loss vary with age ?

3. The literature on skill loss goes back to the early years of this century and over 120 items were reviewed. Although the field of "memory" is currently subject to intensive research effort the work is concentrated on verbal memory and much of it has little immediate relevance to problems of industrial training in manual skills or mixed intellectual/manual tasks. The review concentrated on the retention of perceptual-motor skills.

4. The majority of studies concerned artificial laboratory tasks and the subjects mostly students or servicemen. However, a few studies of workers in real task situations seem, in general terms at least, to conform to the pattern of laboratory findings.

5. A number of unsolved methodological problems have come to light. The problems which most seriously affect general conclusions are the lack of a method for comparing performance and retention on different types of task and the lack of a generally agreed method of classifying real life and laboratory tasks.

6. Some 22 generalisations were drawn from the literature but these may be accepted with various, and sometimes not very great, degrees of confidence. The more important are as follows:

   6.1 Well-learned skills are generally well retained over periods of a year or more without practice.

   6.2 Although it is generally held that motor skills are better retained than verbal knowledge this generalisation cannot be sustained with confidence, largely due to methodological difficulties in comparing unlike tasks using different indices of performance.

6.3 Although procedures, for instance emergency drills, seem to be particularly sensitive to skill loss through lack of practice and more coherent or integrated tasks may be better retained, not enough is known about those characteristics of tasks which favour retention.

6.4 Different training methods have not been shown unequivocally to result in different degrees of retention and more work is needed on the effectiveness of new methods in promoting retention.

6.5 Activities in the lay-off period can either facilitate of interfere with retention. Changes in the direction in which machine controls operate certainly interfere with retention but little is known about the real-life effects of unemployment or unrelated employment on the retention of skill.

6.6 A skill which has deteriorated through lack of practice is very readily revived being normally relearned in a fraction of the original learning time. A skill may also be "refreshed" by rehearsal and this can often be effective even when rehearsal involves the use of simplified mockups. It would, however, be useful to know more about the optimal characteristics and timing of rehearsal.

6.7 Retention is generally a function of the degree of original learning, the better the original learning the better the retention. Nevertheless, additional practice beyond the level of mastery yields diminishing returns.

6.8 There may be problems surrounding the return to work after a long layoff. Whilst some tasks may actually benefit from a "rest" others require a "warm-up" period before the original skill is regained. Recalling an unpractised skill may be stressful and stress may itself affect retention.

6.9 Both specific ability on the task and general ability probably affect retention but there is little evidence to support the common assumption that older workers have worse memories. Further work on the effects of ability and age on skill loss and retention is needed.

7. Tentative answers to the original seven questions may be made along the following lines:

7.1 We cannot say whether particular tasks or trades are subject to different rates of skill loss, partly for methodological reasons to do with the comparison of unlike performances, and partly because of the lack of a reliable taxonomy and partly because of the sheer amount of work which would be needed to provide a comprehensive answer. It is probably not useful to pursue the question in its original form but rather undertake more basic research on the nature of skill loss.

7.2 There is little evidence bearing directly on the question of whether skill loss is greater or less in non-relevant employment than unemployment and this is an area where more work would be useful. There is some evidence that highly similar skills, but with a single changed element such as a change in the direction in which a control operates, may interfere with skill retention. There is also evidence that rehearsal, even of a relatively minimal kind, could keep a skill "refreshed" during a period of layoff or total unemployment.

7.3 Attempts to answer the question of whether different training techniques have different consequences for retention have not been entirely successful. It remains possible that some forms of training may enhance retention. New methods such as discovery training, methods which emphasise 'understanding' and 'adaptive' training should be examined from this point of view.

7.4 The question as to whether greater skill loss can be expected in those who are laid off immediately after completion of training than in experienced workers is in part answered by the finding that "overlearning" or additional practice beyond the point of mastery has diminishing returns in retention. However, it should be borne in mind that useful learning often takes place on the job after the end of the formal training.

7.5 It normally takes much less time and effort to refresh an unpractised skill than to learn a new skill. This is so even when many years have elapsed since the original learning. In general refresher courses should provide good value for money but care should be taken to incorporate training in changed materials or methods.

7.6 The value of output loss and the costs of refresher training will vary with the particular job. Although this is essentially an economic rather than a psychological question the evidence on rapid relearning suggests that usually refresher training will be economically advantageous.

7.7 Skill loss probably does not vary with age but we do not really know and it might well be useful to run a demonstration study in order to clarify the issue in the minds of those concerned with retraining.

8. Whilst there has been a considerable research effort into the functioning of verbal memory comparatively little research has been done on skill loss in recent years. Some of the unsolved practical problems might appear less formidable if a satisfactory theory of skill retention and loss could be developed and tested. Such work should also clarify some of the unsolved methodological problems.

9. The following specific recommendations for further research are made.

9.1 The suggestion that task organisation is effective in retention has not been satisfactorily explored. Research on this issue needs a better theoretical base and in particular a satfsfactory working definition of "organisation", perhaps taking into account task structure and its relationship to any underlying knowledge structure or the "meaning" of the task.

9.2 It is suggested that more research is needed on the long-term retention value of some of the more recently developed methods of training. Among those deserving investigation from this point of view are (a) discovery methods, (b) methods emphasising underlying principles rather than rote learning, (c) adaptive training methods, (d) methods involving simulation and varying degrees of realism, and comparisons of off-the-job and on-the-job training.

9.3 The period during which a learned skill is not practised deserves further research. (a) The effects of positive and negative transfer between jobs closely or distantly related should be more extensively investigated. It is not known,for example, whether there is positive or negative transfer between vehicle control skills and, say, machine-tool handling skills. (b) Since skill loss can be mitigated by rehearsal the nature of efficient procedures, especially including 'symbolic' rehearsal should be further investigated. (c) The particular case of retention of emergency procedures is so common and of such general importance that it deserves additional special attention.

9.4 As noted above the processes underlying skill loss and retention are poorly understood and further basic research is desirable. This should include investigation of the processes operating at the time of recall specifically the phenomena of reminiscence and warm-up both of which could be of importance in situations where long-unused skills may be required at short notice. The role of stress in retention deserves further research. The effort to recall an unpractised skill may be inherently stressful and stress may have the effect of inhibiting or of facilitating skill retention.

9.5 Individual differences in the long-term retention of motor skills is a neglected research area. Little is known about the relations between performance at the end of training and ability and age at retention or retraining. Research in this area would be of value in selecting individuals for retraining. Because of popular myths about memory and age research which demonstrates that, to adapt a phrase, old dogs <u>can</u> remember old tricks, is worth carrying out.

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SKILL LOSS: A review.

Chapter 1. INTRODUCTION.

1. The Questions.

When an individual has been trained to carry out a task as part of his normal work he will, unless affected by poor health or declining ability, progessively improve as a function of the amount of practice. The results of Snoddy (1926) with mirror drawing and Crossman (1959) with cigar rolling suggest that improvement may continue indefinitely. There is a number of situations in which post-training practice is delayed, infrequent or non-existent. For example, in some military and space exploration situations training facilities and practice opportunities may have to be abandoned at the beginning of the mission and the critical task may not occur for some months (Gardlin & Sitterley 1972). More prosaically emergency drills and other relatively infrequently performed operations may be subject to degradation through lack of practice. In times of high unemployment school leavers and trainees may not have an opportunity to practice what they have been taught. When training programmes are used as a policy measure to prepare unemployed individuals for jobs which may not materialise for some time, the so-called "training for stock", the degree of skill loss or degradation to be expected under various conditions is a matter of considerable importance. What employers, prospective employers and the trainees themselves believe about skill loss is important but this review is concerned with evidence of actual decline or degradation of performance.

The following questions have been posed:

(i) What is the rate of performance decay in terms of terminal performance criteria of training over a wide range of skills/trades ?

(ii) Is skill loss in non-relevant employment greater than skill loss in unemployment ?

(iii) What effect do different training techniques have on the retention of skills ?

(iv) Is the rate of skill loss different for a trainee who remains unemployed after training compared with a person who has practised the skill and then become unemployed ?

(v) Is the time to impart a new skill greater/less than the time to refresh a decayed skill ?

(vi) What is the value of output loss versus refresher training cost ?

(vii) Does skill loss vary with age ?

2. Relationships between pure and applied research.

Questions of this sort can seldom, if ever, be answered by direct reference to the scientific literature. The reasons are fairly obvious. Each question referring to one main variable implies (a) that an operationally valid definition of the variable exists, (b) that systematic manipulation of different values of the variable is possible, (c) that a host of other variables are held constant or varied at random and, (d) that the extent of their interactions with the main variables is known. The literature, as will be seen, contains many examples of specific cases from which it is possible to guess at some of the main variables and their influence, but, however solid the data, the identification of the variables is largely a matter of (expert) opinion.

Even given a broad understanding of the most potent variables and their interactions the application to a specific problem case is far from straightforward. For example, in attempting to answer question 1 (short of getting strictly empirical data on each possible case) the researcher would have to make a set of assumptions about the performance and memory variables underlying classes of skills or trades, carry out the necessary parametric experiments and publish the results in such a way that the user could, as it were, look up the values appropriate to his particular case. This may be how physical science research is ideally used but it is not a practical possibility in the behavioural sciences.

The definition of variables, particularly those relating to the nature of the task, is one major source of imprecision. Some will argue that a task taxonomy would be the answer but a valid and unambiguous taxonomy is not available. Real-life tasks vary continuously over an indefinitely large number of variables rather than coming in discrete easily identifiable sets like plant or animal species which have resulted from millions of years divergent evolution. Moreover, most real tasks are hybrid. Taking crude distinctions such as verbal versus non-verbal and continuous versus discrete (or procedural), which have favoured categories in skill acquisition research, almost any task is likely to involve components of each and moreover these components are unlikely to be mutually independent.

It is easy to paint a rather too gloomy picture of the prospects of ever finding answers to the questions posed in section (1). Even a modest amount of research will enable us to provide approximate answers or guidelines which should enable informed decision making to do better than chance, but we will postpone until Chapter 3 suggestions about the kinds of research which might be most profitable.

3. Research Pardigms and their Relevance to the Questions.

Before plunging into the literature it is worth pausing to consider the research paradigms most relevant to the questions. Potentially relevant research extends over a period of about 70 years and during that period there have been considerable changes not only in the style of research and methods of reporting but also in beliefs about the processes underlying the phenomena of interest. It is pertinent to ask whether or what sense 'skill loss' is equivalent to 'forgetting'. The classical research paradigm comprises (i) initial learning of material which is unfamiliar under controlled conditions, (ii) a retention interval which may or may not be filled with some other activity, (iii) a test of retention which may be by any one of a number of different methods including recall, recognition or savings in re-learning. Can this be taken as the basic "skill loss" paradigm? If so, all the vast literature on memory becomes relevant. One possible modification is to add the adjective "motor" and talk of skill loss and retention in terms of "motor memory", a term recently popularised (e.g. Schmidt 1972, Stelmach 1974). We then set ourselves to wonder whether motor memory has the same characteristics as verbal memory. Whilst this seems reasonable it may not help very much because (a) most real tasks have both verbal and motor components and (b) we cannot assume that even where these are identifiable they are therefore independent.

One possible way in which the skill loss paradigm may differ from the conventional memory paradigm is in the nature of the first stage. Most memory experiments deal with material which is essentially new or unknown at the beginning of the experiment. Even in complex and difficult skills like flying it seems probable that much of the essential behaviour is already in the trainee's repertoire. Even if a subject scores zero on his first attempt to play darts, it is almost certain that he has had <u>some</u> experience

of throwing objects. By contrast the subject who has to learn an arbitrary set of paired associates will, apart from some possible idiosyncratic associations which are equally likely to hinder or help, be literally starting at near zero competence. In short, the theoretical starting point of a memory experiment is zero knowledge but this assumption is not justified in a skill loss experiment. We have no way of knowing what the baseline is.

Another possible difference lies in the procedures for measuring recall. In the standard memory paradigm we begin where the response can only be made in the presence of the stimulus material and practise until the response can be made reliably in the absence of that material - in short, it has to be memorised. In the retention test the original stimulus material is withheld. In the skill loss paradigm there is not necessarily any question of removing "stimulus material". The task is performed in the presence of the cues normally present both in the original learning and in the retention task. The emphasis in skilled performance is on making the best use of information available to the senses and not necessarily on storing it. Thus 'remembering' how to ride a bicycle implies being able to combine visual, kinaesthetic and vestibular cues to control and coordinate performance whilst remembering a poem, a list of nonsense syllables or an arbitrary set of procedures implies the storage of information to be retrieved later. To use a computer analogy, the distinction is between retaining the control program or executive routines and storing the data on which the control program operates. Essential control routines, because of their importance tend to be stored in "protected" areas of the computer or may even be "hard-wired" into the system whilst "data" is readily erased and renewed in temporary storage registers.

