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A COGNITIVE MODEL OF WHAT IS LEARNED DURING FLYING TRAINING

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Approved for publication.

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The cognitive model of what is learned during flying training presents an alternative to the familiar concept of flying skill as hand-eye coordination. The model relates the growth of pilot ability to the student's increasingly refined cognitive discriminations about his flying performances made possible by his improved familiarity with the phenomena of flight gained practicing aircraft control tasks.

As the student pilot becomes familiar with his flying tasks, he anticipates his control requirements. Consequently, his performance improves. This leads to better error discriminations, increased aircraft control effectiveness and more familiarity with the pehnomena of flying, which is in turn followed by another incremental

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cycle. This interpretation views the acquisition of flying skill as a spiral-type expanding cognitive process rather than a linear-type perceptual motor skill refinement process.

PREFACE

This report represents a portion of the research program of Project 1123, USAF Flying Training Development, Dr. William V. Hagin, Project Scientist; Task 112301, Development of Performance Measurement Techniques for Air Force Flying Training, Dr. Wayne L. Waag, Task Scientist. It is an expanded version of a paper presented at the 1974 Psychology in the Air Force Symposium at the Air Force Academy, Colorado Springs, Colorado, April 25, 1974.

The contributions of the theories of Drs. Jean Piaget, J. McVicker Hunt, Jerome Brumer, and Heinz Werner to the development of the cognitive model of what is learned during flying training is vast and pervasive. In generating the present theoretical model, their ideas have been synergistically combined with the common observation of instructor pilots that learning to fly an aircraft is essentially a problem of learning what to look for, where to look for it and what to do with it when you find it.

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A COGNITIVE MODEL OF WHAT IS LEARNED DURING FLYING TRAINING

I. INTRODUCTION

This analysis of what is learned during flying training focuses on the student pilot's learning which changes his cognitive structure. It is offered as an alternative to the popular concept of flying skill as perceptual-motor coordination. Once the student pilot has fully developed this cognitive structure, it will enable him to accomplish a flying mission with optimum effectiveness and maximum avoidance of mission-interruptive circumstances. As this analysis unfolds, a concept of complex learning will emerge which characteristically proceeds in an expanding spiral fashion as a function of practice. Accordingly, the student pilot is seen as progressing in turn through pre-solo, pre-graduation and pre-professional/professional phases in his flying training, while his cognitive skills expand in turn through task familiarization, maneuver mastery, and finally to integration and application of his flying performance capabilities.

The present study assumes that human learning begins at birth, continues throughout life, and that it is automatic, specific, and cumulative. In addition, it is assumed that earlier learning influences later learning and that many things are more easily learned if other prerequisite learning has already occurred. Further, it is assumed that a student learns to perform a task in terms of what he things the task is, or what he thinks the requirements of the task are, and that as one task is mastered, from the point of view of the student pilot, new learning tasks are discriminated in what previously was undifferentiated, unorganized experience.

II. PRE-SOLO PHASE COGNITIVE LEARNING

Once Around the Expanding Spiral

The first major objective in flying training is passing the solo check. The instructor must provide training experiences to permit the student to learn how to make a safe landing before he attempts to do so on his own. To satisfy this objective, the student must learn how his aircraft behaves in the three-dimensional aerial environment. He learns to control the aircraft, first far above the surface of the earth, then closer to the surface so that he can proceed with learning to accomplish the solo landing safely.

Familiarization

Initially, the instructor gives the student practice in simple maneuvers such as straight and level flight, turns, climbs, descents, and all possible combinations and permutations of transitions between them. In practicing these simple maneuvers, the student becomes familiar with aircraft control in the various steady states and transitions. In addition, the student learns to visually scan the airspace in which he is flying and the terrain below to make sure he will not approach another aircraft too closely during a maneuver and to make sure he stays in his assigned practice area. At the same time, he learns to scan his instruments to make certain that his straight and level, turning, climbing, or descending flight is proceeding, as required.

Basic Airwork

As he practices basic airwork, the student learns to obtain information from both inside and outside the aircraft. He learns to compare the momentary state of affairs with the maneuver's requirements to generate the appropriate control inputs needed to satisfy the requirements. By practicing these early pre-solo training tasks, the student learns to do the things necessary to make the aircraft behave in three-dimensional space the way he wants to behave. He begins to learn how to get and stay on top of the flight maneuver with which he is involved so that he can satisfy its requirements smoothly and with minimum error.

