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THE PSYCHOLOGY OF LEARNING

IN RELATION TO FLIGHT INSTRUCTION

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Committee on Selection and Training of Aircraft Pilots

Executive Subcommittee

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LETTER OF TRANSMITTAL

NATIONAL RESEARCH COUNCIL

2101 Constitution Avenue, Washington, D. C.
Division of Anthropology and Psychology

Committee on Selection and Training of Aircraft Pilots

June 26, 1943

Dr. Dean R. Brimhall
Director of Research
Civil Aeronautics Administration
Washington, D. C.

Dear Dr. Brimhall:

Because of the marked interest in problems of training, the Committee on Selection and Training of Aircraft Pilots considers it desirable to issue immediately, in advance of the publication of the proposed text on Aviation Psychology, the attached chapter entitled "The Psychology of Learning in Relation to Flight Instruction." This seems particularly appropriate because of the use which has been made of this material in the Training Methods Unit of the Controlled Secondary Instructor Course recently prepared by the Committee, in cooperation with the Division of Research, Civil Aeronautics Administration, for the War Training Service.

It is recommended that the attached chapter be included in the series of technical reports which are being issued by the Division of Research, Civil Aeronautics Administration.

Cordially yours,

Morris S Viteles

MSV/es

Morris S. Viteles, Chairman
Committee on Selection and
Training of Aircraft Pilots

FOREWORD

The history of the Committee on Selection and Training of Aircraft Pilots has been marked by a transition from an initial emphasis upon pilot selection to a growing concern with improved methods for training pilots. This parallels a changing orientation in the Armed Forces, where the extreme importance of training as a device for promoting the effective use of manpower is receiving ever-growing consideration.

Research on pilot training, such as that conducted under the auspices of the Committee on Selection and Training of Aircraft Pilots, represents an extension of the type of experimentation that has long been conducted in university laboratories and in industry. In view of this fact, investigators in the field of pilot training will find much of value in the critical summary of the literature and of the psychological principles of learning in relation to flight instruction included in the material which follows, prepared with the editorial assistance of Dr. Norman L. Munn of Vanderbilt University, for publication in the proposed text of Aviation Psychology. The chapter is published at this time so that its material may become immediately available to those interested in the problems of pilot training.

CONTENTS

THE PSYCHOLOGY OF LEARNING
IN RELATION TO FLIGHT INSTRUCTION

I. INTRODUCTION

Psychologists have been investigating the learning process for more than fifty years. Investigations were first carried out in the psychological laboratory, but later extended to embrace activities of the classroom and industrial plant. The learning process in aviation has received considerable attention in the research program of the National Research Council Committee on Selection and Training of Aircraft Pilots, especially with the aim of facilitating flight training. Recognizing that the best selection methods would be of very restricted value unless effective training methods were also used, the Committee has sponsored, and continues to sponsor, several projects aimed at the improvement of training methods. These projects and their outcomes are considered in the present survey along with other relevant material from laboratory, classroom, and industrial plant.

<u>Approaches to the problem of learning.</u> Laboratory investigations of learning have been motivated by a desire to discover what learning is, particularly in terms of the conditions which produce it (or interfere with it) and its representation in the nervous system. In pursuance of these aims the laboratory investigator has developed scientific methods of studying the learning process and has discovered a number of principles whereby this process may be speeded up and its results made more permanent. Studies of learning in the classroom, in industry, and in aviation have built upon this groundwork of laboratory research.

<u>Learning curves</u>. Progress in the acquisition of skill is illustrated by the learning curve, a graph showing changes in performance as a result of practice. Practice periods or intervals during which performance is sampled are represented along the base (abscissa) and correct responses, errors, time, or other indices of progress at the side (ordinate) of the graph.

Figures 1 and 2 present learning curves drawn to illustrate improvement with practice in two psychomotor skills. Figure 1 shows the average improvement made by 33 subjects during 6 trials on a two-hand coordination test (52). In this test, improvement in performance is measured in percent of time that the subject is able to do the task correctly. A higher percentage of time, therefore, indicates better performance. When the results of the test are plotted directly (per cent of time on the ordinate and practice trials on the abscissa) improvement is shown by a rising curve. In Figure 1 it will be noted that the 88 subjects were performing correctly only about 45 per cent of the time during the first trial, but that they improved with practice until in the sixth trial they were performing correctly approximately 60 per cent of the time.

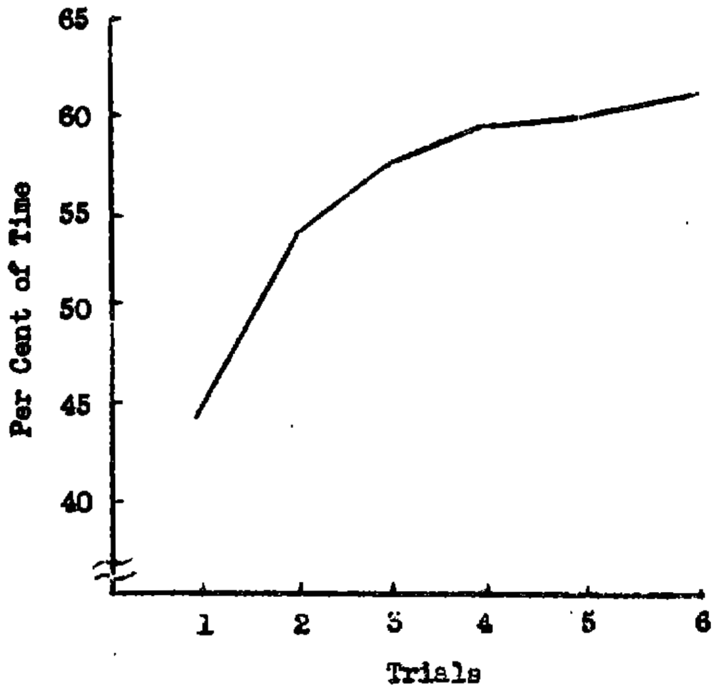

FIGURE 1

CURVE SHOWING IMPROVEMENT IN THE TWO-HAND COORDINATION TEST AS A RESULT OF SIX PRACTICE PERIODS

Figure 2 illustrates the average improvement made by 7 subjects during 10 practice trials on a serial reaction-time test (27). In this test, improvement in performance is in terms of the total number of seconds it takes the subject to react to a series of stimuli. A shorter reaction time, therefore, indicates a better performance. When this time score is plotted against the practice trials (time in seconds on the ordinate and trials on the abscissa) improvement is shown by a curve which declines as learning or improvement proceeds.[1] In Figure 2 it will be noted that the 7 subjects were taking a total of about 374 seconds to react correctly on the first trial, but that they improved with practice until in the tenth trial they were reacting correctly in approximately 225 seconds.

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[1]A declining curve will also be found when the number of errors is plotted against trials.

Most learning curves for motor skills have certain common characteristics. Especially notable is the fact that learning usually proceeds rapidly at first and then more slowly as practice continues. In other words, as far as the measurable aspects of learning are concerned, later practice periods tend to exhibit diminishing returns. This is clearly evident in the two curves presented in Figures 1 and 2.

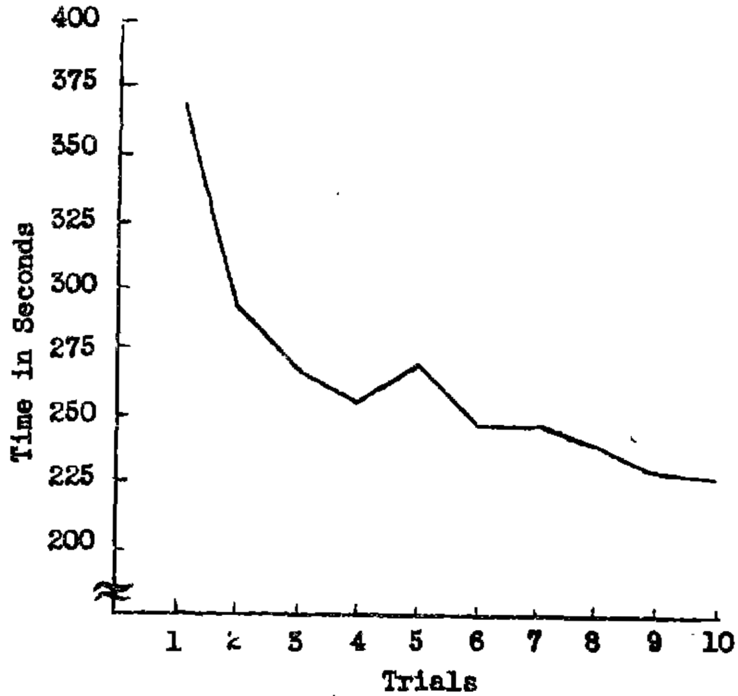

FIGURE 2

CURVE SHOWING IMPROVEMENT IN PERFORMANCE OF THE SERIAL REACTION-TIME TEST AS A RESULT OF TEN PRACTICE PERIODS

The chief reason for diminishing returns in later practice periods is the fact that, as learning proceeds, an individual is approaching his physiological limit or limits provided by the nature of the problem. An individual who runs the 100-yard dash in $9\frac{1}{2}$ seconds, for example, cannot be expected to improve as much as one who requires 10 seconds. The former is already running just about as fast as muscular and nervous systems will allow.

When time scores are used to measure learning there is always, as in the 100-yard dash, a physiological limit. The individual, assuming that he is working with maximal motivation, may reach a speed which cannot possibly be improved. However, if improvement is measured in terms of error scores, the curves when plotted may reach a point at which no further errors are made. Likewise, curves plotted in terms of correct responses may reach an upper limit which is a function of the problem rather than of individual limits of performance. We are not justified in assuming that these curves indicate the individual's physiological limit.