It may be misleading to carry this analogy too far but there seem, nevertheless, to be distinctions between "memory"

and "skill loss" sufficient to justify the restriction of this review to certain types of experiment where the emphasis is on the maintenance of performance after a period without practice rather than on recalling material from memory in the absence of cues.

4. Methodology of Skill Loss and Retention Studies.

A brief account of the methodology of skill retention studies may be of use to the non-specialist before embarking on the literature review. The main sequence of events is, fairly obviously, the initial learning of the skill, a period of no practice which we shall call the retention interval and during which a variety of different events can occur, and a test of retention. Subject and task variables, that is for instance the age and ability of the learner and the nature of the task, of course overlay and may well interact with procedural variables.

The measure of skill in both learning and retention will clearly differ from task to task, for example, percent time on target for a tracking skill or, percent items recalled in serial anticipation list learning. Such measures are not, of course, comparable between tasks, furthermore a given task may admit more than one measure, for example, a time measure and an error measure, and these may give different pictures of the state of learning and retention. It is customary to trace the learning of 'naive' subjects over a number of trials. The choice lies between a fixed length or amount of training for all subjects and allowing the number of trials or the length of training to vary and to end training at a fixed performance criterion, for instance, one or more errorless trials. The supposed advantage of this procedure is that all subjects are equal in skill at the beginning of the retention period.

In experiments varying the amount of training, overlearning can be measured as the number of additional trials given, often expressed as a percentage of the number of trials to criterion. The effect of this, of course, is that the fast learners may receive only a small proportion of the practice given to the slow learners and especially when the degree overlearning is varied as part of the experiment.

The retention interval can be measured in units from seconds to years and may be filled with specified or unspecified activities. In most experiments the best that can be hoped for is that subjects will not have rehearsed the specific skills involved in the experiment. Some experiments deliberately introduce interpolated training. If this is intended to promote learning it is usually termed rehearsal but in some experiments tasks or material are introduced with the aim of interfering with retention, that is to produce retroactive interference with the original learning. Measures of retention can take many forms. In most studies the task and the method of scoring are identical to that employed in the original learning but in transfer studies, for example, where training is given on a simulator which may not perfectly mimic the final task, there could be discrepancies even in the method of scoring.

In verbal memory studies generally one has a choice of recognition or recall tests but in motor skills one is clearly confined to recall or, more properly, reconstruction, which is attempting to perform the task under standard conditions. Assuming the measurement technique remains constant the simplest measure of retention is the absolute or relative performance difference between the last trial of original learning and the first post-retention-interval trial. However, if the trials are short, scores tend to be statistically unreliable whilst if they are long, then additional learning will take place during the retention trials. For this reason most investigations

involve relearning and, if this relearning is carried to the same criterion as the original learning a percent savings score can be calculated, $\frac{OL - RL}{OL} \times 100$ where OL = time or number of trials to criterion on the original learning and RL = time or number of trials to the same criterion on relearning.

Obviously, if retention interval duration is to be a variable in the experiment, separate groups of subjects will have to be used for different intervals since almost any form of retesting is likely to involve an unknown degree of relearning. This naturally increases the problems asssociated with sample size and the matching of groups. Furthermore it means that retention curves are composite with different subjects at different intervals. As in most learning experiments, independent group designs are to be preferred to the more econcmical repeated measures designs, often resulting in the need for large numbers of subjects.

Performance measures are generally dictated by convenience and the type of task and can be used in a straightforward way to measure retention in terms of percent gain or loss, or a savings score. However, a case can be made for the use of quite different measures. Bilodeau & Levy (1964) in the context of simple positioning responses have argued that variability is a more meaningful measure of retention than relative or absolute error. Bahrick (1965) proposed a variance-based measure of retention. Fleishman (1960) and Jones (1969) have both used correlational methods which would permit estimates of the proportion of the total variance attributable to various factors to be looked at as a function of practice, or more generally time, and these methods could be adapted to the study of retention.

In the review that follows it would be tedious to spell out for each study all the methodlogical details. "Retention" will often be mentioned without specifying how it was measured, though savings is the most commonly used method. The non-specialist reader will, I hope, appreciate that confidence in the results of a particular study and comparisons between studies involving many different variables will often be stated as a matter of the reviewer's opinion. To include all the supporting detail would make this review excessively long.

Chapter 2. SKILL LOSS: THE LITERATURE.

1. Historical Introduction.

Ebbinghaus published Über das Gedächtnis in 1885. At the age of 35 and working alone he brought systematic experiment into the field of memory by controlling the material to be learned, the conditions of learning, especially the number of repetitions, and the duration of the "retention interval" and by developing methods of measuring retention including the savings method (i.e. measuring retention in terms of the difference between the number of trials required to reach a given performance criteria in the initial learning and subsequent relearning). Only a few years later in 1899, R.S. Woodworth was calling for a "psychophysics of movement" and Bryan & Harter (1897 & 1899) were carrying out the first empirical studies of skill acquisition, the learning of morse telegraphy. From those early days the acquisition and retention of perceptual motor skills has received only a fraction of the attention accorded to verbal or "ideational" learning. Nevertheless a steady trickle of work, swelled by the occasional burst of interest in particular tasks and problems, has accumulated into a substantial, if somewhat murky, pool of empirical findings. Bourdin (1901) was reported by Swift (1905) to have found very high levels of retention for motor skills and Swift (1905, 1906, 1910) in a classic series of studies with juggling and typewriting showed apparently very little loss of skill over a year without practice, and although there were noticeable losses with an interval of four years, relearning was extraordinarily rapid. Hill (1914) followed up Swift's work with studies of mirror drawing and letter substitution confirming both Swift's findings and Thorndike's expectations of "the superiority of sensori-motor functions for permanence".

The implied comparison with verbal learning became the principal matter of theoretical interest in the 1920's and 1930's (see for example Irion's review, 1969). By 1951 Hovland reviewing learning and retention, reported that motor skills are (i) retained with little loss but (ii) that the source of this superior retention was unknown and,(iii) that not enough studies had been done to permit the specification of reliable retention curves.

The 1950's brought increased activity in the field of skills, particularly due to the number of studies of military training and partly because of the pursuit rotor (a gramophone turntable usually revolving at 78rpm with a small brass disc inset which is chased by the subject with a floppy (hinged) stylus; electrical connection gives a time-on-target score) turned out to be a convenient vehicle for studying some important aspects of C.L. Hull's theory of learning.

The first systematic review was carried out by J.C. Naylor and G.E. Briggs for the Aerospace Medical Laboratories of the U.S.A.F. at Dayton, Ohio in 1961. This was the era of the "Sputnik scare" and the beginning of the race to the moon when research on training in the sophisticated aerospace technologies received a sudden boost. The Naylor & Briggs review was critical of the general quality of earlier work but as well as repeating the more obvious generalisations proposed "task organisation" as a major basic variable underlying differences in retention. This same variable was suggested by Naylor (1962) as relevant to the part/whole learning controversy.

Adams (1967) included a whole chapter on motor response recall in his text on Human Memory and found the early work conceptually impoverished. He too recorded the classical findings of good motor retention and suggested that motor

responses may be less susceptible to interference than verbal responses. Bilodeau's (1969) review, commenting on the lack of generally valid forgetting curve (because motor skills are not readily forgotten) went on to produce a two-stage theory of motor forgetting following the work by Bilodeau & Levy (1964) on the basis of single learning trials with a simple lever positioning response.

Among the more recent reviews, Schmidt (1972) and Stelmach (1974) exemplify a new interest which has developed in recent years amongst physical educationalists. Their reviews, which are mainly concerned with short-term motor memory, add little of theoretical interest, but introduce data on new tasks, notably balancing. A review by Gardlin & Sitterley (1972) follows up Naylor & Briggs but with a strong emphasis on aerospace research and is clearly aimed at the problem of the retention of skills such as manually controlled re-entry at the end of extended space flights during which there will have been little or no opportunity for practice.

The literature, spreading over so many years, encompasses a wide range of techniques and of theoretical assumptions. A very large number of variables is involved and, for obvious reasons, these are not varied systematically or held constant from study to study. The simple organising principle used here then is to group the literature according to the main variables, taken singly, and to try to point out where conclusions based on the manipulation of one variable may be invalidated by failure to control others. Variables such as the type of task used and the nature of the subjects affect all studies. Apart from these we will take the variables in the order in which they appear in the basic experimental paradigm:

Types of Task.
Types of Training.
Amount of Training.
Duration of the Retention Interval.
Interference by Activities in the Retention Interval.
Facilitation by Activities in the Retention Interval.
Conditions at Recall.
Individual Differences.

2. Types of Task.

(i) Natural and Artifical Tasks.

Since our purpose is, if possible, to generalise to real world situations, the first major division will be between real-life or simulated tasks and artificial laboratory tasks. The two groups probably differ in two major ways either of which might affect retention; (a) real-life tasks are generally more complex, and (b) the subjects generally have a genuine interest in acquiring and retaining proficiency. One can never be sure of this in laboratory situations with volunteer subjects.

'Natural' tasks appearing in the literature have included typewriting (Hill 1957, Swift 1906, Towne 1922), simulated lunar landing (Cotterman & Wood 1967), instrument flying (Mengelkoch et al, 1971), a range of military tasks (McDonald, 1967), capstan lathe operating (Henderson, 1974), piano playing (Rubin-Rabson, 1939, 1940, 1941), and process control, (Duncan, 1971). For comparison (albeit rather loose) some studies of the retention of academic skills are mentioned.

'Artificial' tasks have included various forms of tracking (Battig, Nagel, Voss and Brogden,1957, Jahnke,1958, Melton,1964. Hammerton,1963, Trumbo et al 1965,1967) combined tracking and procedural tasks (Naylor et al 1962,1965,1968), mazes (McGeoch, 1932, McGeoch & Melton 1929, Tsai,1924), lever positioning (Bilodeau, Sulzer & Levy 1962, Bilodeau & Levy 1964, Lavery 1964), a variety of gymnastic skills such as ball tossing and balancing (Purdy & Lockhart 1962, Roehrig 1964, Ryan 1962,1965, Meyers 1967).

The findings from real tasks are quite encouraging. Whilst it looks as though skills can be retained without much loss for very long periods there seem to be some differences between tasks, for example, between those requiring perceptual-motor coordination such as the control aspects of flying and those requiring memory for procedures or knowledge of facts. However, there is a fundamental difficulty in making comparative assertions such as that tasks of type X are retained better than tasks of type Y. The difficulty is that we lack a common metric for retention and it is this problem that we turn to next.

There have been studies of retention of verbal material of a more meaningful sort such as Watson (1938) and Ansbacher (1940) on introductory psychology and Worcester (1928), White (1930), Langton (1932), Lahey (1941), on mathematics. These are "real" materials but the objective and multiple choice test used confine the studies to the retention of factual material. Ansbacher (1940) reviewing the retention of psychology concluded that whilst about 50% was retained after 58 months there would have been opportunities to learn outside the original course. Using a control group to correct the retention scores, retention is reduced to 27%. Lahey (1941) reviewing studies of the retention of algebra found that retention depended very much on the test used. However, within one population, retest retention can be quite high and does not necessarily decrease as the length of the retention

interval increases. In some cases due either to additional learning or to maturation of the subjects "retention" scores of over 100% can be found. Her own study made use of the long summer vacations to test retention of algebraic operations and problem solving skill. In the former there was nearly 10% loss between May and September and in the latter a very slight gain. Although it would be unwise to place too much weight on these studies they provide a fairly optimistic picture of the "permanence" of school learning.

The evidence from 'natural' tasks, whatever its limitations, justifies the empirical generalisation that well practised motor skills are not readily forgotten. Swift (1906) had previously taught himself typewriting and after 2 years and 35 days without practice wrote a letter of about 50 words - "The apparent ease with which the few words were written after the lapse of so much time was.....striking". Hill (1934) after an interval of 25 years was able to type at a rate which had originally taken 27 days of practice to achieve.