Landing Configuration Airwork

Once he has gained control of the aircraft in space, the student is given training tasks directly, but not necessarily obviously, related to landing the aircraft safely. The practice of slow flight and various characteristic stalls at higher altitudes serves to build the student's familiarity with the special modification of his control inputs needed to deal with these new flight states he must master. He learns, for example, what the buffet before a stall feels like and how to deal with this information once he learns to recognize it. Subsequently, in landing configuration, the student learns that flight control and power inputs operate differently than at normal cruise speeds. He learns that he must anticipate his control inputs more carefully as it takes longer to regain

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airspeed or altitude when he has slowed down and his landing gear and flaps are down.

Normal Landing

After he gains familiarity with and acceptable mastery of the simple maneuvers, transitions, slow flight, stalls, and various different aircraft configuration states, the student is given practice in putting his skills together in real time to learn how to land the aircraft. The student's information seeking and processing skills and his ability to anticipate control requirements are further extended during practice landings. Here, opportunities are provided for learning what the effect of being in one state at one instant has on the ease or difficulty of obtaining a specific subsequent state of affairs with the aircraft. In attacking the landing task, the student learns the importance of information seeking/processing requirements since undesirable consequences of inadequate information processing skills can appear quite suddenly, for example, during a final approach.

III. PRE-GRADUATION PHASE COGNITIVE LEARNING

Twice Around the Expanding Sprial

It has been said of flying training that the proper role of the instructor pilot (IP) is to keep the student alive until he learns enough to teach himself to fly the aircraft safely. This statement focuses on the fact that the student does have to do his own learning. During the pre-graduation phase of flying training, the student pilot learns training tasks which build on those he has already begun to master during his pre-solo training. Before finishing this phase of training, he will have acquired the ability to handle an aircraft reliably, safely, and acceptably in a set of fundamental maneuvers which can be combined as required to satisfy the exit-level performance criteria of his flying training program.

Reliable Safe Flying Performance

Given the student's demonstration during his solo check that he can indeed fly and land the aircraft, the first order of business in post-solo training is the improvement of his overall level of flying skill. If his IP has done the job of making him error-conscious successfully, the student will begin to detect and discover ways to avoid errors in his flying performance [illegible] are [illegible] to him. As he [illegible] and [illegible] his flying performance, he [illegible] will be better able to discriminate new needs for improved control. Meanwhile, by reducing the variability of his performance, he will be able to observe more clearly how his corrections work with the newly perceived errors. Thus, by increasingly enlightened trial and error, he will, in fact, begin to teach himself how to fly more reliably and more safely.

High Performance Maneuvering

Normally, a student pilot will encounter some form of high performance maneuvering, such as aerobatics, soon after he passes his solo check. What the student learns here relates to his growing ability to take maneuver requirements and turn them into reliable maneuver performances. To accomplish any high performance maneuver, which by definition involves the outer regions of the aircraft performance envelope, smooth, accurate control inputs are required. Unsmooth, inaccurate control leads to maneuvers that nearly any student can recognize as inadequate. Consequently, the student teaches himself to be smoother and more accurate in handling his aircraft, and because his control inputs at one instant clearly effect control input requirements at the next instant, he also learns to anticipate better his control input requirements.

Functional Precision Aircraft Control

Instrument flying is, and has been, presented in one form or another in most pilot training programs. Its objective is safe, accurate control of an aircraft without reference to the surface of the ground over which the aircraft is flying. Two new cognitive growth opportunities are presented for the first time during instrument training: the student has to learn to control his flight path very accurately and to achieve flight path criteria in accordance with a time requirement, and he has to learn to navigate from Point A to Point B using an enroute navigation chart rather than by looking at the ground.

The ability to detect and react appropriately to his instruments acquired during this stage of his training provides the student pilot the means for continued precision refinement of his aircraft control skills. In addition, by solving navigation problems on instruments, the student has the opportunity to develop a symbolic, dynamic representation of his position in space over the [illegible] orientation, [illegible] development of [illegible]

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Advanced Aircraft Control Skills

There are idiosyncratic tasks in various flying training programs that serve one or another student preparation or screening objective. The task might be a cross-country flight, proficiency in formation flying, a certain accuracy in weapons delivery performance, or all three. Typically, the flying tasks involve an older skill applied in a new way or to a new set of circumstances. In acquiring advanced aircraft control skills, the student has to increase his information processing skill to include the demands of the new task while not degrading his previous level of performance to an unacceptable level. For example, he has to learn to fly formation without suffering the embarrassment of getting lost while practicing.