Furthermore, many responses may be further perfected by continued practice, even though the learning curves show what is apparently "perfect" performance in terms of errors or correct responses. Aspects of learning which do not yield to precise measurement, but which are nevertheless of great importance, are being acquired during the final period of little or no apparent gain. In aviation these would include such factors as gaining increased proficiency in getting the "feel of the plane" and achieving automaticity of performance. In such cases, the amount of gain in relation to cost of training becomes a particularly important consideration.

When curves are plotted for individuals, there is usually much fluctuation in efficiency from trial to trial and the general trend may thus not be observed readily. The trend is more obvious when data for several individuals are averaged, as in Figures 1 and 2.

2. MEASURING PROGRESS IN FLIGHT PERFORMANCE

Faulty methods of operation necessarily characterize the performance of the inexperienced pilot, and the instructor's task is to eliminate these as early as possible in the training program. A practical approach to the instructor's task is through the study of what happens as the pilot learns, for only by analyzing the learning process will it be possible to arrive at useful recommendations with respect to methods of instruction.

As in all experimental work, the analysis of the learning process should preferably be based upon objective and accurate measurements of performance. Difficulties in obtaining such measurements under actual flight conditions, however, have usually made it necessary to resort to qualitative evaluations based on direct observation. Recent investigations, on the other hand, by Viteles and Thompson at the University of Pennsylvania (50, 51) and by Kellogg at Indiana University (19) have shown that progress in flight performance can be studied by means of objective techniques.

Whether objective measures or qualitative evaluations are used, the task of analyzing the learning process may be approached in two ways. The first is the <u>global approach</u>, in which an effort is made to evaluate the total performance of the student pilot; the second approach is to break the total operation into <u>simpler components</u>, such as movements made in controlling rudder, aileron, and elevator, and to determine what changes take place in each of these components during the training period.

In the studies at the University of Pennsylvania both qualitative estimates of over-all (or global) performance and quantitative measurements of the underlying flight components were obtained from analysis of motion photographs of pilot performance during flight. Standardization of flight test conditions so as to minimize the effects of variables other than the training process was obtained by the use of Standard Flights developed as one phase of the University of Pennsylvania Research Project (50).[2] These flights provide standard test situations by specifying the order, character, and flight pattern of the maneuvers included in each flight. Each maneuver is appropriately prescribed as to altitude, length (in terms of degrees of turn, time, or change of altitude), ground reference points (when necessary), angle of bank, etc. Separate flights are used for each of the four stages of the C.P.T. Program.[3] These provide for a repeat performance of the basic maneuvers included in the previous stages. Weather and air factors are controlled by setting up a fairly narrow range of conditions of wind velocity, visibility, and air turbulency under which the flights may be made. Use of these flights thus makes possible comparison of performance from flight to flight and a study of the progress of learning from stage to stage.

A method of analysis of the photographs by means of direct inspection during slow-motion projection was developed which provided reliable <u>qualitative</u> estimates of flight performance.[4] This method when applied to photograph records of the flight performance of 33 C.P.T. students at the end of approximately five hours of instruction (within Stage A) and of approximately 35 hours (within Stage D) revealed a statistically significant correlation between estimates of over-all performance at the two stages of instruction. The relationship was not sufficiently high, however, to warrant the use of initial performance (as evaluated) as an accurate predictor of the final performance (46). An interesting by-product of the investigation was the finding that there was higher intercorrelation among <u>aspects</u>[5] of flight performance in the Stage D flight than in the Stage A flight, suggesting that with increasing progress in learning the individual has "rounded out," i.e., has developed each of these aspects of performance to more nearly the same degree.

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[2] The Supplement to this report has also been issued as (45).

[3] The controlled C.P.T. flight course is divided into four stages: A, B, C, and D. Stage A ends when the student solos, usually between the eighth and the tenth hours. Stage B covers five additional hours, through the thirteenth hour. Stage C ends at approximately 25 hours, and Stage D at 35. Provision is made for additional hours in each stage in cases where the student needs further practice on certain maneuvers.

[4] A detailed description and an evaluation of this method of analysis are found in (51).

[5] In this study eight aspects such as Wing Control, Nose Control, Directional Control, Slip-Skid Tendency, etc., were rated separately.

In addition, a method of quantitative analysis based on measurements during successive frame-by-frame projection has been developed at the University of Pennsylvania (51). A control recorder (mounted on the instrument panel) provides an indication of the position of the three controls by means of pointers moving horizontally along linear scales. Movements of the pointers represent change in the position of each of the three controls (rudder, aileron, and elevator).

For convenience in studying the progress of learning, a quantitative description of control movement habits is provided. This description is in terms of such indices as the number of discrete movements of each control during a maneuver, the per cent of total maneuver time during which a control is in motion, the total extent of movement of each control, the number of regressive movements, and the frequency of short and small movements (50).

Quantitative indices, when obtained from several flights, may be plotted to form a learning curve. Learning curves of student groups exhibiting varying degrees of success in flight instruction can then be studied in order to determine which aspects of flight performance differentiate the groups.

An example of the type of comparisons made possible by this method is found in Figure 3, which presents learning curves based on data obtained in an investigation by Viteles and Thompson. A group of nine students was divided into "superior" and "inferior" sub-groups by use of a composite rating based upon paired comparisons by the instructor at three stages of training, direct observation by the instructor during standard flights, and the final flight-test rating made by an inspector.

Analysis of the first graph in Figure 3 reveals that the two sub-groups are not differentiated with respect to rudder adjustment during the photographed 30 seconds of straight and level flight for any of the four flights taken. In addition, neither group changes significantly from flight to flight in respect to rudder adjustment.

The two groups are likewise quite similar with respect to aileron adjustment except, possibly, in the final flight (Flight 3B). In this flight the inferior group continues to decrease its percentage of total maneuver time during which the ailerons are in motion while the superior group exhibits a fairly large increase over the previous flight.

The graph representing the per cent of time during which the elevator was in motion, however, shows a fairly consistent increase in successive flights in both groups with the "superior" group obtaining higher values of this index in all four flights.

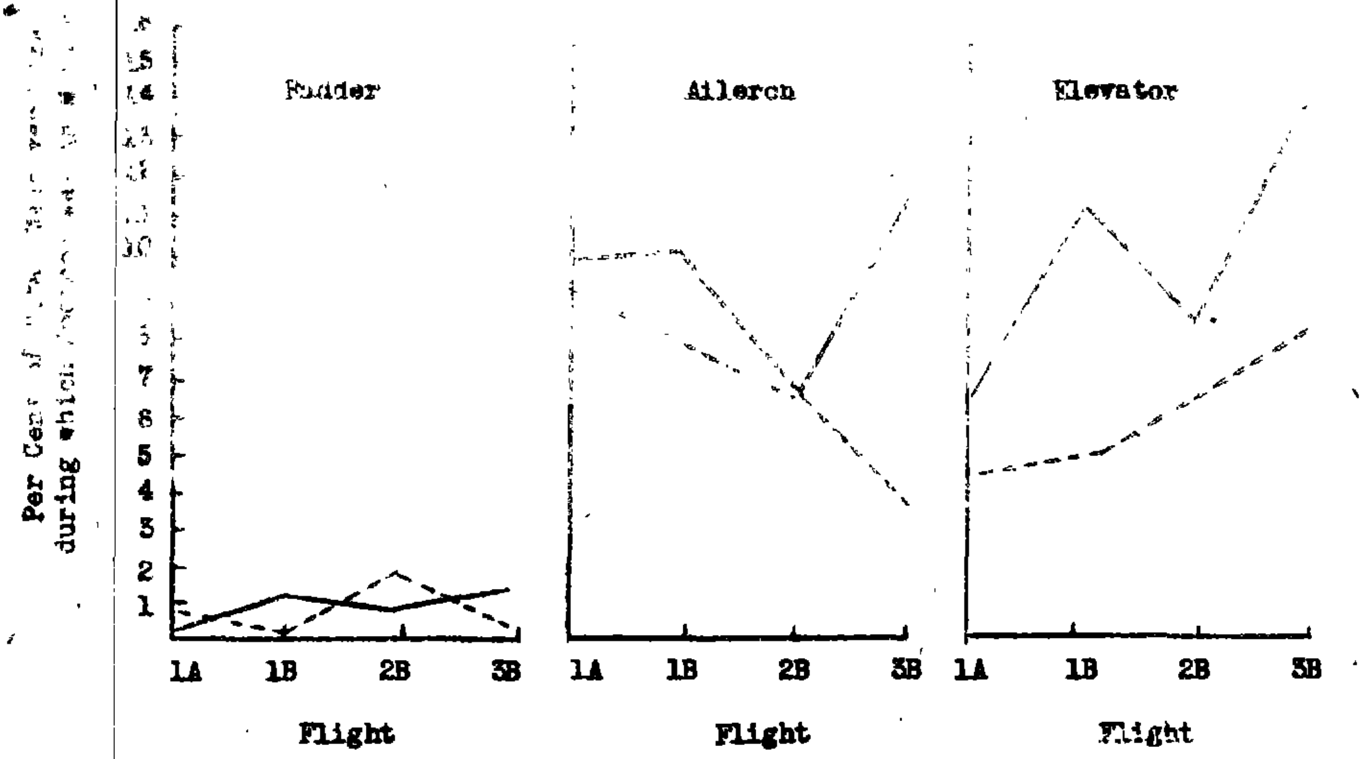

FIGURE 3

CONTROL ACTIVITY INDEX - STRAIGHT AND LEVEL FLIGHT
FOR 30 SECONDS
(After Viteles and Thompson.)

The Control Activity Index was computed for each student by dividing the total length of time the control was in motion by the total time taken by the maneuver. The obtained quotient when multiplied by 100 represents the per cent of the total maneuver time during which a control was in motion. In the above graphs, the solid line represents the average value for the superior group and the broken line the average value for the inferior group. Flight 1A was made after 10 hours of instruction, Flight 1B after 16 hours, Flight 2B after 24 hours, and Flight 3B after 35 hours.