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Cotterman & Wood (1967) found substantial losses over periods up to 13 weeks in performance on a simulated Apollo Command Module but this was largely ameliorated simply by watching other crews perform. Similarly, Hengelkoch et al(1971) using ROTC volunteers in a Link flight trainer found significant losses after four months without practice, greater for procedural than control aspects of the simulated flying task. McDonald (1967) described the retention of "combat skills" over a one year period. Rifle marksmanship showed a slight but insignificant loss and physical skills such as running, crawling and grenade throwing showed little loss but scores on a multiple test involving "military courtesy", first aid, guard duty and reporting, showed a 50% loss. Henderson's(1974) capstan lathe operators showed virtually no skill loss over

6 - 14 weeks of unemployment except for slightly lower ratings of the "finish" of items.

(ii) Motor versus Verbal Tasks.

The evidence just cited suggests the widely held belief that "motor skills" are better retained than "verbal skills". McGeoch and Melton (1929), and McGeoch (1932) sought to confirm this assertion by comparing maze (motor) and nonsense syllable (verbal) and a maze with a "rational" learning problem. The rational task was a kind of "mental maze" which involves learning a sequence of letter-digit pairs. If subjects notice that each digit is only paired with a single letter the task is less formidable than it seems at first sight. This series of studies brought out, but did little to solve, a number of methodological problems. How can tasks be taken as equivalent in all respects except being "verbal" or "motor"? How can the degree of learning or the amount of forgetting be compared in the absence of a unified scoring system? McGeoch's results were equivocal depending in part on how retention was measured. He found that nonsense syllables were better retained than mazes when both were measured by the number of trials taken to relearn the task to a given criterion but the difference between the two types of task was found to be insignificant if error scores were used. The "rational" task was better retained than the maze when the retention interval was one week, but not when it was three weeks. Freeman & Abernathy (1930 & 1932), taking the point that the verbal and motor tasks must in some way be comparable, used typing a short passage with the key labels blanked out compared with translating the letter in the same passage into a code, that is, the comparison of a "motor" and a "verbal" coding task. These results favoured "motor" memory. Waters & Poole (1933) taking up McGeoch's finding on the superiority of "rational" learning pointed out that the

better retained task might simply have been easier to learn. Their experiment compared the Warden finger maze with the Peterson mental maze (rational learning) in three groups. Group 1 learned both tasks to one errorless trial, Group 2 learned the Warden maze to one errorless trial and the mental maze to three errorless trials, and Group 3 learned the mental maze to one errorless trial and the motor maze to three errorless trials. In Groups 2 & 3 ten further 'overlearning' trials were given to the mental and motor mazes respectively. The results show that sheer amount of training is a potent variable in retention. Whilst the mental maze was learned in fewer trials, when both types of material were learned to the same degree retention was also equivalent. Van Tilborg (1936) confirmed this finding with "mental" and "motor" mazes, whose initial task difficulty was equated, over 50 days retention interval.

The problem was taken up again by Schlosberg (Leavitt & Schlosberg 1944, Van Dusen & Schlosberg 1948), comparing pursuit rotor with nonsense syllable learning. During this period the theory of reactive inhibition, that is that repetition of a response tends to inhibit its future occurrence, was being used to account for some features of learning curves and especially the phenomenon of "reminiscence"*. Reminiscence is the apparent improvement in performance which is sometimes found after a rest or period without practice or rehearsal. All 48 subjects learned both tasks and 12 were required to relearn both tasks after either 1, 7, 20, or 70 days. In the full 70 days the nonsense syllable savings score was 51.4% and the pursuit rotor savings score was 75.2%. Even in the one-day retention group pursuit rotor retention was better but the authors

* See Appendix, Figure 4.

felt that some of this difference might be due to reminiscence, a well-known feature of pursuit rotor learning. In the second study by Van Dusen & Schlosberg (1948), the hypothesis that learning an arbitrary list of nonsense syllables provided a less "integrated" task than the pursuit rotor was tested. They used a paired-associate task in which subjects were required to learn pairings between switches labelled with nonsense syllables. The pairings could then be tested either by speaking the syllables or by turning the switches with the syllables concealed. Retention was studied over 1, 7 and 28 days. Although motor responses showed apparently better retention none of the differences whether at 1, 7 or 28 days was statistically significant.

This last experiment points up one of the less obvious difficulties in comparing verbal and motor tasks. Quite early in the study of maze learning (Warden, 1924) it was demonstrated that subjects could use either verbal or non-verbal (e.g. visuo-spatial or kinaesthetic) methods of learning. Newman & Ammons (1957) using a very similar paired associate switching task, but without nonsense syllable labelling, found that although it was presented as a motor problem 44% of their subjects used a verbal code to memorise the task. In short, although the task may appear to be 'verbal' or 'motor' the external observer can never be sure (without an additional investigation) what kind of coding the subject is using.

The question of whether verbal or motor tasks are better retained then turns out to be not nearly as sensible as might appear. It is still true that motor tasks have often been shown to be rather resistant to forgetting for long periods. Roehrig (1964) for instance, found a balancing task showed "perfect recall" after 50 weeks. With the exception of one subject, "the curves appear to continue as if there was no time lapse". Ryan (1962, 1965) also using the stabilometer*

* an electro-mechanical device consisting of a platform balanced on a fulcrum with a system for recording the stability of a subject standing on the platform.

found very little loss over 21 days but in the second study using retention intervals of 3, 6 and 12 months, initial relearning scores were down 50%, 57% and 80% respectively on the final trial of initial training. Nevertheless, four 30 second trials were enough to make good the loss in the 3 months and 6 months delay groups. The discrepancy between this finding and Roehrig's may well be due to the fact that Roehrig's subjects were characterised as highly intelligent and highly motivated and practised daily for a month, whereas Ryan's subjects had only twelve 30 second trials. The apparently high level of retention on balancing may therefore simply be a function of the amount of practice given, a conclusion which receives some support from a study by Carron & Marteniuk 1970.

(iii) Continuous versus Discrete Tasks.

A generalisation which seems to be clearly supported in the literature is that continuous tasks like tracking are better retained than discrete procedural tasks. Ammons et al (1958), and Brown et al (1963), Adams & Hufford (1962), Mengelkoch et al (1971), have all used flight trainer tasks which combine flight control (i.e. tracking), with procedural tasks, usually a series of push-button responses to signal lights. Adams & Hufford found the procedural aspects of such a task virtually completely forgotten over 10 months of no practice but the procedures were relearned in a couple of trials. Ammons et al, using separate tracking and procedural tasks and retention intervals ranging from 1 minute to 2 years, found retention losses on both types of task related to both the amount of practice and the length of the retention interval. Relearning in both types of task was rapid. Mengelkoch et al, found substantial losses of retention of procedures over 5 months but in flight manoeuvres "statistical significance of retention loss was less frequently found than for procedures".* Unlike Ammons et al, it was

*Note: see Figures 7 & 8 in Appendix A.

found that different amounts of initial training did not affect the retention of the tracking element although this variable did affect the number of trials taken to relearn the procedures.

In these studies we can see the great difficulty in drawing firmly based general conclusions. Even supposing the tracking and procedural elements were roughly comparable other variables in the experiments can be very different. Mengelkoch et al, employed University of Illinois ROTC students who had up to 4 hours of "academic" training and 15 hours of flight training. Ammons et al, however used 538 subjects (enlisted men) on the procedural tasks and 465 subjects on the aeroplane control task, in the first case using either 5 or 30 training trials and in the second 4 x 1 minute trials. Even supposing these studies were more similar, the comparison between tracking and procedural tasks still presents considerable difficulty. We would expect task difficulty and degree of learning to affect retention as well as experience during the retention interval. However, tracking and procedural tasks have not, (probably could not) be equated for difficulty.

Hammerton (1963) proposed that tracking may be well retained because it is typically "overlearned". He took an extremely difficult tracking task (acceleration control) and trained volunteer subjects until they had reached a fixed criterion. A sub-group was then trained up to an even more stringent criterion and retention was tested after 26 weeks. Overlearning was shown to improve initial recall when compared with learning to the standard criterion. In both groups however, there was measureable loss of performance and Hammerton concludes that if the task is sufficiently difficult retention losses can be demonstrated.

We have no way of assuring that the amount of practice is comparable. Whilst we can count the number of steps in a procedure and hence the number of repititions we have no way of recording the "number of repetitions" in continuous tracking. There is no way therefore, one could assert that with the degree of difficulty or the amount of learning held constant there are differences in retention between the two types of task.

(iv) Task Organisation: Integrated vs Non-Integrated Tasks.

In attempting to account for apparent retention differences between tasks Van Dusen & Schlosberg (1948) and later, Naylor and Briggs (1961) suggested that more highly "organised" or "integrated" tasks might be better retained. Certainly some of the best retained tasks such as balancing (Roehrig 1964, Ryan 1962) seem to involve a single highly co-ordinated activity. Nevertheless, in a fairly extreme case of non-integrated task, simultaneous reading and writing of different materials, Downey & Anderson (1917) found fairly considerable "retention of capacity to maintain two processes" after two years with no practice and rapid relearning of this difficult skill. Naylor and his associates (Naylor, Briggs & Reed 1962, 1968) and Trumbo (Trumbo, Noble, Cross & Ulrich 1965; Trumbo, Ulrich & Noble 1965; Trumbo, Noble & Swink 1967; Swink, Trumbo & Noble 1967) have investigated task organisation as a factor in retention.

The Naylor task comprised 3-dimensional tracking, that is to say using rudder and stick to keep three dials, indicating pitch, roll and yaw, steady, and combined this with switching procedures to be followed in response to various signal lights. Two degrees of "organisation" were obtained by varying the predictability of the signal lights. Amount of training and length of retention were also varied. The coherent procedural task was better retained and also led

to better performance and retention than the tracking component of the task. Howevever, amount of training turned out to be the most potent variable and it seems probable that the level of skill attained in the original training task may be sufficient to account for the differences found.

Trumbo's task consisted of pursuit tracking of a target which moved in 1 - 15 discrete steps or deflections. The task combined some aspects of both tracking and procedures and the sequence of the targets could be made more or less predictable. Using this task Trumbo, Noble, Cross & Ulrich (1965), and Swink, Trumbo, & Noble (1967) have found retention to be related to the predictability of the stimulus sequence but, with amount of practice and length of retention interval also contributing to retention and speed of relearning.

It is difficult to see "task organisation", as defined in these studies, as anything other than a way of manipulating task difficulty and hence the degree of learning which can be achieved within a fixed practice period or fixed number of trials. All the experiments employed fixed length trials rather than training to a criterion and only if training had been carried out to a common criterion would it have been possible to attribute differential retention to the nature of the task per se. Whilst the components of an organised or integrated task would be more predictable the operational definition of "organisation" only in terms of predictability hardly does justice to the concept. However, no-one has yet suggested any more satisfactory way of defining this intruiging but elusive variable. We have to conclude that what at first seemed an interesting idea has not so far been satisfactorily followed up.

3. Types of Training.

The type of training given can affect the efficiency of skill acquisition but it is less clear whether, other factors being equal, the kind of initial training affects retention. In the classical motor skills literature type of training refers to variables such as massed versus spaced practice, part versus whole learning, learning with or without knowledge of results and varied or general versus specific task training. In the applied field "types of training" generally refers to whole philosophies of training, such as TWI, Skills Analysis Training, Discovery Learning, Schematic Learning, Programmed Instruction, Computer-aided Learning and so on. Type of training in this sense can seldom be tied down to a limited number of readily manipulable variables and so comparisons in the rigorous scientific sense are virtually impossible.

(i) Massed versus Spaced Practice.

Naylor & Briggs reviewing massed and distributed learning found only two studies with clear effects. Both used tracking type tasks. Lewis & Lowe (1956) found better retention with distributed practice. Lewis & Lowe had whole week intervals between trials whilst Jahnke & Duncan compared 20 second and 10 minute rest periods. In the light of these differences and the superficially more equivocal results from Reynolds and Bilodeau (1952), Rubin-Rabson (1960a),and Montgomery (1953) a clear superiority of one method remains to be demonstrated.

(ii) Part versus Whole Learning.