The results shown in the graph are described by Viteles and Thompson as only provisional and illustrative in character, because of the small number of cases involved. However, insofar as the results are acceptable, they suggest that with increasing flight experience, pilots tend to keep the elevators in motion during a larger percentage of the total maneuver time in order to maintain level flight, and that the better pilots are more sensitive to the need for this type of adjustment than the poorer pilots.

Another example of learning-curve analysis may be taken from an investigation at Indiana University under the direction of Kellogg (19). By means of the Kellogg Pilot Response Recorder (a graphic recorder in which movements of the controls are recorded as tracings on a moving tape) graphic records of control movements were obtained during a standard flight performed by student pilots. The flight involved four left and three right turns.

Traces representing control movements were measured with a graphometer which reduced them to numerical form in terms of the total extent of control movement. A student's performance was then described as the ratio obtained by dividing his score (in terms of graphometer readings) by the instructor's score on a similar flight made immediately before or after the student's flight. This comparison flight provided an indirect weather control in that a base or standard was provided for each student flight.[6]

A learning curve based upon elevator movement is shown in Figure 4. This curve indicates that elevator movements decreased, within five test flights, to about one-fifth of their original extent. From this point, the average extent of elevator movements closely approximated that exhibited by the instructor.

The data from which the learning curves in Figures 3 and 4 were drawn are not comparable. In the first place, the curves in Figure 3 are for straight and level flight alone while the curve in Figure 4 is for a flight course involving four left and three right turns. In the second place, the first-mentioned curves are based upon the proportion of <u>time</u> during which controls were in motion and the other upon the average <u>extent</u> of elevator movements.

In presenting these curves, it may be well to mention the limitations of the methods and results: (1) Photographic and mechanical records of the simpler aspects of flight, while useful in studying how individual control-movement habits are acquired and how they are organized into the appropriate patterns of response for particular maneuvers, are nevertheless limited in scope when the total task to be learned, including judgment, observation of regulations, etc., is considered. (2) As indicated earlier, the number of subjects is too small as a basis for generalization. More than a single sample of a maneuver should be analyzed at each stage of instruction, particularly since many of the maneuvers, as for example the 90° turn and 45° bank, require only a few seconds of time for their completion.

In general, these illustrations from the work of Viteles and Thompson and of Kellogg should be considered at this point as examples of approach rather than as definitive findings. Presentation of definitive

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6 This assumes, of course, that variations in weather conditions affect the instructor's performance to the same relative degree that they affect student performance.

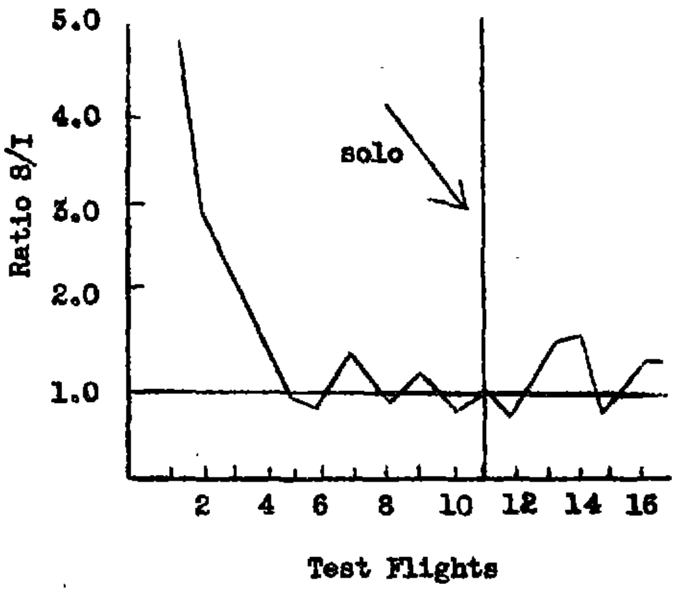

FIGURE 4
ELIMINATION OF OVERCONTROLLING IN USE OF THE ELEVATOR
(After Kellogg.)

This figure presents the student-instructor ratios (S/I) of elevator movement obtained from one student for successive flights made after about every 30 minutes of flight instruction over a period of 12 hours of instruction. Inspection of the graph shows that the student at first moved the elevators five times as much as the instructor, hence overcontrolled to a considerable extent. Elevator overcontrol was gradually reduced until, at the end of the fifth period, the amount of elevator movement equalled that of the instructor and thereafter remained near the instructor's level.

findings awaits the completion of a more extended current project at the University of Pennsylvania involving further refinement in methods of photographic analysis.

<u>Ratings of flight performance</u>. The chief advantages of having instructors or other experienced flight observers rate a student's performance at various stages of flight training are: (1) Expensive equipment is not necessary. (2) A time-consuming analysis of records is not required in order to determine the nature of each student's performance. (3) Ratings may be confined to relatively simple mechanical aspects of total performance, as in photographic and mechanical recording,

or they may take in such aspects of over-all performance as observance of regulations, confidence, and judgment. (4) The observer can put together a mass of observations not recordable.

The chief disadvantage of ratings by instructors and inspectors, however, is that such ratings are notoriously unreliable. In other words, the same individual's performance tends to be rated differently by different raters. This is true even when all ratings are made during standard flights. Moreover, instructors often have fixed ideas which prevent them from rating in an objective manner. Thus one instructor would not rate a student better than grade 3, regardless of his actual progress, because he believed that "no student can fly better than grade 3 until he has had at least 30 hours in the air"(5).

The value of rating scales for investigations of improvement in flight performance has recently been increased by development of the Ohio State Flight Inventory (29).[7] This is used (by raters especially trained for the job) to rate performance during specified maneuvers of standard flights. It places emphasis upon checking the presence or absence of specific movements of the pilot and attitudes of the plane rather than upon rating performance "average," "grade 3," or the like. In observing turns in climbs, for example, the rater checks, at the stage of entry, such specific and objectively observable items as "simultaneous application of controls," "uses rudder, no aileron on entry," "keeps nose up during entry," etc.[8]

The use of instructor's ratings to plot learning curves is illustrated by Kellogg's (19) study, in which rating was in terms of such errors as getting the nose too high, losing altitude, slipping, banking too steeply, etc. One of these curves is presented in Figure 5. There is to be noted a rapid initial decline in the number of errors observed by the instructor, followed by a relatively slow decline. The representativeness of this learning curve may be challanged, however, on the ground that it is based upon the improvement of only

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7 Early steps in the development of this inventory are described by Edgerton and Walker (5). Later stages in its development have been under the direction of R. Y. Walker, as Director of Training for the National Research Council Committee on Selection and Training of Aircraft Pilots.

8 Other aspects of flight performance, such as judgment, emotional control, and relaxation, are rated by another improved scale, the Purdue Scale for Rating Pilot Competency (21). (This scale, frequently referred to as the Purdue Rating Scale or the Kelly Scale, was prepared by E. L. Kelly and is printed by the Purdue Research Foundation.) While preliminary studies by Kelly and Ewart (23) suggest the utility of the scale both as a predictor and as a criterion, there is not yet conclusive evidence that it is adapted to studies of learning.

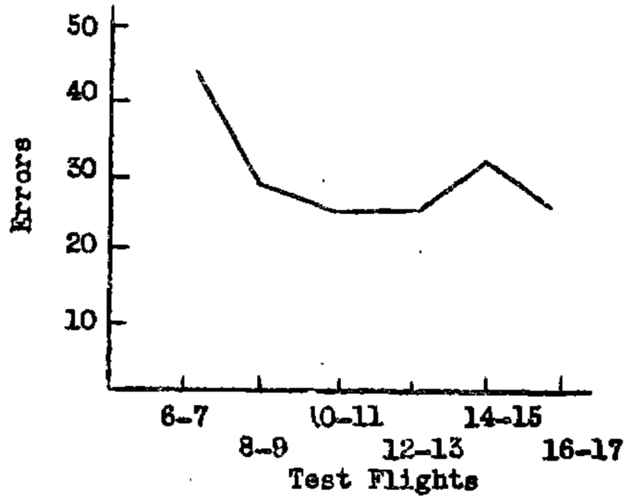

FIGURE 5
LEARNING CURVE BASED UPON RATINGS BY AN INSTRUCTOR
(After Kellogg)

This curve shows a decrease in the number of errors observed by the instructor during the successive test flights of one student over a ground course involving seven turns.

one student. Moreover, the reliability of the instructor's ratings is not known. A curve having a somewhat similar trend is reported for another student.

3. TRIAL AND ERROR, UNDERSTANDING, AND INSIGHT

<u>Trial and error in learning</u>. When confronted by the need for acquiring new skills, individuals usually exhibit "trial and error" behavior. Their responses are exploratory, but to a large degree random. When the instrument to be manipulated is completely unfamiliar, learning must "start from scratch." This situation is frequently present when industrial operations removed from the sphere of everyday experiences are to be learned. In learning to operate such familiar mechanisms as a bicycle, however, the individual's exploratory activity is reduced by reason of the fact that he knows that he must sit in a certain place, that his feet must manipulate the pedals, that balance may be achieved by movements of the handle bars and distribution of bodyweight, and that a thrust forward of the right handle bar turns the machine to the left. The trial-and-error aspects of learning to ride a bicycle apply, therefore, only to skill in making movements already known to be required.

It is obvious that foreknowledge like that of the would-be cyclist may yield a large decrease in random behavior, hence a saving in time and energy. The average aviation candidate has no such precise foreknowledge of the way in which airplanes are operated. If he has any preconceived notions concerning the operation of planes, these are frequently false.[9] One of the first things the candidate must learn is that airplanes are not guided like bicycles, automobiles, sleds, and other devices with which he may already be familiar, for planes turn to the right when the right rudder bar is thrust forward. Moreoever, he is likely to underestimate the complex coordinations called for in such an apparently simple maneuver as turning.