Part versus Whole is in not much better case. Rubin-Rabson (1939,1940) in a series of studies of piano-playing looked at two different methods of part training, one hand at a time and

practising short sections of a whole piece, on memory for piano music. In neither case was a significant difference found. Naylor et al (1963) in one of a series of experiments with a combined 3-dimensional tracking and procedural task described in the previous section used part or whole task "rehearsal" following initial training and followed by retention tests after 5 or 10 days. Rehearsal by part methods was generally less effective tham whole methods up to 5 days but with the longer interval there was no difference between rehearsal methods.

(iii) Knowledge of Results.

Knowledge of results, whilst generally agreed to be a sine qua non of learning may affect retention in simple positioning skills. Annett (1969) has reviewed a number of studies where knowledge of results so immediate as to be useable as a cue controlling ongoing responses raised performance levels only temporarily. Removal of this kind of KR, sometimes known as action feedback, is like taking away a crutch and performance is affected dramatically. In this limited sense KR can actually militate against retention. However Lavery (1964) in a similar sort of task but interspersing a batch of no-KR trials actually found that more precise knowledge of results gave better retention. In a very different situation, maze learning, Gilbert & Crafts (1935) compared the effects on learning and retention of either a shock or a harmless buzzer as an error signal. Signal and shock were found to be effectively equivalent with a small advantage to the harmless signal on retention.

(iv) Other Training Methods.

Bearing in mind that "training methods" as conventionally understood are too loosely defined to permit rigorous generalisations there is scattered evidence that some methods may be more conducive to retention than others. Studies of retention per se are, however, rare and the evidence is suggestive rather than conclusive. No studies can be found which permit a conclusion to be drawn about the value of discovery methods but an experiment by Fleishman & Parker (1962) showed some advantage with a 14 month retention interval, for training which began with a "commonsense introduction and demonstration" and included analysis of performance over and above simple knowledge of results. The task was a very difficult joystick and rudder control task with acceleration control on the first and velocity control on the second plus an exponential control lag. It would seem that some degree of understanding of this very difficult task benefits both acquisition and retention. However, the hypothesis that tasks which are better understood are better retained, whilst having some appeal, seems not to have been directly tested.

The many results with programmed learning, most with intellectual rather than motor skills, on the whole indicate that retention is good where acquisition is good. In general, end-of-training perforance is the best predictor of performance after an interval of no practice. A study by Goldberg & Dawson (1964) on 47 clerical trainees tested at the end of training and 6 months later found greater losses with programmed instruction than with classroom teaching but, as in so many of these teacher versus machine "competition" experiments the teacher can usually do better if he analyses and structures the material as carefully as is required to write a programme. Kay, Annett & Sime (1963) reviewing some 40 studies found retention in general

superior after programmed than conventional instruction. Still in the field of verbal rather than motor learning, but nevertheless highly suggestive,is a recent study by Atkinson (1976) on computer-aided learning. The computer was programmed to use an adaptive teaching strategy for German vocabulary teaching and this was contrasted with a random strategy and a student chosen strategy. The 'strategy' simply means the rule governing which items are chosen to rehearse next. The computer strategy was based on a theoretical model which, in brief, suggested that there is greater benefit in practising material which is nearly but not quite fully learned. The effect of this is to give what appears to be relatively poor performance during training but much better performance when tested one week later. Although there have been a number of studies of adaptive control in motor skill acquisition there is no information on retention. It may be that adaptive control strategies are possible which are particularly conducive to retention.

4. Amount of Training.

A major variable is quite simply the amount of training given before the "layoff" or retention period. This can be measured in the number of practice trials, the amount of time spent or in terms of the actual performance level or criterion reached. The latter is often adopted in investigating the amount of overlearning, that is to say the amount of practice given additional to that required to reach a specified criterion. The literature contains examples of the amount of training used which range from a single trial (Bilodeau, 1969) to many hours or weeks of practice but only those studies which varied amounts of training within the same task and subject population will be considered here.

In general the amount of practice does seem to be relatively potent (sometimes the most potent) variable affecting retention. Early studies by Luh (1923) and Krueger (1929) on nonsense syllables and monosyllabic nouns respectively set the general picture. Subjects learned to a given criterion and then continued with 50%, 100% or 150% more trials. Luh looked at retention over 4 hours, 1 day and 2 days, and Krueger at 1, 2, 4, 5, 14 and 28 days. Although overlearning was beneficial to retention the returns for effort are diminishing. Luh found that 150% overlearning only improved retention by 17% over a 4 hour retention period and only 10% over 2 days. Krueger too found that the increase in retention was usually proportionally less than the increase in overlearning. Krueger (1930) followed up this experiment in verbal learning with a study of finger maze learning with similar results.

Ammons et al (1958) using a procedural task trained subjects for either 5 or 30 trials and retested them after 1 minute, 1 day, 1 month, 6 months, 1 or 2 years. Retention was found to be a function both of the amount of training and the duration of the retention period. The more training and the shorter the interval, the better the retention. With a pursuit-tracking task however, the absolute loss over a 2 year retention period was the same whether subjects had been originally trained for 1 hour or for 8 hours. Hammerton's (1963) study of a very difficult tracking task in which 2 groups of subjects learned to two different criteria and were tested after 26 weeks also showed that the more highly trained group retained their skill better, although both groups showed a retention loss. In a series of studies by Naylor and his associates at the Aerospeace Medical Centre (Naylor, Briggs & Reed, 1962; Buckhout, Naylor & Briggs, 1963; Naylor, Briggs & Reed, 1968) using a 3-dimensional tracking task

*Note: See Appendix, Figure 9.

combined with a procedural task the amount of initial learning was consistently shown to affect retention, indeed Naylor concluded that it was probably the major factor in retention. In short, the generalisation that retention is a positive but negatively accelerated function of the amount of original learning in both simple and complex tasks seem justified.

5. Duration of the Retention Interval.

The record for a retention interval must go to Hill (1957) who carried out an experiment on typing skill under Thorndike at Columbia in 1907 and tested his retention 50 years later when he had already been 10 years in retirement. He can be forgiven for having 'cheated' by carrying out a relearning test after a mere 25 years. The essential finding was that despite complete absence of actual practice for 25 years the level of performance reached by the end of the first day of relearning had originally not been achieved until 27 days of practice. After the second quarter century of no practice and some decline in physical condition it still took only 8 days to reach the same performance level. Burtt (1941) read three selections in Greek each day for 3 months to a child, starting at 15 months. For the next 3 months three more selections were read daily and this procedure continued until the child had been thus exposed to a total of 21 selections and was 3 years old. At 8½ the child learned 2 of these plus 3 new selections by the anticipation method and this process was repeated again at 14 years and again at 18 years. Amazingly, an average of 30% saving was found at 8½ years, 8% at 14 years, but none at all at 18, that is 15 years after the original learning. Although these two

studies lack controls they do suggest that the retention of both motor and verbal skills is much better than is commonly supposed.

Although several studies (Ammons et al, 1958; Bell, 1950) systematically varied retention intervals and retention is probably a negatively accelerated function of the interval duration it is not possible to be precise about the "curve of forgetting" of the sort demonstrated by Ebbinghaus for the special case of nonsense trigram learning. On the basis of a great deal of data on a simple lever positioning task Bilodeau & Levy (1964) proposed the unusual doubly inflected curve.* A rather rapid but decelerating curve of forgetting occurred during the first minute and following that on a longer positively accelerated curve. Although this curve has a rationale (see Bilodeau 1969) its value in the present context is limited (a) because it is based on the repetition of a single simple linear movement and (b) because the ordinate unlike most other retention measures we have discussed in this review, is a measure of consistency.

Youngling et al (1968) using a much more complex task, an orbital satellite control situation, found skill loss to vary linearly with retention intervals up to 200 days. Bahrick(1964) warns against a variety of measurement artifacts, for example, varying sensitivity of different measures and concludes that it is unwise to base general conclusions on the shape of curves of forgetting. A representative sample of learning and forgetting curves are shown in Appendix A.

*Note: See Appendix, Figure 10.

6. Interference by Activities in the Retention Interval.

Activities occuring during the retention period may interfere with the retention of the original skill. In the field of verbal learning interference of this kind, called retroactive interference because it is assumed to interfere retroactively with the trace of the original learning, can reduce retention. Indeed "interference" constitutes one of the main hypothetical processes causing forgetting.

In motor learning studies it is typically very difficult to do more than ensure that subjects do not practice the same task during the retention period. There is no way in which they could be prevented from riding bicycles, driving cars or otherwise exercising skills which might interfere with or enhance the original learning. The problem has been investigated by giving training on a modified form of the original and to-be-remembered task, by Lewis (1947), Lewis & Shephard (1950), Lewis, McAllister & Adams(1951),McAllister & Lewis (1951), and McAllister(1952). The task, a modified Mashburn Apparatus, otherwise known as the Complex Co-ordination Test involves using an aeroplane-like joystick and rudder control to illuminate sequences of lights on a display panel. The relationship between the direction of movement and the sequence of lights could be varied. In verbal learning studies similarity of stimulus and response material could be varied, for example, by using homonyms or synonyms in the search for acoustic and semantic interference. In most tasks one can vary the stimuli, responses or stimulus-response connections. The Lewis experiments used the latter. Quite simply the interfering task used involved the opposite stimulus-response (or display/control) connection to that used in the original learning. Lewis, McAllister & Adams (1951) compared 3 degrees of original learning and 5 different amounts of interpolated

practice on the reversed task. The results are quite striking and as Adams (1967) pointed out quite the opposite of what one would have predicted by a simple extrapolation from the results of verbal learning experiments. The so-called interference decrement (that is the retention loss due to interpolated learning) increased, as expected, with the amount of interpolated learning, although the increase was not a simple linear function. However, quite unlike the parallel verbal studies, the greater amount of original learning the greater the amount of interference. In verbal learning a well established habit is less susceptable to interference but, if these results are to be believed, the more established the original habit the more will interpolated practice of the reversed task interfere. This finding may conceivably be due to some measurement artifact as suggested by Schmidt (1972) and ought perhaps to be confirmed.

With an eye to generalisation to tasks other than the Complex Co-ordinator it must be admitted that there is a very considerable gap in our knowledge. Reversing display-control relationships is only one of a very large number of ways in which interpolated tasks could be related to the criterion task and it is not particularly typical of what is likely to happen in the industrial situation. It will not, for instance, tell us anything about the likely interference or facilitation effects expected by practice with milling interpolated between training and criterion performance on operating a lathe. However, controls on vehicles can sometimes operate in opposite directions in different models. Schmidt (1972) suggests more work is clearly needed to define the nature of the interfering tasks and to determine whether the "laws" of motor and verbal interference are similar. Note that if verbal laws of interference translated to the motor field it would be quite reasonable to

suggest that driving a small delivery van could interfere with the skill of driving a juggernaut. Whilst one suspects that this is not the case we do not actually know. A little work has also been done on pro-active inhibition. Duncan and Underwood (1953) had their subjects learn a motor paired associate task, moving a lever in response to coded coloured lights, and then learn a second version, varying in similarity to the first. The degree of original learning was varied and a one day or a one year retention interval was used. The greater the amount of learning on the first task the more forgetting occurred in the second task, that is, pro-active interference was demonstrated. Britt (1934) on the other hand, demonstrated positive transfer in learning two different mazes. Having previously learned and then, after 48 days, relearned one maze, facilitated the learning of a second maze. These results on pro-active interference and facilitation are somewhat inconclusive. The problem of pro-active interference could become important if people typically learned a variety of different skills during the course of their working lives.