When the student knows beforehand what to do in operating an airplane, he must, of course, still acquire skill in doing it. However, his practice becomes "directed" in that attention is focused upon the fundamental features of the operation and upon getting the proper combinations and timing of movements necessary for acceptable performance.

It has been demonstrated in industry that the efficiency with which operations are carried out is increased by eliminating as much trial and error as possible at the outset. This is accomplished by demonstrating correct methods and insisting that trainees practice only these. The value of discovering correct methods and focusing all activity upon these from the start has been brought out in studies by Viteles (49), Shaw (43), and Cox (3).

Viteles, who studied the training of street car motormen, found that it was customary to send a trainee out with different motormen each day. But each motorman had his own "tricks" including many that were quite inefficient, hence a trainee was confronted by different and sometimes inefficient patterns of operation from day to day. Moreover, the methods of one operator often differed so much from those of other operators that much confusion occurred. Viteles (49) says,

> "Instead of receiving from day to day uniform training in a definite series of responses involving the same muscular combinations, there were variations in the patterns of response employed from day to day. For handling the air brake, for example, one motorman recommended taking 'long bites' of air, another 'short bites.' One man employed one technique, involving one series of muscular actions for closing the door and starting the car simultaneously; another had a second method, involving another, almost antagonistic series of muscular responses.

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9 This criticism will, of course, become increasingly less pertinent as young people obtain more extensive knowledge of airplane operation, such as is being given in the current programs in the secondary schools, developed through the initiative of the Civil Aeronautics Administration.

> "The total effect was to create interference in habit formation -- a condition which retards the development of skill, lengthens the training period, and promotes an uncertainty of response which continues after the close of the training period to the danger of the public and of the operator" (pp. 395-397).

This situation was corrected by studying the methods used by superior motormen and teaching these alone to trainees.

Shaw (43) describes how detailed analysis of efficient movement patterns (micromotion analysis) provides a means of ascertaining and then teaching correct methods of work and how the efficient operation of industrial plants and the satisfaction of workers in their jobs are thereby increased.

The value of teaching correct methods of work and at the same time making operations meaningful to workers is well illustrated in Cox's (3) study on different methods of training individuals to assemble electric lamp holders. In this study two methods of learning were compared. One, designated as "practice" was that of allowing the individual to learn by sheer mechanical repetition. Subjects were given no instructions concerning the proper method of operation. Left thus to their own devices, they exhibited much trial and error and progressed slowly. With the other group, a "training" method was used. Trainees were instructed in general principles underlying efficient procedures and were also given exercises which emphasized important aspects of the assembling operations. When learning curves for groups of individuals with equal initial ability, but either "practiced" or "trained," were compared, it was evident that "training" produced significantly greater gains in proficiency than did sheer "practice." This is illustrated by the fact that a "trained" group equalled in 40 trials the score made by a "practiced" group of equal initial ability only after 300 trials. The score involved in this comparison was the time required to perform certain assembling operations. Transfer of skill to different operations was practically absent in the "practiced" and present to a significant degree in the "trained" subjects. In his conclusions Cox says,

> "These results appear of great practical significance, wherever work requiring manual skill is involved, especially when it is remembered that the limits of proficiency to be attained by training may far exceed those attainable by uninstructed repetition. The results indicate the wastage that must be produced by the customary practice of allowing beginners in the assembly room to drop into the work as best they can. And they suggest that a very real advantage would follow from the replacement of this current crude procedure by a short

course of systematic training in the general principles underlying manual control illustrated by specific examples from manual operations. A like procedure may be frequently adopted with advantage in other forms of manual activity ..." (p. 176).

Determination of the most effective behavior patterns for specific flight maneuvers is as important for aviation as determination of efficient patterns of specific kinds of work is for industry. Probably the most fruitful means of determining correct flight operations is to take moving pictures of superior pilots during performance of specified flight maneuvers. Viteles and Thompson (50) made such photographic records by placing a moving picture camera in the cockpit of the plane in such a position that the pilot's manipulations of the controls could be recorded. The records were then subjected to a minute study (both frame-by-frame and slow-motion analysis) in order to discover movement patterns and their timing. Such a study of photographic records of performances of pilots rated as superior reveals information concerning the most effective behavior patterns for each basic flight maneuver.

Such photographic records have the added advantage that they may be used to teach both instructors and students the methods used by superior pilots. Study of photographic flight records also makes possible discovery of those "tricks of the trade" which add to efficient performance. These may then be passed on to students directly. Without such direct instruction the students might not learn these "tricks." If they did learn them, it would be only through good fortune in getting a superior flyer as an instructor or through eventual discovery of them, perhaps after much needless trial and error.[10]

Understanding. Within recent years there has been discussion among psychologists and educators concerning the fact that, while it is possible to acquire skills without knowledge of their fundamental nature, the most efficient learning is that which arouses understanding.

Some individuals acquire understanding more or less spontaneously as an outcome of trial-and-error activity. Understanding is best fostered, however, by explanations given during the learning process. In learning to fly, especially, the individual needs to learn the "why" of what he is doing. That this is not a necessary outcome of the process of acquiring skill is illustrated in Kelly's (20) study of instructor-

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10 There are also indications that the Ohio State Flight Inventory (29) can be used effectively for training purposes by emphasizing during instruction those faults which are noted on the Inventory. Actually, the Ohio State Flight Inventory may become more useful for instruction than it is as a criterion device, the purpose for which it was originally intended.

student conversations during flight. Expert instructors sometimes did not understand their own flying behavior sufficiently well to make operations understandable to their students. One instructor, for example, told the student that a plane is steered "like a sled." This is poor teaching for, while the steering manipulation as such is like that of a sled, the same manipulation leads to diametrically opposite results in sled and plane. A thrust forward of the right foot, for example, turns the sled to the left, but it turns the plane to the right.

Cox's "training" method gained much of its advantage from the fact that operations were made meaningful to trainees from the start. Each trainee was not only told the correct things to do, but informed of underlying principles as well.

Ground school instruction, flight manuals, daily instruction sheets, and instruction in the air may facilitate acquisition of understanding as a means of facilitating and making more effective the acquisition of skill. The Fundamentals of Elementary Flight Maneuvers (9) and the Fundamentals of Secondary Flight Maneuvers (10) have been espcially designed with this in mind. Their use may lead to a marked reduction in the trial and error responses of flight students. These sheets, based upon research sponsored by the N.R.C. Committee on Selection and Training of Aircraft Pilots, enable the student to think over in advance and thus to gain in his understanding of the new maneuvers to be undertaken in the next flight period. They also provide cues which individual instructors might fail to call to the student's attention, viz., "Ride with the plane during the turn," "Don't lean toward or away from the bank," etc.

Another factor which facilitates understanding is use of descriptive and explanatory terms which avoid ambiguity and which are uniformly used throughout the training and post-training period. Development of Patter books (36) (37) has to a large degree satisfied this need.[11]

Insight. The term insight is sometimes used to designate a type of learning, in contradistinction to trial and error, and sometimes to refer to a product of learning. Regarded as a type of learning, insight is characterized by a more or less sudden "grasping" of relationships. The individual after a period of little or no apparent progress, "gets the idea" and the problem is, as it were, solved at a single stroke. Such sudden learning is evidenced by a precipitous improvement in the learning curve.

Insight is facilitated when individuals learn to relinquish responses which lead nowhere and to try new ones. It is, as everyone

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11 Patter books are training aids in the form of small booklets containing carefully prepared descriptions of each of the maneuvers in the primary and secondary C.P.T. courses. The Patter is intended for the use of instructors and is written in the style which instructors would use while actually instructing during flight.

knows from his own experience, a commonplace practice to repeat inadequate responses time and again (perseverate) when confronted by a problem having no ready solution. That this perseverative behavior may be reduced by proper instruction and that such reduction greatly facilitates solution of problems is illustrated in a study by Maier (28). College students were given various mechanical problems to solve, one of which was that of blowing out a candle from a distance of eight feet. The only equipment comprised two four-foot rods, six paper clamps, three short lengths of rubber tubing, and four short pieces of glass tubing. The solution was to join rubber and glass tubes alternately, to stiffen the eight-foot tube thus produced by clamping it to the rods, and to blow through the tube. One group of 206 students tackled the problem without preliminary instructions. On the other hand, a group consisting of 178 students comparable with the first in ability was given a 20-minute preliminary lecture which was finally summarized as follows: "(1) Locate a difficulty and try to overcome it. If you fail, get it completely out of your mind and seek an entirely different difficulty. (2) Do not be a creature of habit and stay in a rut. Keep your mind open for new meanings. (3) The solution-pattern appears suddenly. You cannot force it. Keep your mind open for new combinations and do not waste time on unsuccessful efforts." Within the time limits allowed, 48 per cent of the uninstructed and 68 per cent of the instructed students solved the problem.

When a group of 169 students in the same study tackled two problems of equal difficulty, one with and one without the preliminary lecture, twice as many achieved a solution with as achieved it without the lecture. It is quite evident, then, that insight is facilitated by instructions such as those described.

Aviation offers many opportunities for insight. At times, the difference between life and death rests upon the pilot's ability to grasp the significance of situations and make the correct response almost immediately. Information given during the training process, understanding aroused, warnings against the dangers of blind trial and error, and especially of perseveration, may all add to the chances that a pilot will act with insight when situations call for it.