7. Facilitation by Activities in the Retention Interval.

Not all intervening activities militate against retention, some facilitating effects have been found. For example, Bunch (1946) found that when a maze is learned and then almost immediately relearned the learning of a different maze between the original learning and relearning was interfering, but with a 120 day interval learning the different maze just before relearning had a facilitating effect on relearning. Although this seems to be an isolated finding which might, perhaps, be attributed to warm-up, various kinds of rehearsal have been

shown to be effective in warding off skill loss. A series of studies by Naylor's group at the Aerospace Medical Center (Naylor & Briggs 1963; Naylor, Briggs, Brown & Reed, 1963; Brown, Briggs & Naylor, 1963; Buckhout, Naylor & Briggs, 1963) looked at various kinds and amounts of rehearsal during the no-practice period on subsequent retention of both procedural and tracking skills. The procedural task resembled an aircraft check-out routine in which lights of various colours are "acknowledged" by push-button responses which have to be made in a particular sequence and with a fixed time delay. The general plan of the first experiment (Naylor & Briggs 1963) was to give practice on days 1 - 5, no practice on days 6 - 14, various kinds of rehearsal on days 15 - 19 and no further practice until the retention test on day 30. Some subjects rehearsed the timing of the responses, others their spatial location, another group rehearsed both timing and location and a control group had no rehearsal. Rehearsal, even of only one aspect of the task was shown to be helpful to retention. In the second study (Naylor, Briggs, Brown and Reed 1963) which combined a 3-dimensional tracking task with a procedural task, rehearsal was found to be more help to the procedural task than the tracking element. Various forms of part-task rehearsal were used and although whole task rehearsal was superior when given in small amounts (5 days work) part-task rehearsal was equally effective for larger amounts. This finding has the interesting implication that it may be possible to keep a complex skill in "good condition" by rehearsing only selected aspects, if one can identify those aspects of the task most in need of "refresher" treatment. In a third study, Brown, Briggs & Naylor (1963) using the same basic tracking-cum-procedural task compared nine different conditions including various simplified and generalised versions of both the tracking and procedural aspects of the task. In this case tracking retention was not perfect in the control

condition and retention was enhanced by rehearsal, including rehearsal of a simplified version of the tracking task.

In a more recent study by Macek, Vilter & Stubbs (1965) a procedural task, the "star discrimeter" was used. This consists of a lever which can be moved into one of six positions in response to coloured light signals, and is essentially a form of serial association learning. Various forms of rehearsal were used for example, rehearsing the light/lever position combinations presented on a memory drum using various labels or analogues of the star positions. Rehearsal and retention was over a six week period following initial training. The three main findings were that (i) the more similar the rehearsal task to the criterion task the better the retention, (ii) the more complex the criterion task the more important was the relevance of the rehearsal task, (iii) warm-up, that is, special practice just prior to the retention test proper, was not as effective as rehearsal regularly spaced out over the retention interval.

These results are generally quite promising in that they suggest that skill may be kept at a relatively high level by a relatively small investment in rehearsal, perhaps even only symbolic rehearsal of the criterion task. Whilst Naylor's group consistently emphasise the importance of the degree of original learning, rehearsal even in "impoverished" conditions may be helpful to retention.

Two studies of simulation training by Grimsley (1969a and 1969b) confirm this result. A missile firing control panel simulator was used in three versions, a "hot" (i.e. fully functional) panel, a "cold" (non-functional) panel, and a photograph. The task was a 92-step procedure and retention was measured over 4 and 6 week intervals. After 4 weeks there was an average 16% loss in all three simulation conditions.

Whilst actual practice gave better retention there was no difference in retention due to simulator fidelity as such. The photograph was as effective as the fully functional panel.

Rather improbably, there is some evidence that "imaginary" practice may aid the retention of motor skills, and it may even show some actual improvement in performance. If this were so, refresher courses might even consist of persuading the trainees to imagine that they are indulging in practice. Sackett (1934 & 1935), used the Miles finger relief maze as the retention task, well aware of the earlier work by Husband & Warden showing that a maze may be interpreted by the subject as a visual, verbal or spatio-motor problem. After having learned the maze, subjects either practised making drawings of the maze, thinking about it, or (hopefully) following the instructions not to think about it. Whereas trials to criterion in original learning had been 20.45, 21.7 and 21.8 trials respectively, relearning scores were 4.3, 5.75, and 8.35. Only the difference between drawing,(4.3 trials) and non-rehearsal (8.35 trials) was statistically reliable. In the second study subjects were instructed to think their way through the maze 3 or 5 times for 7 days. The trend in favour of symbolic rehearsal was still present but still failed to reach statistical significance. However, Perry (1939) was able to produce quite clear evidence in favour of "imaginary" practice on five different tasks, a pegboard, mirror drawing, digit-symbol substitution, tapping and card sorting. In Perry's "imaginary" practice the subjects were confronted with equipment on which real practice was carried out and were requested to "think their way through" the task but without moving their hands. The imaginary practice, much more controlled than in Sackett's case, included having the subject report when he had completed the trial and even recording his "imaginary" score! Perry presented his results in terms

of equivalence with "real" practice. In each case five imaginary practice trials were given and these were found to be as effective as two actual trials on card sorting, three actual trials on the tapping task, four on mirror drawing, five on digit symbol substitution and, surprisingly were more effective than the five actual trials on the peg-board task. Perry attributes these results to the degree to which each of these rather different tasks is capable of symbolic or verbal representation. Although this explanation is attractive it is clearly post hoc and it does not appear to be confirmed by a more recent study by Vandell, Davis and Clugston (1943) who used dart throwing and basket ball throwing over 20 days with real practice on days 2 - 19 or mental practice on days 2 -19. A control group simply worked on day 1 and was given the retention test on day 20. The control group showed no improvement whilst the mental practice, as in Perry's study, carried out in the real environment, was almost as effective as active practice.

The implications of these studies, which do not appear to have been followed-up in the intervening years, are considerable, both in terms of the theory of skill acquisition and in terms of the practical possibilities of mental or symbolic rehearsal used to maintain the level of performance of a motor skill during a lay-off period.

8. Conditions of Recall.

Most studies of motor retention have used the relearning or savings method. Relearning is usually fairly rapid. Typical results are those of Braden (1924)* whose subjects took 10 days to achieve a level of accuracy in ball tossing

*Note: See Appendix A, Figure 2.

after a 22 month interval which had originally taken 100 days to achieve and Bell (1950)** using the pursuit rotor who found that his subjects took 8 one minute trials to reach the level they had attained a year earlier after 20 trials.

For the majority of experimental studies the task conditions at recall are physically identical to those obtaining during the original learning. However, in real life, even with physically identical conditions the retention or relearning situation could well be subjectively different. Repetition of responses not only improves performance but can sometimes have detrimental effects attributed to reactive inhibition. Such effects have been found for both verbal learning tasks (Hovland, 1940) and motor tasks such as the pursuit rotor (Ammons, 1947; Irion 1949) and can give rise to the phenomenon of 'reminiscence', that is, better performance <u>after</u> a rest period than on the trials just before rest. Reminiscence as such has not been demonstrated for the rather longer "rest" intervals of retention experiments, but its existence under some conditions draws attention to the fact that the absence of practice is not always deleterious.

Another well known but probably short-lived phenomenon is that of "warm-up". This is often seen in the relatively rapid improvement found during the first few trials of resumed practice. Warm-up trials do improve retention (Macek et al, 1965). The warm-up process is not fully understood but may involve re-orientation to the task and possibly the "recalibration" of responses. Reminiscence and warm-up effects in pursuit rotor learning are illustrated in Appendix A, Figure 4. Reminiscence and warm-up effects can

** Note: See Appendix, Figure 1.

complicate the measurement of retention, particularly where simply pre-rest-post-rest difference measures are used, but they may also be relevant to a condition which probably obtains in all retention in real-life, which we may loosely designate "stress". Starting a new job or resuming work after a lay-off period is likely to be stressful. It is well known that moderate amounts of stress can benefit performance whilst excessive amounts are generally deleterious, but little is known except anecdotally about the effects of stress on retention. Examinees often complain that they recall answers after the examination is over. It is not known whether stress actually inhibits retention or whether failure to recall simply accentuates felt stress, or even if relief from stress has a disinhibiting effect on recall. There is evidence that stresses of various kinds affect perceptual-motor performance (Broadbent, 1971) but these effects are sometimes beneficial and sometimes detrimental.

Various psychoactive drugs can interact with stress effects. Payne and Hauty (1955) have reviewed evidence showing that work decrements in tasks such as multi-dimensional tracking can be mitigated by drugs such as dextro-amphetamine sulphate and methyl caffeine. It is by no means impossible that long-term retention and stress interact and that this interaction might be affected by pharmacological agents but the relevant research is yet to be carried out

9. Individual Differences.

As with much of the psychological literature on almost any topic students constitute the main subject populations, with a few, but sometimes extensive, studies in which American servicemen were used. There has been no systematic examination

of the relationships between individual difference variables, for example age or ability, and retention variables. There are, however, some hints that performance at the end of original learning, which will generally be positively correlated with ability, is a good predictor of retention. Fleishman & Parker (1962) in a realistic flying task for example, found correlations of between 0.84 and 0.98 between original performance and retention and moreover these correlations were unaffacted by the duration of the no-practice period. Roehrig (1964) who found almost perfect retention on the balancing test remarked on the high ability and motivation of his subjects and Carron & Marteniuk (1970) found differential retention on the same balancing task with different ability subjects. So, by and large, one would expect that level of attainment, which may in part depend on underlying ability, and motivation is effective in retention. With regards to age and the notorious failing of memory of the aged Welford (1958) and his associates have found two main effects. One could be described as a progressive reduction in information processing capacity as age increases and this can show up in tasks which rely heavily on short-term memory. Second, older subjects tend to introduce compensatory strategies if their performance is being limited by any significant loss in processing capacity - that is they tend to alter their approach to the task in order to make the best use of whatever capacities they retain. Welford's researchers produced no evidence to show poorer long-term retention with increasing age. There have been hints, but little more, that the effects of stress become more severe with increasing age (Hauty et al, 1965) and to the extent that stress may adversely affect retention some effect of increasing age might be expected. However, the older worker is also likely to be more experienced and one of the more reliable generalisations is that retention is closely related to the level of skill

attained. Thus, although there is a possibility that age may handicap retention, the greater experience of the older worker may more than compensate for this disadvantage. Once again it must be stressed that the absence of any thorough investigation of relationships between retention and individual differences makes generalisation hazardous.

10. Summary of Principal Findings.

1. Well learned perceptual-motor skills are generally well retained over long periods without practice.
2. Meaningful verbal material which has been well learned can also be well retained.
3. Verbal nonsense material often shows poorer retention than a motor skill when both are learned under laboratory conditions but attempts to establish the relative permanence of verbal and motor learning have failed for methodological reasons. The difficulties include that of establishing task equivalence in all respects except the verbal/motor distinction, especially equivalence in difficulty and in degree of initial learning. Even with apparently motor task subjects may sometimes be able to adopt either verbal or motor learning strategies. For these reasons the generalisation that skill is better retained than knowledge cannot be sustained.
4. Continuous tasks such as tracking appear to be better retained than discrete tasks, such as switching procedures. However, studies in the literature have failed to equate continuous and discrete tasks for difficulty and degree of learning, there being no method of scoring which is common to both types of task. It may well be the case that continuous tasks are typically overlearned by comparison with discrete tasks.

5. As in verbal learning, meaningful material is better retained than nonsense, so also more organised, coherent, or integrated motor tasks seem to be better retained. However, no satisfactory and comprehensive definition of task organisation is available and so support for this generalisation remains weak. Apparently positive results may be simply due to the more 'organised' task being easier to learn. This would give an advantage in terms of degree of mastery at the termination of the original learning period.
6. The generalisation that different types of task show inherently different retention is not sustained. Progress towards generalisations in this area is hampered not only by comparative measurement problems mentioned in paragraphs 3 and 4 but also by the lack of any generally agreed taxonomy of tasks and skills.
7. The classical practice variables such as massed and spaced, part and whole, have not been shown to have differential effects on retention.
8. There has been little systematic research on differences in retention as between different broadly defined training philosophies such as skills analysis training, programmed instruction etc.
9. It is possible that adaptive training strategies which are especially conducive to long term retention could be devised.
10. If, as seems probable, degree of retention is heavily dependant on degree of mastery at the end of the original learning, then any training method which is conducive to effective learning will probably also be conducive to retention.
11. Retention is a function of degree of initial learning and this is probably true for both simple and complex tasks. The function is probably negatively accelerated,

that is, overlearning gives progressively smaller returns in retention.

12. Significant amounts of retention have been found after periods of no practice of up to 50 years since original learning and there are many examples of good retention after periods of a year or more without practice.
13. There is no generally valid curve of retention, that is to say a single function relating degree of retention to the duration of the retention interval. Retention curves are necessarily composite since the act of measuring retention provides an opportunity for rehearsal. The shape of the retention curve probably depends on the nature of the task and is strongly influenced by the measure of retention employed. Different measures of retention do not necessarily correlate perfectly.
14. Activities in the retention interval can either facilitate or interfere with retention.
15. Reversal of display/control relationship has been shown to cause interference in retention but more particularly so when the original habit was over-learned. This finding, if confirmed, is the opposite of what one would expect from comparable findings in the field of verbal learning. Little is known about the interfering effects of less obviously relevant activities.
16. Rehearsal during the retention interval facilitates retention.
17. The more closely the rehearsal task resembles the criterion task the better the retention. However, practice using simplified tasks or symbolic representations of the task and even purely 'mental' practice has been shown to have some worthwhile benefits on retention.

18. Well-learned tasks are relearned rapidly, sometimes in only a few trials, even after extensive intervals of no practice.
19. The first few trials after a break from practice may be adversely affected by warm-up decrement or beneficially affected by reminiscence.
20. Retention testing may be stressful and stress may affect retention but no reliable generalisations are possible on the available evidence.
21. Individual differences in ability may affect retention but this result may be due to the confounding of ability with performance at the termination of original learning, which is itself a good predictor of retention.
22. There is no evidence that age, within the normal span of working life, has any systematic effect on the long-term retention of skills. It is possible that stress at recall after a long period of no practice may be more severe with increasing age but it is also possible that longer working experience may more than compensate such a handicap. Evidence on these matters is, however, very sparse.

Chapter 3. CONCLUSIONS AND RECOMMENDATIONS.

1. Some Tentative Answers.

The shape and content of Chapter 2 have been determined by the experimental literature but it is now time to return to the original questions and attempt to translate the findings of Chapter 2 into appropriate answers. The literature has also thrown up a number of other questions, more or less directly related to those posed in the original brief and which seem to merit further attention. These will be discussed in Section 2 of this chapter.

As has already been shown in previous sections it is not possible to draw very rigorous conclusions nor to offer generalisations with a high degree of confidence. Amongst the principal reasons are the difficulty of generalising from one task to another and the variety of ways in which retention can be measured to say nothing of a host of lesser methodological problems. What follows constitutes an attempt to answer the original questions but qualified by a greater or lesser degree of confidence in the evidence and pointing out where further research would seem to be desirable.

Question 1.

What is the rate of performance decay in terms of terminal performance criteria of training (over a wide range of skills/trades)?

The question can be interpreted as asking for the shape of the retention curve and parameters of the curve for different skills and trades. Retention curves, like learning curves, are

highly dependent on the specific methodology. They can have some limited uses in basic research in so far as a theory may predict the shape or parameters of a curve but it is unwise to take them out of context. Retention curves tend to be of the negatively accelerated exponential type when retention is measured either by the difference between the last training trial and the first retention trial or by the savings method, but they can have other shapes, e.g. positively accelerated, if retention is represented by a measure of performance variability. The doubly inflected curve suggested by Johnson and Van Doorn (1976) is found only in very special and limited circumstances.

The question of whether retention parameters can be assigned to different skills/trades cannot be answered directly from the literature since there have been so few studies of retention of specific skills and trades. The next best thing is to make some informed guesses on the basis of assumed relationships between the tasks which have been studied and an appropriate range of real tasks. This step implies a valid task taxonomy but the present reviewer does not believe that any one taxonomy can be adopted with much confidence. Such taxonomies as exist are either largely intuitive or simply convenient within the context for which they were designed. Psychological science does not yet command a clearly agreed and closely defined set of categories.

It may be more helpful to discuss the retention characteristics of jobs in terms of major variables like verbal/non-verbal, discrete/continuous, easy/difficult and perhaps the degree of organisation. Most text books including some of the latest, (Baddeley 1976), repeat the old story that motor skills are better retained than

verbal material. Whilst it is true that tasks like balancing and tracking are well retained and the typical laboratory nonsense list is rather rapidly consigned to oblivion, this generalisation cannot be sustained for a number of reasons. First there are few studies in which the tasks compared can be said to be comparable in any respect except that one is "motor" and the other "verbal", but the more similar they are the more similar do their retention scores become. Second, although a task may be apparently "motor" trainees may well use verbal technique to aid learning and memory and so it is difficult to classify the task with confidence without taking account of the learning and retention strategies used by the subjects. Third, meaningful "verbal" material which has been well learned is probably much more stable than the literature on nonsense lists and arbitrary paired associates would lead one to believe. This review has turned up a number of instances of good retention of Greek, Psychology and Algebra for example, which have been remembered for quite long periods.

A practical distinction can be made between discrete and continuous tasks where the former involve remembering sequences of actions and the latter involve continuous correction and there is prima facie evidence that the former tend to be forgotten more readily. This has been found both in laboratory type tasks and in real life. whilst the distinction is not completely watertight from the theoretical point of view, in practical terms complex procedures are more likely to present a problem after long periods of no practice than are control skills. Fortunately, this is a problem which can probably be dealt with quite adequately if opportunities are provided for rehearsing procedures.

Variables such as task difficulty and "coherence" or "organisation" do seem to affect retention. This would lead one to suspect that more difficult skills are more sensitive to lack of practice. However, the more difficult tasks will, almost by definition, require more or longer initial training and since degree of learning turns out to be a potent factor in retention it may simply be that the more difficult tasks are likely to be less well learned.

To summarize, the literature does not provide any very dependable guide to the question of differential rates of forgetting as between tasks, let alone skills or trades. Although there is plenty of evidence that perceptual-motor skills can be retained for very long periods the myth that motor memory is better than verbal memory is not supported and various rather more sophisticated modifications of this myth lack strong support.

Question 2.

Is skill loss in non-relevant employment greater than skill loss in unemployment?

No studies relating to unemployment have been found. Although unemployment is a serious matter, even a catastrophe for the individual concerned, it does not constitute a unique psychological state which can be distinguished from being in employment. The definition of these states is social, not psychological, and there is no *prima facie* reason for suspecting that being employed will *per se* make any difference to the retention of previously learned skills. The term "non-relevant" is difficult to define but nevertheless one possible interpretation of this question is whether the learning of a different skill during the no-practice period will affect retention. In other words, the question may be aimed at the retroactive interference paradigm, that is where retention following "empty" intervals is contrasted with with retention after interpolated learning of tasks which

The evidence on this more precise question is that interference has been clearly demonstrated in the case where the interpolated task involves a display/control reversal. In practical terms learning to use a machine which closely resembles the original machine but has reversed display/control relationships will very probably interfere with retention of the original task. However, nothing more general has been demonstrated. We do not, for instance, know if driving an articulated lorry will interfere with, say, retaining the skill of driving a crane. We would have problems attempting a general answer to such questions for the same reason that we have problems with the task taxonomies and with the concept of "similarity" between tasks.

Although it is not part of the original question the review has thrown up evidence a refresher training during the no-practice period, can aid retention. Moreover refresher training (or rehearsal) probably does not have to be of the identical task or the whole task to be beneficial. Procedures, which can be fairly readily forgotten, can be rehearsed on relatively crude mock-ups and even the injunction to mental rehearsal may have some benefit. The findings so far do not allow us to specify the precise values for optimal timing, amount or realism of rehearsal but it seems likely that relatively short periods of relatively cheap refresher training could help to maintain skill levels over quite long periods and so reduce the length and cost of retraining.

Question 3.

What effects do different training techniques have on the retention of skills?

Most of the relevant literature comes from laboratory studies rather than real life. The classical variants on training methods such as massed and spaced, part and whole, knowledge of results, seem to have very little systematic effect on retention. Since degree of original learning seems to be about the best predictor of retention one could argue that any method will give retention in proportion to the degree of mastery which can be achieved using that method. Although research on the classical training methods has yielded little of interest, modern methods such as "discovery" and adaptive training have not been examined for comparative retention. In so far as general principles and strategies may be better retained than specifics there seems a distinct possibility that methods which emphasise general principles might have advantages both in retention and in transfer.

Question 4.

Is the rate of skill loss different for a trainee who remains unemployed after training compared with a person who has practised the skill and then becomes unemployed?

Again translating the ambiguous terms of the question into a more concrete question which asks simply "is retention a function of the amount of original learning?" the answer is with some degree of confidence "yes". Amount of training has come out as probably the most potent single variable affecting retention but it also emerges that "overlearning" shows rapidly diminishing returns.

In interpreting this question we have to bear in mind that in many industrial situations "learning" differs from practice

on the actual task and that, even after an extensive off the job training course, trainees will continue to learn improve performance on the job. This will be particularly so where the training is inadequate or where it is geared more to the demands of a public examination than to the conditions of an actual job. In short we cannot assume that the individual who is technically qualified has actually learned the job. Attaining "experienced worker standard" is a much more relevant criterion.

Once again we cannot be precise about the parameters but an individual who has reached EWS and then lost his job is not likely to show very much more retention loss than someone with rather more practice if the evidence on over-learning is to be believed. It must, however, be pointed out that there is not much evidence relating to very extended amounts of practice in original learning. In most of those studies surveyed original learning was fairly minimal and would not even begin to approach the amount of practice an operator would be likely to get with as little as 3 months work experience.

Question 5.

Is the time taken to impart a new skill greater/less than that taken to refresh a decayed skill?

The evidence from this survey shows fairly conclusively that even where retention after a period of no practice is not very good it can in most cases be 'refreshed' rather quickly. There is a quite striking evidence that even after many years the amount of time and effort required to re-learn a skill is very much less than that required to

learn it initially. In practical terms, then retraining is a real possibility even when some years have elapsed since the original learning and will in most cases get the desired result. One caveat should be mentioned - job practices, methods, tools and materials may change and this could create more difficulties than are caused simply by forgetting. These difficulties could be serious if the job changed in a way which made the originally learned skills inappropriate e.g. if display-control relationships on a machine had been reversed.

Question 6.

What is the value of output loss versus refresher training?

The answer to this question will vary enormously with the specific case for reasons which have little to do with the psychology of learning and forgetting. Any answer must depend on the economic value of output and the cost of training, both of which can vary indefinitely and which are not necessarily correlated. However, the results of the review are generally encouraging on the likely results of refresher training as indicated in the answer to question 3.

Question 7.

Does skill loss vary with age?

There have been no systematic studies on this question and very few which have looked at any of the more obvious individual difference variables. Although 'mature' trainees

may well expect, and respond better to, different handling than is often meted out to young trainees there is no psychological evidence to suggest memory differences dependent on age over the span of the normal working life. Although there are some differences in short term retention (Welford 1958) age effects in the long.term retention of skill do not seem to have been demonstrated. The subjects used in most of the experiments reviewed were young, either students or airmen, but there is the occasional suggestion that retention is greater in more able, more intelligent or more highly motivated subjects. We cannot however, say that any of these is a significant variable when the effect of level of skill reached have been partialled out.

Several questions not asked in the original brief suggest themselves. There is some evidence to suggest that stress at the time of recall may have an adverse effect on retention. Since an individual taking up employment after an extended break may be under stress, relearning 'on the job' may have an adverse effect on retention and may result in an employer or supervisor underestimating the individual's potential. If this is so some refresher training immediately before taking up a new appointment may be beneficial and may either reduce stress or reduce any deleterious effects of stress. This is, of course, related to the question of how any rehearsal or refresher training should be distributed over the no-practice period. All learning and retention studies can be regarded as transfer experiments where there is identity between the learning and the retention task. If embarking on training where the trainees will not be immediately employed the question must arise as to whether one should train for a particular task and risk the possibility that that skill, even if well retained, will never be needed or whether always to engage in some more general or non-specific training which will have less transfer (retention) to whatever job is actually obtained but will have <u>some</u> transfer to a wide range of jobs.

2. Oustanding Problems.

It is tempting to argue that because the gap between pure and applied research in Psychology is often great the only possible strategy is to push ahead with applied research, that is to attack what appear to be the most important questions in as direct a manner as possible. If we were to attempt the direct approach to question 1 the determination of the parameters of retention curves for a wide range of skills and tasks would constitute a massive undertaking. If one were to multiply this effort by m different learning methods and n individual difference variables one could guarantee employment for a large team of psychologists for several decades! For this reason it is worth considering whether there are not some more general questions, the answers to which might illuminate a host of lesser questions.

One result of this review is to reveal the enormous imbalance between work on verbal memory on the one hand and the retention of skills on the other. This imbalance has become more striking in recent years with the burgeoning of work on verbal short and long-term memory compared with a mere handful of studies on short-term memory for very simple motor responses and virtually no significant studies of the long-term retention of complex perceptual-motor skills since Adams' review a decade ago.

Whilst a number of important contributions have been made to theories of short and long-term memory for verbal and pictorial material there has been no serious attempt to formulate or test a theory of the retention of skills. This imbalance in basic research ought to be corrected in order to guide and inform more directly applied research efforts.