In speaking of insight as a <u>product</u> of learning, we are using a synonym for understanding. As already suggested in our discussion of trial and error, short cuts in the learning process may be produced by making every operation as understandable to the student as possible. Sometimes an individual's "insights" may be anticipated, the information otherwise obtained by insight being given to him beforehand. Students are, for example, often left to discover for themselves that they should not lean with the plane in a bank, that flying "through the small end of the sock" or "coming out of the large end of the sock" is the best guide to the correct direction in landing, etc. They could just as readily be given these "insights" directly as part of their instruction as be left to discover them by trial and error.

4. LEVELS OF COMPLEXITY IN LEARNING

Studies of the learning process in telegraphy, typing, and other relatively complex skills have shown that acquisition of simpler movements, like hitting the correct keys of the typewriter, is followed by organization of movements into increasingly complex patterns. Thus the individual who is at first conscious of the need for hitting the correct keys comes to forget about the keys and to concentrate on movement patterns such as produce words. Later, in typing familiar phrases and sentences, he pays no attention to words, but is aware only of the larger units. He may even be far behind his copy, his fingers automatically taking care of material previously read. Since they involve habit patterns of increasing complexity built one upon another, such complex habits are referred to as "habit hierarchies" or "higher order" habits (1,8).

It is obvious that flying skill is an extremely complex habit hierarchy. Thompson's introspective reports while learning to fly an Aeronca Chief[12] show this just as clearly as it was shown in the cases of telegraphy and typewriting. He was at first aware primarily of the necessary movements of the separate controls. As these movements became familiar, they fell into patterns which seemed automatically to give the plane desired attitudes. Later still he was able to turn attention away from the controls as such, and to look for familiar landmarks.

As experience in flying continues, pilots report that the "feel" of the plane is acquired, that they "fly with the seat of their pants," and that flying becomes "instinctive," in other words, movements made in controlling the plane become increasingly automatic. They require a decreasing amount of thought. Spurrell (44) writing in the early days of military aviation, claimed that

> "A flying fighter must undergo three distinct stages in his education. He must be taught to fly. He must learn to fly instinctively with no more conscious mental effort in handling his machine than a cavalryman of the old school exerted in keeping his seat and managing his horse. Secondly, he must learn to fight, to drop his bombs with calculation and precision, but making many of the incidental movements subconsciously, and to manipulate his machine gun with a trained but free mind. Thirdly, having learned both to fly and to fight in the air, he must learn to use military intelligence. He must be able to watch what is going on in a melee, decide quickly whether to single out an opponent or go to the aid of a friend, to use judgment when bombing in choosing

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12 Excerpts appear in Viteles and Thompson (50).

objectives, and using information which may come his way.

> "Learning to fly may be compared with learning any other motor accomplishment. The required movements have to be worked out....until they become the property of reflex centers and can be performed automatically, not merely without requiring thought, but without interrupting thought" (pp. 559-560).

It is often claimed that wings, ailerons, and rudder become, as it were, extensions of the expert pilot's own body and that he then flies with as little effort and forethought as is required in walking.

Several orders in a habit hierarchy may develop simultaneously. For example, while the "letter habits" of typewriting (see p.17) are being acquired, the individual is also to some degree learning "word habits" and "phrase habits." Since complex skills are usually formed in this way, there is questionable value in attempting to teach them one unit at a time. This problem, however, will again be considered when part-whole learning is discussed.

5. LEARNING, REMEMBERING, AND FORGETTING

An essential factor in learning is retention. In order that one trial shall bring improvement over performance in previous trials, the nervous system must retain certain effects of previous activity. This retention is memory in a purely organic sense. It may occur with or without the individual's awareness of its existence. Highly automatized habits, as we have seen, tend to function purely on this unconscious or reflex level.

The term "remembering" is used primarily to refer to recall and recognition of verbal material, such as numbers, words, poetry, and various kinds of information. "Remembering" may, however, also be used to refer to aspects of motor skill such, for example, as recalling correct movements and recognizing previously encountered aspects of a situation.

In a purely organic sense we probably never forget. Psychologists have demonstrated that recall, and even recognition, of things that an individual has learned may later be impossible, yet the same material (whether a poem or a motor skill) be relearned with a large saving in time and effort over that originally required.

It is perhaps obvious that activities practiced most tend to be retained best. Motor skills, like riding a bicycle or flying a plane, are remembered much better than poetry, because such motor skills are repeatedly performed whereas poetry is not repeated frequently. Investigations of learning in which motor and verbal skills were practiced to the same degree demonstrated that both skills were forgotten with approximately equal readiness (32,48).

Flight instruction, however carried out, has a large verbal element, but retention of verbal instruction is greatly facilitated by the fact that the verbal is soon integrated with the motor, as when a student who is told the procedures to be followed in landing, actually puts them into practice. Such instructions are primarily to aid the development of motor skills, and are in line with what has already been said about the teaching of principles and correct procedures.

Studies of forgetting have been carried out in the classroom and laboratory. These indicate that forgetting is at first rapid, then slow. Thus in the classic investigation of Ebbinghaus (4), about 42 per cent of the nonsense syllables which he had memorized were forgotten within 20 minutes, 66 per cent in a day, 72 per cent in two days, 75 per cent in six days, and only an additional 4 per cent in 31 days. Later investigations of forgetting have tended to support the findings of Ebbinghaus.

Several investigators have discovered ways of slowing down the forgetting process. Among the most significant of their findings are the following: (1) that sleep or other relative inactivity, if it closely follows the learning process, tends to retard forgetting; (2) that forgetting is slower the more one repeats the activity; (3) that use of efficient learning methods (viz., distributed effort and recitation) tends to reduce forgetting; and (4) that understanding or insight greatly facilitates remembering (4, 17, 18, 25).

6. MOTIVATION IN LEARNING

Motivation. Individuals are motivated to the degree that they exhibit activity focused upon a task, whether this be the making of a touchdown, the achieving of a good grade in school, or learning to fly. Highly motivated individuals throw themselves wholeheartedly into the tasks confronting them. We say, especially with reference to wholehearted group activity, that good morale is present.

Needs such as those for food and for the ordinary comforts of life play an important role in motivating individuals. Nevertheless, one often finds that interests and attitudes which do not at first seem to be directly related to such needs are also important.

The investigations reported by Mayo (30), Roethlisberger (40), and Roethlisberger and Dickson (41), which were carried out at the Hawthorne Works of the Western Electric Company over the years since 1927, suggest that favorable attitudes and sentiments concerning the job, the management, and other workers sometimes play a larger role in producing maximum effort than do increased pay, shorter hours of work, and improved physical working conditions like better illumination, rest pauses, and refreshment periods. In one of these experiments five girls, whose job was to assemble relays, were segregated from other workers over a period of years while their individual and group output was observed. After records of output under "normal" conditions had been obtained, the following changes in working conditions were introduced: rest pauses of various lengths and frequency, rest periods with refreshments, and shorter working days and weeks. Each condition successively increased the number of relays assembled. It thus appeared that the increase was due to the experimental variations in work conditions. However, when the workers were returned to the original conditions after a period of 13 months of experimentation, <u>output continued to increase.</u>

The conclusion finally reached was that merely experimenting with it had changed the group. There was apparently a marked improvement in morale. The girls were now "participating members of a working group with all the psychological and social implications peculiar to such a group....They had become bound together by common sentiments and feelings of loyalty."[13] There was also an improved attitude toward the management and supervisors because of their apparent interest in the welfare of the girls. It is reported that each girl came to feel that she was important, that she was no longer a mere cog in a machine.

The above and other experiments by the same investigators all suggested that attitudes not directly allied to getting more money and greater physical comforts have an important place in motivation. An interview program was finally introduced. Each employee was now able to air his worries, criticisms, etc., to a skilled interviewer who reported these to the management, but not the name of the person who made them. As a result, there developed the feeling that the management was interested in bettering each worker's lot. Even though the things criticized were not necessarily changed, many workers felt that suggested improvements, such as better food in the cafeteria, had been instituted. They sometimes thanked the interviewer for having the conditions "corrected" when the only change had been in their own attitude.

The goals toward which effort is directed are frequently referred to as "incentives." In the classroom and industry we attempt to arouse maximum effort by use of such incentives as money, grades, promotions, and social recognition. Military aviation provides somewhat comparable incentives, but it offers additional inducements to maximum effort in the form of knowledge that mastery of the plane is good life insurance, knowledge that such mastery enables the individual to get at the enemy in an effective manner, and knowledge that aviation involves greater individual freedom, greater opportunities for initiative, and greater chances for personal glory than some other branches of the service. For some individuals, moreover, satisfaction of the desire to fly is in itself sufficient incentive to arouse highly motivated behavior.[14] Almost all who enter pilot

13 Reprinted by permission of the President and Fellows of Harvard College.

14 The relation between "desire to fly" and achievement in learning to fly has been investigated in studies sponsored by The National Research Council Committee on Selection and Training of Aircraft Pilots. Results of these studies will be made available in technical reports published by the Division of Research, Civil Aeronautics Administration.

training do so on their own initiative because they wish to fly. The desire to fly, and other incentives like those mentioned above, provide an extraordinarily high motivation for acquiring the primary skills of aviation.

Motivation and the learning process. That motivation is of great importance in learning has been shown by the results of numerous experiments. Its validity has been demonstrated for a large number of skills, both motor and verbal, and for a variety of incentives, which have included such items as food, money, praise, social recognition of various kinds, and avoidance of blame or physical punishment. These studies have shown not only that motivation is necessary for efficient learning, but that the efficiency of learning is, by and large, greater the more intense the motivation (56).

The importance of motivation in learning is especially evident when we apply new incentives after the learning curve has flattened.[15] It has been shown in industry, especially, that bonuses and other incentives may increase the output even of experts. Kitson (24), for example, found that typesetters of long experience increased their average output by over forty per cent following institution of a bonus dependent upon units of accomplishment above a particular standard. Likewise, the skilled relay assemblers of the Hawthorne Plant experiments discussed above, increased their output when attitudes toward the job and the management became more favorable.