But what sort of basic questions need answering? Much of the research reported in this review has used fairly simple indices of performance. When more than one has been used it is not unusual to find different scores (say of time and errors) supporting different conclusions. Rather than being an embarrassment this should be a challenge. The qualitative, even subjective, approach of some of the earliest workers, such as Swift, has something to commend it for we know very little about what happens to a skill as an organised pattern of behaviour when there has been a period without practice. To put it briefly, we do not know what exactly is lost when skill is lost. Does the skill regress, that is, does the operator who is laid off for a year behave just as he did at some earlier stage of practice? Alternatively does the skill become some kind of caricature of its former self, simplified and stylized, or do parts of it simply disappear? Does the overall strategy remain intact but with the former precision of timing lost? Is it only the most difficult aspects or components of the skill which are forgotten? Are the most recently acquired components or aspects of the skill the first to disappear for lack of practice? Answers to these questions could shed some light on the nature of skill loss and retention and perhaps lead to a general theory which could stand comparison with theoretical work currently being done in the field of verbal learning.

The review has also thrown up a number of other unresolved problems which are not only of general interest but which bear more or less directly on practical problems. One of the most important of these is the question of what task characteristics lead to better retention. The verbal versus motor and continuous versus discrete classifications seems to have been relatively unprofitable but the idea of "task organisation" has not

been fully explored. The key problem is whether it is possible to put a satisfactory interpretation on the concept which distinguishes it from task difficulty. The practical questions which might follow would be, for example, is a skill or task which is embedded in a contextual web of meaningful ideas better retained? Will training which emphasises the comprehension of underlying principles and the relation of the general to the specific give better retention than methods aimed at achieving bare competance by the shortest route? The analogy between some variable or set of variables defining the concept of "organisation" and the concepts of meaningfulness and schematisation in classical memory work seem to be worth pursuing on both theoretical and practical grounds.

The classical approach to "types of training" has produced few results of any significance for retention but this does not mean to say that special forms of training which are especially conducive to long term retention could not be developed. There is at least one result which suggests that adaptive training methods may be especially conducive to retention and this is certainly worth following up.

It has been suggested that realism in training is much to be desired and that the use of simulators and various kinds of symbolic representation make less of an impact on trainees than "hands on" experience. If this is so it would have a significant effect on the way training courses were organised and the material they used if periods of no practice were anticipated. However, the relative value of hands on experience and other forms of training needs to be carefully assessed in relation to the usual distribution of off-the-job and on-the-job training in a given trade or job.

Amongst the more hopeful findings to emerge from this review is that refresher training can be quite effective in overcoming decrements due to lack of practice. However, there is a range of questions relating to the nature of rehearsal procedures which are both theoretically interesting and of practical significance. In particular further work is needed on th use of symbolic representations and simulations in refresher training. Is even 'mental practice' viable and cost-effective and how can it best be managed?

Related to the matter of rehearsal is an extremely important set of practical issues to do with the retention of infrequently used procedures, notably emergency procedures. For reasons which are not entirely clear procedures are in practice, liable to be forgotten. The question then arises as to whether anything can be done by way of initial training or by the optimal spacing of rehearsals to maximise the retention of emergency procedures?

The review has revealed how little we know about the processes which operate at the time of recall after periods of no practice, especially those associated with taking up a new job after a period of unemployment. Warm-up decrement may operate in such a way as to give a false impression of an operator's capabilities during the early stages of resumption of work. If rehearsal could facilitate rapid warm-up this source of potential difficulty might be removed. Reminiscence too is sometimes found but under what circumstances can we expect an operator to perform better after a period of no practice than before?

Perhaps one of the most important areas for research is into the possibility of stress during early retention trials (or on re-employment). Is the recall situation stressful and, if so, does stress facilitate or inhibit retention? This

particular question also has important theoretical consequences for stress has been shown to affect performance in some of the kinds of ways in which,it is possible, lack of practice may also show its effects. The last major problem area which also featured in the original set of questions is that of individual differences. There is virtually no evidence relating to the question of whether age affects the long-term retention of skills. There are, however, suggestions in the literature that ability may be a significant variable in retention. Insofar as the less able youngsters are often those who are umemployed longest it is a matter of practical significance to know whether general ability or specific ability in a given task is a good predictor of retention. Research findings in this area are important in planning training for the young unemployed against future employment possibilities.

3. Summary of Research Recommendations.

Before listing the research recommendations arising from this review there are some general points which should be borne in mind. First, the original questions to which this review was addressed are not exclusively psychological in the sense of being answerable solely within the context of the experimental study of learning and forgetting. Social and economic factors are important in determining training policy and learning efficiency pure and simple is not the only criterion by which any training method is to be recommended. Some methods might not be acceptable on economic grounds and some might be considered inappropriate to a given case on social grounds. I have tried to point out problems which may need other types of expertise but the review is basically limited to questions of efficiency of learning and memory.

Second, whilst a large number of detailed proposals could be extracted from the summary of chapter 2 and the first two

sections of this chapter it seems better to make the recommendations in broad terms, that is concentrating on the kinds of questions it would be useful to pursue rather than proposing detailed experiments.

Third, a general plea for the support of more basic work must be entered. The review has revealed an almost complete lack of theoretical development during the 70 or so years since the first relevant work was done. There has been a considerable investment in memory research but the work which has been done is only marginally relevant to most of the practical problems of skill loss and there has been very little recent work on the long-term retention of motor skills. A good theoretical base is needed for sound practical results and investment in basic research is needed in order to attract researchers of high calibre into the field.

In the list of recommendations which follows it is envisaged that research should have both a pure and an applied aspect, since these are mutually beneficial. For convenience the list is arranged in the same order as the sections in chapter 2 but each research topic is also identified as being relevant to one or more of the questions posed in chapter 1 as indicated by the arabic numerals in brackets.

Recommendations.

1. Types of Task (also Q 1,3).

The suggestion that task organisation is effective in retention has not been satisfactorily explored. Research on this issue needs a better theoretical base and in particular a satisfactory working definition of "organisation", perhaps taking into account task structure and its relationship to any underlying knowledge structure, or the "meaning" of the task.

2. Types of Training (also Q 2).

It is suggested that more research is needed on the long-term retention value of some of the more recently developed methods of training. Among those deserving investigation from this point of view are (a) discovery methods, (b) methods emphasising underlying general principles rather than rote learning, (c) adaptive methods, (d) methods involving simulation and varying degrees of realism, and comparisons of off-the-job and on-the-job training.

3. Retention Interval (also Q 3,4,5,6).

The period during which a learned skill is not practised deserves further research. (a) The effects of positive and negative transfer between jobs closely or distantly related should be more extensively investigated. It is not known, for example, whether there is positive or negative transfer between vehicle control skills and, say, machine-tool handling skills. (b) Since skill loss can be mitigated by rehearsal the nature of efficient procedures, especially including 'symbolic' rehearsal should be further investigated. (c) The particular case of the retention of emergency procedures is so common and of such general importance that it deserves additional special attention.

4. Retention and Relearning (also Q ,5,6).

(a) The process underlying the deterioration of unpractised skills are poorly understood and further basic research, including the development of a testable theory of skill loss is suggested. Such research would pay closer attention

to qualitative features of skill loss and make use of multiple indices of performance.

(b) Processes operating at the time of recall, especially the phenomena of remininscence and warm-up could be of particular importance in situations where long-unused skills may be required at very short notice.

(c) The role of stress in the retention of skill deserves further research. The effort to recall an unpractised skill may be inherently stressful and stress, whether caused by this or some other factor, such as an emergency, may either inhibit or facilitate skill retention.

5. Individual Differences (Also Q6)

Individual differences in long-term retention of motor skills is a neglected area of research. Little is known about the relations between performance at the end of training, ability and age at retention or retraining and research in this area would be of value in selecting individuals for retraining. Because of popular myths about memory and age, research which demonstrates that, to adapt a phrase, old dogs can remember old tricks, is worth carrying out.

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APPENDIX

Learning and Retention Curves

The following illustrations may be of assistance to the reader unfamiliar with the literature on learning and memory.

Fig.1 from Bell, 1950 shows a learning curve for a pursuit rotor (tracking) task and the effect of a one-year no-practice period.

Fig.2 from Braden, 1924 is a learning curve for ball tossing (A) and relearning the same task after an interval of 22 months (B). Note that relearning is comparatively rapid.

Fig.3 from Meyers, 1967 shows virtually no effect of a 13 week break on the learning curve for a balancing task. Warm-up and reminiscence effects are not apparent in the data.

Fig.4 by contrast, shows some unpublished data by Annett and Carstairs on pursuit rotor learning from over 500 Open University students. The curve A-B shows initial learning during 10 one-minute trials. An 8 minute rest is taken at B-C resulting in a marked improvement on resumption, the reminiscence effect. The further short-lived improvement C-D is attributed to warm-up.

Fig.5 shows a classic retention curve for nonsense syllables
Fig.6 from Ebbinghaus, 1885 whilst Fig. 6 shows the curves obtained by Leavitt and Schlosberg, 1944 for the retention of pursuit rotor skill and verbal nonsense material. It should be noted that both use the savings method of measuring retention, hence 100% savings would mean perfect retention. Leavitt and Schlosberg appear to overcome the difficulty of comparing two unlike tasks by representing

retention on each as a percentage of the respective immediate retention scores. This does not, however, eliminate the fundamental difficulty since, amongst other problems we do not know how well each task was learned initially, what is their relative difficulty, or how the two scoring systems compare in terms of sensitivity to underlying changes.

Fig.7 and 8 from Mengelkoch et al., 1971 show learning and retention curves for a procedural element (Fig.7) and a tracking element, altitude control, (Fig.8) of a complex flying task. There is some loss in both elements but this is more marked in the procedural skill. In both cases the loss is quickly restored by further practice and in both cases the greater the original learning the smaller the loss. The dashed curves are for a group having only 5 training trials.

Fig.9 from Krueger, 1929 shows the effect of varying degrees of overlearning on the retention of verbal nonsense-material. The longer the retention interval the less the benefit from overlearning.

Fig.10 is from Bilodeau and Levy, 1964 representing the loss in accuracy of reproducing a simple linear movement. The ordinate is an index of recall based on the correlation between adjacent responses. Fairly rapid forgetting during the first few minutes is followed by a much slower but positively accelerating deterioration over a few days. The curve demonstrates how the basic shape is highly dependant on the type of measure employed.

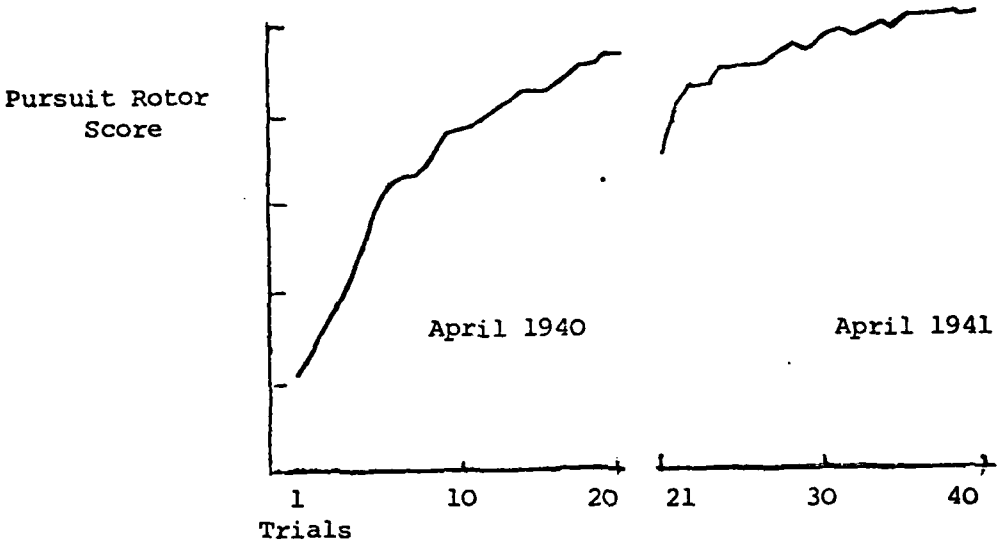

FIG.1. After Bell, 1950.