In aviation, as in a classroom, the attitude of students toward the instructor may play a large role in determining the degree of motivation aroused. Loyalty is sometimes a strong motivating factor. On the other hand, lack of confidence in the instructor, or attitudes of distrust and resentment, may work against maximum motivation.

Some instructors constantly "bawl the student out" while others make a judicious use of praise and encouragement. Several laboratory experiments have indicated that praise is generally more effective than blame in producing efficient learning (56). In one study (47) the experimenter provided lists of 40 words each arbitrarily joined with a number from 1 to 10. The lists of words and the numbers they were paired with were read through very quickly to the student serving as subject. The experimenter then read the words one at a time and the student was required to respond by saying one of the numbers from 1 to 10. Every time the student responded correctly by saying the right number he was rewarded (praised) by being told "right." If he said the wrong number he was punished (reproved) by being told he was "wrong," and then required to keep guessing until he made the correct answer. The results showed the rewarded ("right") responses to be repeated a great many more times than the punished ("wrong") responses.

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[15] When the curve flattens out and then, because of increasing motivation or some other factor, shows further improvement, we refer to the portion exhibiting little or no change as a plateau. The final stages of many learning curves, which appear to indicate that the physiological limit has been reached, would be regarded merely as plateaus if additional incentives were offered and, as a result, the curves indicated further improvement.

A study by Hurlock (15) also demonstrates the relative value of praise and reproof as incentives to improvement. On the basis of an arithmetic test, 106 students were divided into four groups matched in ability. Each group was given five practice periods of 15 minutes each in similar arithmetic tests. One of the groups worked in a separate room as a control group. The other students all took the tests in a single room, but the individuals in one group all received praise at the beginning of each session, those in a second group all were reproved, while those in the third group were completely ignored. Results showed that in most cases, regardless of age or sex of the students, praise was superior to reproof as an incentive to rapid improvement in the arithmetic task. Some students actually reacted adversely to the reproof, doing more poorly than they probably would have done if left alone. Students who were ignored, that is, neither praised nor reproved, showed less improvement than either of these two groups.

Mowrer (34) stresses the importance of instructor-student relationships for good motivation in learning by pointing out that

> "One individual can produce learning in another individual by either of three methods: (1) the 'teacher' may create the 'problem,' i.e., make the 'student' uncomfortable, and the student may solve it; (2) the student may have the problem, and the teacher may help him find the solution; or (3) the teacher may both create the help solve the student's problem. Although the same basic learning process will be involved in any case, the social consequences will be very different according to which of these three methods is employed. If method 1 is used, a negative (avoidant) attitude toward the teacher will develop; if method 2 is used, a positive (approach) attitude will develop; if method 3 is used, a mixed, or ambivalent, attitude will develop; the good 'leader' like the good 'teacher,' naturally employs method 2 as extensively as possible" (p. 424).

These and other aspects of the student-instructor relationship are of extreme importance in promoting efficient learning.[16]

Supplying the individual with accurate information on his improvement with practice may often be satisfactorily employed as a motivating technique. In this technique the individual is informed

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16 The practical aspects of such relationships will be discussed in subsequent publications.

of his previous level of attainment in a given task and is thus led to compete with his own past performance. The value of supplying information or "knowledge of results" obtained as an incentive to increased output is well illustrated in experiments by Ross (42).

Ross studied 59 college students in a simple motor task of "tallying." At the outset of the experiment he gave sufficient practice trials to bring all students to approximately the same level of efficiency. Following these trials he then divided the group into three sections. Individuals in Section I were given complete and accurate information regarding their own progress from day to day, i.e., they knew exactly at what level of efficiency they were working and how this compared with their previous records. Individuals in Section II were only partially informed of their progress, i.e., they knew only whether they were above or below the average performance for the group. Those in Section III were given no information on their progress. At the end of 9 practice trials the group with full knowledge of results (Section I) had gained from 2.2% to 8.5% more than Section II (only partially informed) and 4.5% to 12.6% more than Section III which had been given no information.

An experiment by Elwell and Grindley (6) also clearly demonstrates the part played by knowledge of results. Individuals attempted to direct a spot of light on to the bull's-eye of a target by means of coordinated movements of the two hands. In practice trials the light was visible all of the time; in experimental trials with knowledge of results the light was visible in the starting position and as soon as the movement was completed; in experimental trials without knowledge of results the light was not visible at all. It was found: (1) that there was no improvement in the accuracy of performance when the subjects were prevented from seeing which part of the target was struck, (2) that performance rapidly improved as soon as the subjects were allowed knowledge of their results, and (3) that removal of the source of knowledge of their results after the habit had been perfected led to a deterioration of the performance. The experimenters indicate that knowledge of results appears to influence the acquisition and maintenance of a muscular skill in the following ways: (1) Subjects tend to repeat only those operations which they know were successful. (2) They tend to modify their responses in the direction of the pattern of performance which they know to be correct. (3) With knowledge of their results, they show a general attitude of "interest" or "keenness," which is conducive to accurate performance.

The importance of the above-mentioned factors in flight training is brought out in an analysis of student comments by Ewart (7). He says,

> "The most consistent complaint of practically all students in their retrospections was that the instructor was extremely reticent in offering praise

"or encouragement, and particularly that he never let them know how they were doing, whether good or bad. The students reported that this left them with a feeling of uncertainty, lacking confidence, and in many cases give them little motivation to improve their performance" (pp. 1-2).

7. EFFICIENT METHODS OF LEARNING

The importance of teaching correct methods from the start, instead of allowing individuals to engage in random activity, has already been pointed out (pp. 12-14). Assuming that we know the most efficient operations for a given task and arrange to teach these alone, a further problem is to see that they are learned with maximum efficiency. One prerequisite, of course, is that the learner be highly motivated.

Apart from the principles of teaching correct methods only, and of arousing good motivation, psychologists have discovered certain economical training procedures which, although they have not yet been tested in relation to flight instruction, at least have suggestive value in this connection. Three principles which have been found to induce economical learning in the classroom and laboratory are: (1) An appropriate distribution of practice periods and rest periods leads to a saving in time and effort. For example, Ebbinghaus (4) demonstrated years ago that 68 concentrated repetitions of nonsense syllables gave less learning than 38 repetitions distributed over three different practice periods, inserting one day between sessions. These results were later corroborated by other investigators (26, 38) and extended to a variety of other tasks. (2) Frequent recitation facilitates acquisition. This principle is well illustrated in an experiment by Gates (11), who found that efficiency in the learning of nonsense syllables and biographies varied directly with the percentage of the total learning time which was given over to recitation. (3) In some situations and in some skills, it is better to tackle each problem as a whole rather than piecemeal.

It must be noted that none of these principles holds for all situations or for all people. Whether a given principle will operate depends to a large degree on the complexity of the task, the past performance habits of the individual, the length and difficulty of the task, the pressure of time, etc. There is a definite need for research in the specific situations of flight instruction, if such principles are to be properly applied.

<u>Distribution of effort</u>. That distributed practice in learning is more economical than concentrated practice has been shown in a

large number of researches dealing with both verbal and motor skills. There are two problems here, viz., the optimal length and the distribution of practice periods. While research has shown that certain lengths and distributions of periods are better than others in the case of particular skills, particular organisms, and particular conditions of motivation, etc., they have not indicated an optimal length and distribution of periods which might be applied to all skills or under all conditions. Thus, if training in aviation is to involve an optimal distribution, this must be worked out in relation to the particular skills involved.

As a matter of fact, it is quite possible that practical considerations demand highly concentrated rather than widely distributed practice in aviation training. Motivation and the time available for training are important factors here. If the student desires his wings as soon as possible so that he can get at the enemy, he may actually work more effectively with concentrated practice than would otherwise be the case. Moreover, competition with others in his group gives the student motivation which might counteract otherwise undesirable concentrations of practice.

There is another practical consideration. Suppose, for example, that as much is learned in 50 practice sessions distributed over 50 days as in 60 practice sessions telescoped into 30 days. Even though the wider distribution required 10 fewer practice sessions, it might be of practical advantage to give 10 extra sessions and save 20 days. Which would be more practical, one session a day for 50 days or two sessions a day for 30 days, would depend upon how quickly trained individuals were needed, and upon the number of instructors and amount of equipment available.

Optimal distribution of learning is a problem which, up to the present time, has not been investigated in aviation, although Brimhall (39, pp. 52-53) and others have seen the possible significance of different distributions than are now in use. The problem can be solved for aviation only by an experimental attack which takes cognizance of practical considerations such as those mentioned.

Recitation and review. Recitation vs. passive learning has been studied primarily in the classroom and with verbal rather than motor skills. The usual procedure has been to have one group of subjects learn by putting 100 per cent of its time into reading, a comparable group by putting 80 per cent of its time into reading and 20 per cent into recitation, and so on, with different distributions of time given to reading and recitation. These investigations have shown unequivocally that a large amount of recitation is desirable. This principle is in line with the adage that "We learn best by doing."

The advantage of recitation over passive learning is due to a number of factors. One of the most important of these is that recitation constitutes a review of what has been read. In his efforts to reproduce, the individual becomes aware of his deficiencies and of his strong points as he could not possibly become aware of them while engaged in merely repetitive activities.

The recitation principle may be utilized to advantage both in the ground school and in relation to flight instruction. As far as purely verbal ground school work like learning the principles of aerodynamics is concerned, recitation may be used as in any other classroom. On the other hand, actual flight is a "recitation" of much that has been learned previously on a verbal level. In order that this "recitation" might be made more effective, manuals have been developed (see p. 15) which coordinate ground instruction and flight instruction in such a way that each period in the air is a definite rehearsal of what has been studied on the ground. Thus the student studies the use of the rudder and brakes and the various conditions to be observed in taxiing, imagines himself taxiing, then actually practices taxiing; and so on with other maneuvers. By use of such a manual, the student is constantly aware of the fact that what he is studying on the ground will shortly thereafter be rehearsed in the plane.