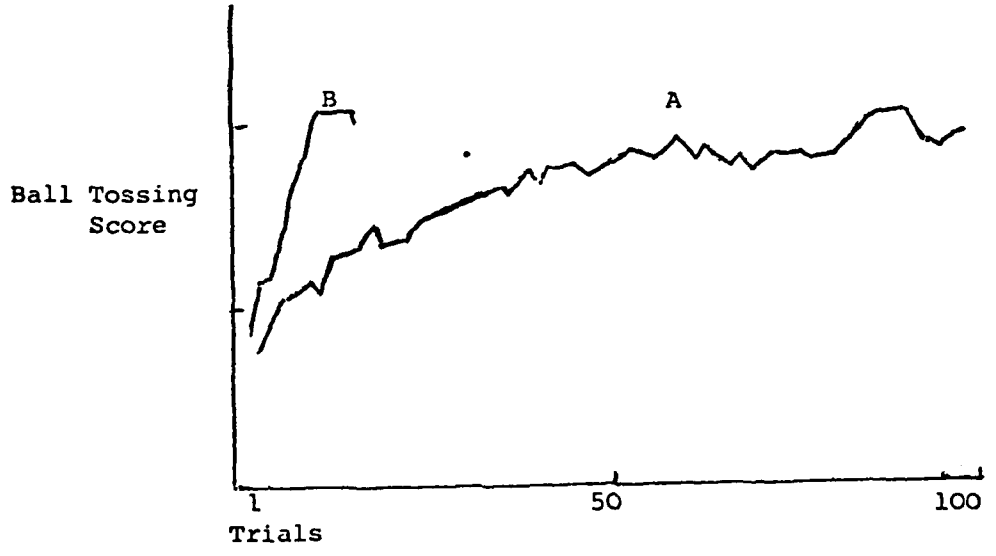

FIG.2. After Braden, 1924

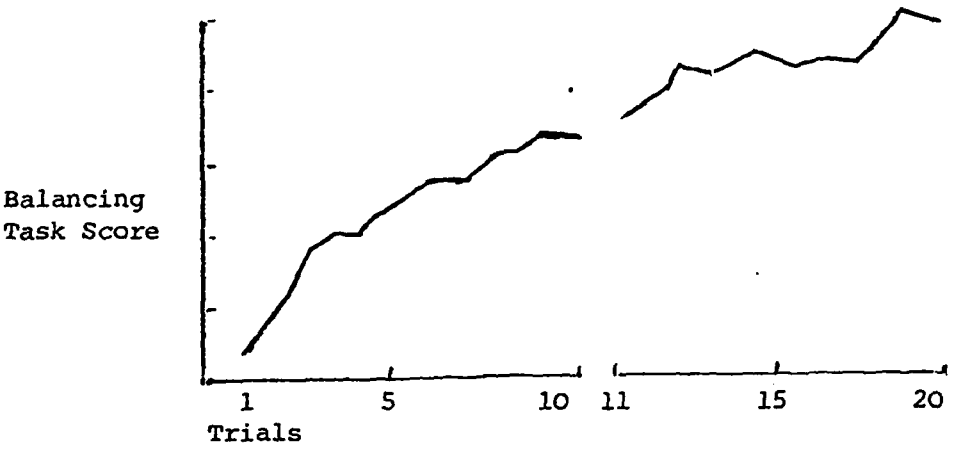

FIG.3. After Meyers, 1967.

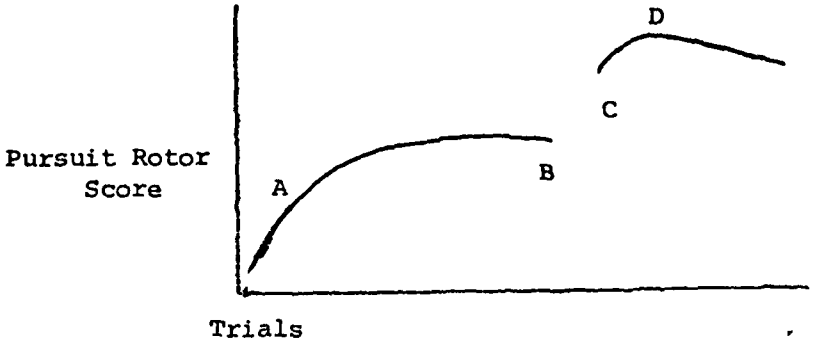

FIG.4. Annett & Carstairs, unpublished data.

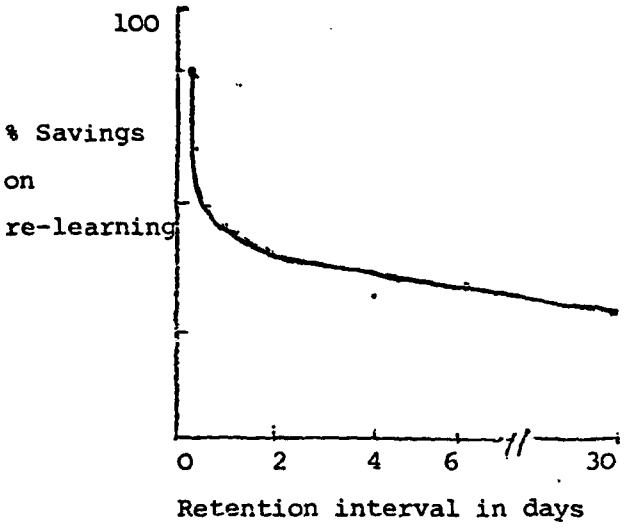

FIG.5 After Ebbinghaus, 1885.

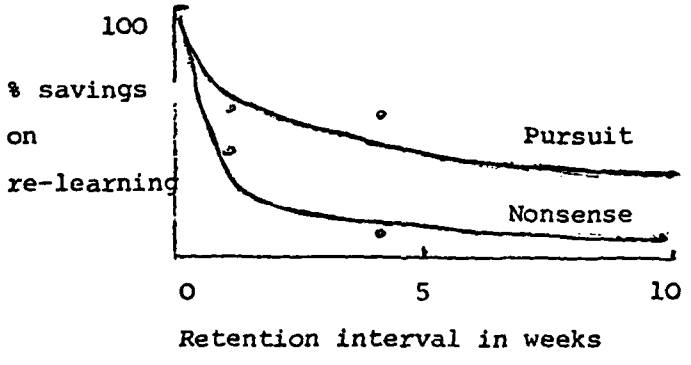

FIG.6 After Leavitt & Schlosberg, 1944.

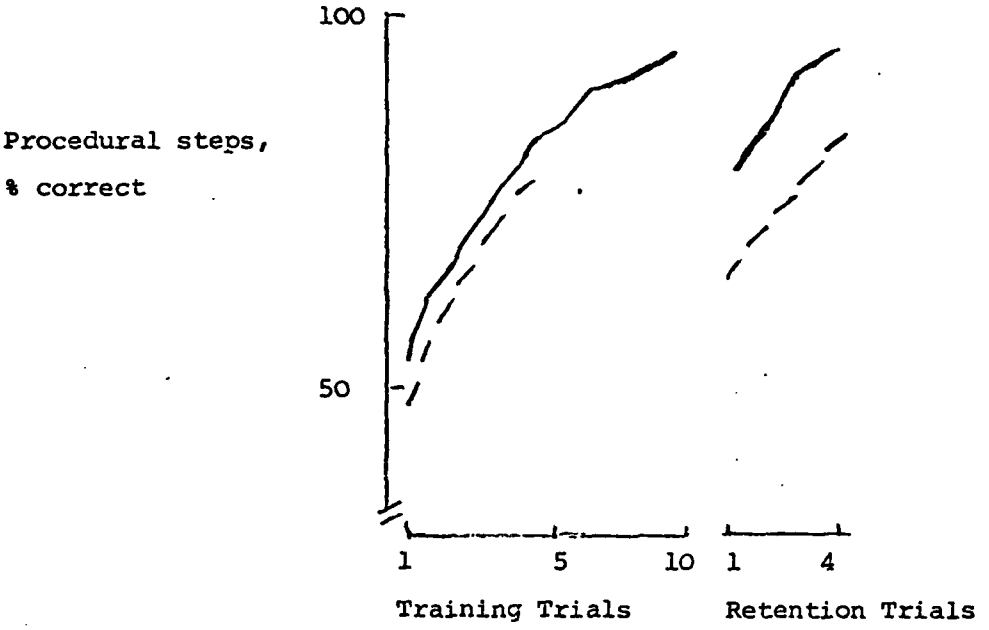

FIG.7 After Mengelkoch et al., 1971.

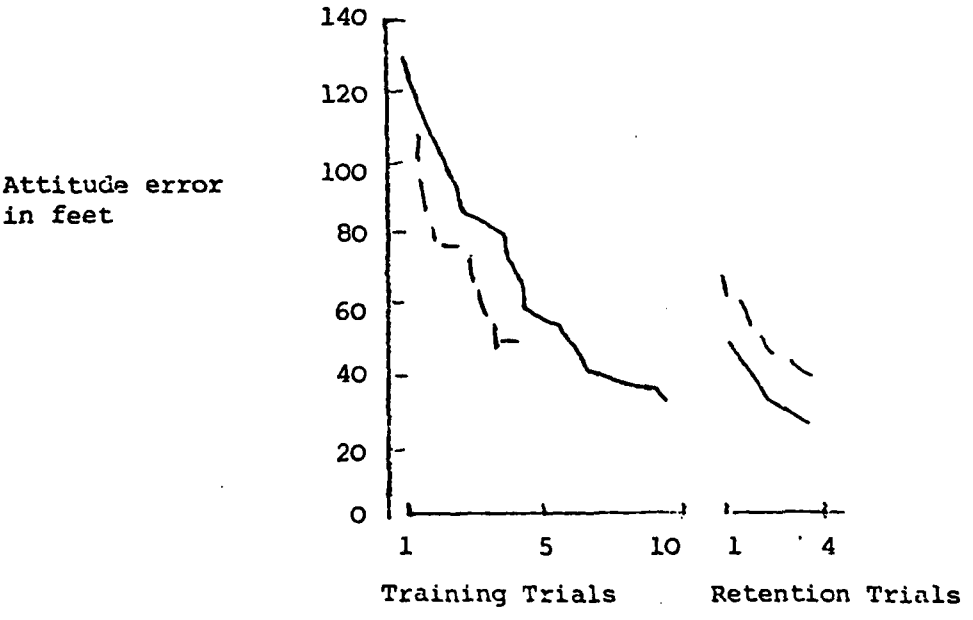

FIG.8 After Mengelkoch et al., 1971

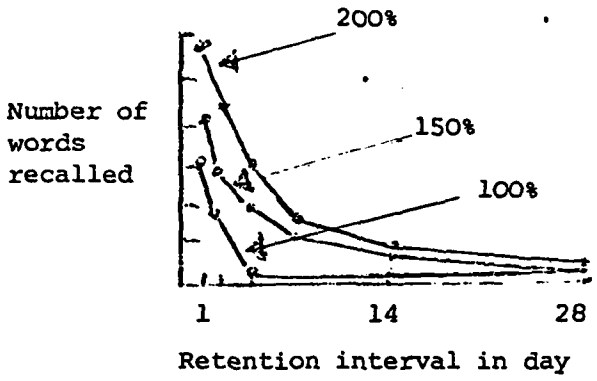

FIG.9 After Krueger, 1929

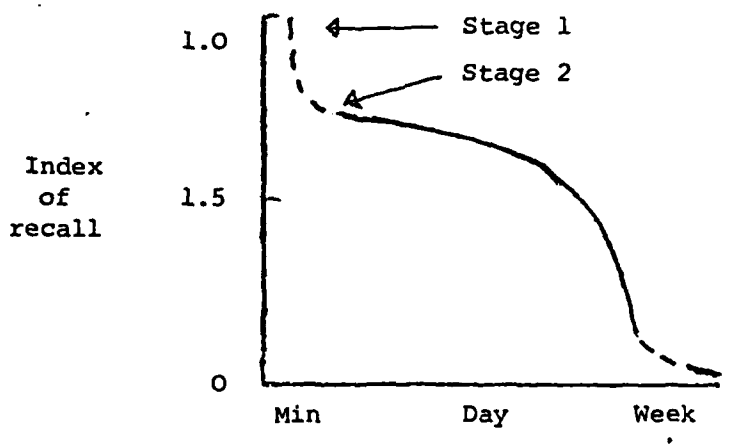

FIG.10 After Bilodeau and Levy, 1964

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