Objective methods of measuring flight performance (19, 50) and standardized flight inventories such as the Ohio State Flight Inventory (5, 29) also provide a means of reviewing the student's air work after he has returned to the ground. By means of photographs or other records of performance his strong and weak points may be made obvious to him and he may study them at leisure. Kelly's procedure for recording conversations between student and pilot during flight (22) also offers opportunities for later review of the lesson.

Whole vs. part learning. A fundamental problem in the determination of efficient methods of learning is the question of the relative efficiency of whole vs. part learning. In part learning, the learner concentrates on one portion of the material, or on one aspect of the skill, at a time, mastering each separately and later combining the separate parts. The whole method, on the other hand, calls for practice of the entire task as a unit without isolation of the elements making the whole.

Definitive research on the problem of whole vs. part learning as applied to aviation is of extreme importance since the task of piloting a plane is not a single skill but a complex of many skills. The four basic elements of throttle, rudder, aileron, and elevator control adjustment must be combined into desirable patterns of coordination for even the simplest maneuvers. Further, the basic maneuvers of straight and level flight, climb, glide, and turn are combined to form the advanced maneuvers. Even the most complex maneuvers of acrobatics and combat tactics are merely elaborations of these four basic maneuvers.

The present training program seems to be oriented largely from the viewpoint of "part" learning. During the first lesson, the student is given practice on the controls separately so as to learn the effect of pressures on each of the controls. Straight glides and gliding turns are individually practiced before being combined to form an approach to landing. Even after the student gets into the advanced maneuvers, provision is made for re-practice of the basic maneuvers individually throughout the later stages of instruction.

This emphasis upon the elements in flying may result in a pilot who thinks and acts in terms of the individual controls rather than of the plane as a whole. It may underlie, also, the tendency of students to consider the rudder and elevator as "exchanging" functions when the plane is banked for a steep turn.

A question often raised by flight instructors concerns the use of instruments in flying. Should beginning students be first taught to fly "by the seat of the pants" in light planes containing the absolute minimum of instruments, or should they be given from the beginning an opportunity to add information obtained from flight instruments to the visual cues concerning plane attitude and flight path obtained from observation of the plane during flight? The problem is largely one of whole vs. part learning since the addition of instruments <u>after</u> learning to fly requires a reorientation as to the total information used by the pilot.

The need for research on the relative efficiency of part vs. whole learning is further emphasized because the vast amount of research already carried out in the laboratory, classroom, and industrial plants has shown that it is extremely dangerous to apply the findings in one field or on one task without confirmation by actual experiments. Investigators have arrived at different conclusions, depending upon the type of task to be learned, the method of learning, the intelligence of those learning, etc. Woodworth (55), in his summary of laboratory and classroom research on this problem, comes to the conclusion that

> "The net result of all the studies of part and whole learning seems to be something like this: the parts are easier to learn than the whole and the learner is often happier and better adjusted to the problem when beginning with the parts. He carries over some of the skill and knowledge gained in learning the parts into the subsequent learning of the whole performance. But he finds that putting together the parts is a serious problem requiring much further work. In the end he may have saved time and energy by commencing with the parts - or he may not - much depending on the size and difficulty of the total task and on the learner's poise and technique. If he can adjust himself to the whole method and handle it properly, he can learn quite complex performances effectively by the whole method. In a practical situation it is probably better to start with the whole method while feeling free to concentrate at any time on a part where something special is to be learned" (p. 223).

Viteles (49), after summarizing a large amount of research on whole vs. part learning in relation to industrial training, feels that, in general, the part method is to be questioned. He believes that it is perhaps best to acquaint the learner with the total process and then to split it into "natural subdivisions," each "as large as possible in order to take advantage of the associations between movements inherent in the task as a whole." He points out, moreover, that a careful analysis of each process to be learned is necessary before the most effective use of whole or part-whole methods can be made.

8. TRANSFER OF LEARNING

The problem of transfer is that of determining to what degree, if any, the learning of one subject or one skill influences learning of other subjects or other skills.

Transfer has been investigated extensively, using a variety of verbal and motor activities. Among the motor activities involved in such investigations have been maze tracing, shooting at targets, mirror drawing, sorting cards, and typing.

In research on transfer, experimental and control groups comparable in all significant respects, such as intelligence, age, sex, previous experience with the problem involved, etc., must be used. The experimental group is trained on a particular skill which we shall designate as skill A. The other group receives no training on A. Then both groups are required to learn skill B. If the experimental group learns this in significantly fewer trials, with significantly fewer errors, or in a significantly shorter time than does the control group, we conclude that learning of A has facilitated acquisition of B. In other words, positive transfer is evidenced. If on the other hand, the experimental should be less efficient that the control group in learning habit B, we would be forced to conclude that learning of A interferes with learning of B. This is what is referred to as <u>negative transfer</u> or <u>habit interference</u>, e.g., transfer from stick to wheel control or vice versa. Both kinds of transfer have been found in laboratory, classroom, and other situations. However, positive is much more prevalent than negative transfer.

<u>Some transfer problems in aviation</u>. Aviation training raises several questions in which the problem of transfer of training is fundamental. One of these concerns the former Civilian Pilot Training course in general. Did training of civilians in light planes have value for the services? More specifically, did it facilitate acquisition of skill in piloting larger, faster, and more complex military aircraft?

A partial answer to this question is now being obtained from knowledge of the success of Civilian Pilot Training students who have entered the air corps of the army or navy. A recent report indicates that the washout rate of former C.P.T. students is only about 40 per cent of that of students who had not had previous C.P.T. courses. It should be remembered, however, that C.P.T. students who enter the service constitute a group which, apart from its previous training, is more highly selected than the non - C.P.T. group. It is a group from which a certain number of washouts have already been eliminated and it may be more highly selected in terms of intelligence and education. We should thus expect a lower washout rate quite apart from the factor of transfer.[17] At present it is impossible to tell how much of the greater success of C.P.T. students is attributable to selection, how much to transfer of learning, and how much to the exact identity of tasks performed at the two levels of training.

Another series of problems concerns the possible value of apparatus which, like the Link Trainer, is aimed at development of flying skill on the ground. That such substitutes for actual flight conditions facilitate development of ultimate aviation skills is often accepted merely on the basis of faith in positive transfer.

Transfer experiments with the Link Trainer. Recent preliminary investigations with the Link Trainer suggest that contact training with this device may have transfer value with respect to such factors as air time before the solo and control of certain ship attitudes. Conlon (2), whose study involved only 10 C.P.T. students and apparently did not include a control group, offers the tentative conclusion that five to seven hours contact instruction in the Link "teaches a correlation of controls, etc. equivalent roughly to three hours of flight instruction" (p. 2). Acceptance of such a conclusion on the basis of an experiment involving only 10 students, would of course be quite hazardous.

Greene's (12) study, in which 10 C.P.T. students were given about six hours of Link training prior to regular flight instruction, likewise produced inconclusive findings. No control group was used, the numbers were too small to produce reliable results, and the students appeared below par in ability, since two were dropped for incompetency and the remaining eight were below average in rated flight ability at the end of their course. The instructors reported, however, that "the Link training seemed to have given the men unusually good coordination and calmness in the air." It is estimated that there was a saving of about $2\frac{1}{2}$ hours of air time prior to the solo as a result of the six hours of Link training. However, as Greene himself points out, an experiment with large comparable groups, one given the Link training and the other not, will alone show whether the above-mentioned advantages are real or illusory.

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17 In addition there remains the possibility that the C.P.T. course gives confidence in flying, reduces tenseness, is good "propaganda" for aviation, etc. Moreover, we should not be satisfied with merely comparing the relative progress of the two groups during a particular stage of military aviation. Differences indicating transfer might also show up in combat performances.

Greene, Chamberlain, and Crannell's (13) recent study does little to decide the actual value of Link training for, like the studies discussed above, it lacks adequate numbers of subjects and suffers from deficiencies in experimental design. Three groups of 14, 8, and 11 C.P.T. students were given, respectively, 10, 5, and 1 hour of Link training prior to regular flight instruction. Each group, as indicated by initial scores on the Link, appeared to have the same average competency. The students were rated by instructors for both Link and flight performance. Graphic records were also available for these performances. Flight instructors did not know the nature or extent of their pupils' Link experience, hence apparently were not influenced in their ratings by preconceptions concerning the value of Link training. The chief results of the experiment were: (1) Groups with the greater amount of Link training were rated higher than those with only one hour of such training. (2) The difference in favor of the groups with greater amounts of Link training decreased toward the later stages of flight training, but was still evident in the later phases of primary flight training. (3) Students with the greater amounts of Link instruction, as shown by records from a Redhed-Savage Ride Recorder, had less tendency to slip while turning. However, they were not superior in avoidance of skids.

The smallness of the groups involved in this experiment, striking inadequacies in the experimental design, and a wide variation of competence within each group render highly questionable the significance of differences obtained. It is contended by the authors, however, that "the consistency with which the groups with more Link time are found to be superior throughout the battery of ratings and other tests of flight competency suggests that some real difference in ability may be present" (p. 21).

In view of the inadequacy of research results, no sound conclusions can be drawn on the usefulness of the Link as a contact pretrainer. Before the status of the Link as a pretrainer can be ascertained, research must answer such questions as: Which, if any, aspects of flight training are facilitated by contact pretraining in the Link? How much of an advantage, if any, may be expected? Is this advantage sufficiently large to warrant the necessary outlay for Link trainers and for pretraining instructional personnel? Which operations, if any, are most advantageously (from the standpoint of their transfer effect) taught in the Link? What is the optimal duration of Link training for production of such transfer? Is the transfer effect, if any, permanent or temporary?

One should not, of course, overlook the possibility that some habits acquired in contact training with the Link <u>interfere</u> with acquisition of certain aspects of flying skill. It has been pointed out, for example, that the Link is deliberately built as a completely unstable airplane, whereas all real planes possess a high degree of inherent stability. As a result, the student may acquire habits of operation on the Link which are undesirable in the operation of a real plane in real air. So, for example, the sensitivity of the unstable instrument may result in habits of overcontrolling in terms of frequency and undercontrolling in terms of pressures. It seems pertinent to inquire, therefore, whether research discloses any negative transfer effects and, if so, whether the positive effects are sufficiently great to warrant ignoring these negative ones.

Habit interference in aviation. Habit interference, or negative transfer, is a serious problem in aviation. There are several situations in which the tendency for one habit to interfere with another may result in increased learning time or in actual danger. A recent accident was reported which occurred when a pilot, in attempting to correct for undershooting a field, pulled back on the throttle and pushed the stick forward, resulting in a nose dive into the ground. This incorrect pattern of adjustment was due to the fact that the pilot was flying a plane in which the controls were placed differently from those in the plane in which he had been trained. He was used to advancing the throttle with the right hand and pulling back the stick with his left hand and the "left hand back, right hand forward" habit pattern transferred itself automatically, to the pilot's astonishment and resulting distress. This instance is an example of the possibility of habit interference resulting from the lack of standardization in light plane construction.

Among other specific instances of habit interference which are bothersome in aviation training are: the tendency to use the wheel or stick rather than the rudder pedals for turning, as carried over from automobile driving; the tendency to push the left rudder pedal to start a right turn, carried over from sledding; and the transfer from stick operation to wheel operation and vice versa.

9. EMOTION AND THE LEARNING PROCESS

The relation between emotional stress and learning has so far received little attention from experimental psychologists. Nevertheless, this problem is so relevant to learning of aviation skills that it seems worthy of discussion in the present chapter.

An especially suggestive study is that of McKinney (33) in which college students, learning to trace through a stylus maze under conditions of emotional stress, made significantly more errors than did a comparable group learning the same skill under normal circumstances. The most emotion-provoking situation of those used, and the one associated with the greatest number of errors, was that in which the students were made to feel inferior. They were instructed as follows:

> "You should not take over six minutes to master this task. This is sufficient for a person of average intelligence. At the lapse of this period an interval timer will ring. Should it happen that you have not finished by then go ahead until you have finished."

A buzzer sounded every minute. This, as shown by the subjects' reports, was an additional emotion-provoking factor. Control subjects were told nothing about a time limit and were not stimulated by means of a buzzer. Errors (entrances into blind alleys) averaged 53 for the control and 136 for the experimental group.

Experiments on trial-and-error responses in problem situations have shown that subjects working under emotional stress exhibit a maximum of random (and especially perseverative) responses and a minimum of those evidencing rationality. Even though they have been behaving with a high degree of rationality, subjects tend to revert to less adequate responses following the unexpected onset of such stimuli as an electric shock, cold shower, or klaxon horn (Patrick, 35). Similar phenomena are considered in abnormal psychology under the concept of <u>regression</u>.

A further problem is that of forgetting. It is a well-known fact that strong emotion may produce amnesia for events just preceding it. Harden (14), investigating this experimentally, found that an emotional situation which just follows learning of nonsense syllables tends to retard their recall. The emotional situation involved electric shock, collapse of the chair in which the subject was seated, firing of a gun, the sound of falling metal, and sudden darkness. One subject who experienced this situation became completely amnesic for the material previously memorized.

Although problems of emotion and learning like those discussed have not yet been investigated in relation to acquisition of flying skill, several investigators are studying the incidence and causes of emotional stress or "tension" under flight conditions. Particularly applicable to research in this field are methods developed by Kelly (20) to record conversations of instructor and student, while at the same time obtaining measures of emotional stress in the latter. Jenkins (16) and Williams (53,54) have developed ways of investigating "tension" during flight and present evidence that instructors who are themselves tense turn out tense students. Jenkins says,

> "...there is a statistically significant variation in recorded tension in terms of the instructors involved. That is to say, there is a statistically significant variation between students trained by a particular instructor and those trained by another instructor, in terms of amount of tension recorded...
>
> "I sat out in Lowell Kelly's laboratory and listened to two men teaching spins. One chap...had a youngster up for his first spin. He had not talked very much through the rest of the flight, but he began to talk very deliberately and very slowly and he said, 'All right now, I am going to come back on the stick, and you will notice that the nose of the airplane continues to rise.' He told

the student about the tail buffeting and stalling. Presently he told him that he was going to give some right rudder and then pointed out that the airplane was rotating violently. Then he told him that he was going to bring it out of the spin, which he did and all of this in the same level of speech, and the same tempo and the same pitch.

"Another man, with a very large number of hours who obviously did not like spinning, produced a very different record. The youngster, sitting in the back seat with a total of 12 hours or some other large amount of time, hears the fellow up front on whom his life depends, and when his voice rises a full octave and his speech speeds up, well, even a baby is a pretty good muscle reader and this is not a baby back here. They told me that every student this man turned out was spin-shy. Now he is a darn good pilot, he is a darn good instructor, except that, when it comes to spins, he is very unhappy and his unhappiness transmits itself to the kid in the back seat.

"That is exactly what we find and I think it is a very important result. There is this characteristic variation between the students trained by different instructors, in the amount of tension that they exhibit (pp. 75-76).

10. SUMMARY

Problems involved in learning to fly may be investigated by methods which have already proved their fruitfulness in laboratory, classroom, and industrial plant.

Progress in acquiring skill may be represented by a learning curve. This is a graphic plot of changes in some aspect of performance as a function of the amount of practice. Learning curves have been plotted for aspects of flight performance, but these curves are inadequate in certain respects which have been indicated. Some of them are nevertheless similar in general trend to those found in acquisition of other complex motor skills. For most of these skills the measurable aspects of performance have been found to exhibit a rapid initial improvement followed by relatively slow progress. The final stages of practice, even though characterised by little measurable improvement in skill, may nevertheless involve increasing proficiency in terms of such factors as getting the "feel of the plane" and achieving automaticity of performance.

Researches in laboratory, classroom and industrial plant have shown advantages in teaching "correct" methods of work from the start. The alternative methods of utilising instructors whose performances differ widely and of allowing trainees to learn the correct responses through trial and error, are wasteful. Methods used by expert flyers in performing basic flight maneuvers have been investigated by photographic recording of skilled performance. Records of this nature are valuable not only in discovering the most effective procedures to teach but also in teaching these procedures to instructors and trainees.

The most efficient learning occurs under conditions where trainees develop understanding as well as skill. Understanding is facilitated by teaching of principles and use of unambiguous and uniform terminology throughout training. Insightful behavior occurs most readily when individuals are instructed in the value of quickly relinquishing inadequate responses in favor of other possible alternatives or of looking for new meanings. Without such instruction there is frequently a tendency to repeat inadequate reactions again and again (perseverate). Insights which students are often left to discover for themselves should, where possible, be taught from the outset, thus speeding the acquisition of efficient flight performance.

Many skills involve levels of complexity and are referred to as "higher order habits" or "habit hierarchies." Flying is a very complex habit hierarchy. In formation of such complex skills, certain subsidiary habits must be learned, at least to some degree, before there is progress toward mastery of the complex habit patterns. Laboratory studies of learning and observations reported by flyers indicate that several subsidiary skills are normally mastered at the same time and that progress on complex coordinations occurs, to a certain degree, while simpler ones are being learned. It seems fruitless, therefore, to confine attention to one subsidiary skill at a time. There is much to be said for training on total behavior patterns at the same time that subsidiary ones are being mastered. The final stage in acquisition of motor skills approximates complete automaticity of the reactions involved.

Motor skills like flying a plane tend to be remembered much better than verbal skills. This is due not to any inherent difference between motor and verbal skills but to the fact that motor skills receive much more repetition than verbal ones, and perhaps suffer less habit interference. Flying involves both verbal and motor skills. Laboratory experiments on forgetting show that the process is at first rapid then slow. Certain factors tend to slow up the forgetting process. Among these are relative inactivity following a lesson, repetition of a skill beyond the level of sheer accomplishment, use of efficient learning methods, and arousal of understanding or insight concerning what is learned.

Learning is most efficient when the learner is strongly motivated. Some conditions surrounding motivated behavior have been indicated and we have pointed out the high degree of motivation present in flight candidates. That attitudes of students toward their instructors play an important role in motivated learning has also been mentioned.

Studies in the classroom and laboratory have shown that learning tends to be most efficient (1) when the size and distribution of practice periods are optimal for the particular skill being learned, (2) when opportunities for recitation and review are offered, and (3) when, at least in some situations and for some skills, the task to be learned is approached as a whole rather than piecemeal. These factors, while tested in laboratories, classrooms, and industrial situations, have not yet been sufficiently investigated in relation to flying. Although distributed learning is theoretically more efficient than massed learning, the latter may prove more practical in aviation. Improved opportunities for recitation and review are now available in aviation training. No experimental data are available, but it appears likely that greater emphasis upon whole than upon part learning would increase the effectiveness of flight training.

Transfer has been studied with the Link Trainer. Their investigators suggest that contact training with the Link prior to regular flight instruction may save air time and facilitate acquisition of the skills involved in performing certain maneuvers, but the experimental evidence for this conclusion is inadequate. The possible transfer value of preflight training in the Link needs further investigation. Habits acquired prior to flight training sometimes interfere with acquisition of flying skill. Variations in the controls of different ships also introduce the problem of negative transfer.

Experiments on emotion in relation to the learning process suggest that emotional stress not only retards acquisition but also interferes with retention. These factors are just beginning to be examined in relation to flight training.

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