IV. PRE-PROFESSIONAL/PROFESSIONAL PHASE COGNITIVE LEARNING

The Final, Wide Sweep Around the Expanding Spiral

Just as the pre-solo pilot learns how to fly and land his aircraft, the undergraduate pilot learns how to fly well enough on his own so he can continue to learn on his own. During this phase of the pilot's cognitive growth, he will capitalize on his increased ability to discriminate error produced by his improving precision aircraft control skills so as to generate ever better aircraft control performances. Consequently, he learns what must be done to succesfully accomplish a mission and how to do what must be done.

Satisfying Quantitative Criteria

Current undergraduate pilot training emphasizes quantitative performance criteria - increasingly referred to as criterion objectives. Once he graduates, however, the pilot-learner will be confronted with quantitative criteria of the sort that defines the product rather than the points [illegible] way. What the pilot-learner must do to satisfy these quantitative criteria is to attain progressively better and better control over his flying performance so he can detect the errors he [illegible] and find the appropriate correction. No [illegible] part of the post-graduate pilot's learning will [illegible] the importance of being in [illegible] and farther out in a maneuver [illegible] he will not [illegible] to worry with corrections [illegible]. This is the [illegible] "what leads to what" learning the pilot first encountered during his pre-solo [illegible] cognitive learning. In this instance, however, it relates to dramatically finer elements of his aircraft control skills.

Mission Planning and Execution

As the pre-professional pilot overcomes his inadequacies in dealing with his flying performance quantitative requirements, he learns about things which can degrade his performance. In mastering the flying techniques needed to avoid the performance degradation effects of the previously unknown factors, the pilot also learns about things they may not necessarily have to be dealt with given suitable foresight and mission planning. As a result, he will learn to deal with the unavoidables and to plan around the rest. This important bit of cognitive learning closely approximates the flying skill referred to generally as judgment.

Instructor pilots quickly point out that they teach judgment right from the beginning, during pre-solo training. The type of judgment referred to here, however, is antonomous judgment in uncertainty, rather than the typical instructor-student critical interaction following an instance of the student's poor judgment.

Acquisition and Demonstration of Readiness

Because the post-graduate pilot keeps finding out about more and more flying skills he has to acquire and maintain, he has to learn to take advantage of all opportunities to practice and demonstrate his readiness to perform his flying mission. Very seldom will the pilot-learner find enough flying time given him to refine his flying skills, particularly as he continuously detects smaller errors in his flying performances. Given increasingly inadequate time to practice flying skills, the pre-professional pilot must invent ways of combining maneuvers, ways of evaluating his performances, and ways of determining which way of doing something works best for him. He must compete with his last performance the way a professional golfer maximizes the training value of a practice round.

Mastery of Mission Accomplishment

To master the art of accomplishing a mission, the post-graduate has to learn how to adequately prioritize requirements so as to maximize the likelihood of mission success. The would-be competent professional pilot has to learn to be able to do what needs to be done to achieve his goal, nothing more. He must be able to strive for excellance but not for perfection. What makes this cognitive learning so difficult is that, very often, the pilot-learner has achieved significant success through his previously perfect or near-perfect flying performances. At this point, he is faced with the task of deciding to stop trying to be perfect all the time on the maneuvers he knows, just to be as sure as possible that he is producing adequate performance all the time on the maneuvers he is required to perform. The reason why this increment of cognitive growth is essential for the pilot-learner to progress to the level of the competent professional is simple: unless he acquires this ability, he will run the risk of either being perfect or incomplete and inadequate over the full range of mission requirements. To master the skill of accomplishing a mission, the competent professional pilot has to learn to look beyond himself for satisfaction.

V. IMPLICATIONS FOR FLYING TRAINING RESEARCH

Related Investigations

Currently, four research efforts based on the cognitive model are underway at the Flying Training Division, Air Force Human Resources Laboratory (AFSC), Williams AFB, Arizona, investigating the effects of cognitive pretraining on the acquisition of skill in the normal landing pattern, the effects of preinstruction interpretation strategies on the learning and retention of meaningful textual materials, the transfer of a multi-media training program in learning basic instrument flight skills in ground trainer and aircraft and alternative training methods of teaching visual and auditory information processing skills in flying training. The results of these investigations may show how the effectiveness of flying training can be improved through manipulation of the cognitive characteristics of the student pilot's learning experiences.

Consideration of Cognitive Relationships

While these studies will provide objective data bearing on specific training issues, a more compelling illustration of the implications of the cognitive model of what is learned during flying training may be found by considering the relationship between the student's early learning about aircraft control error detection and correction, and his later learning about requirement priorities and mission accomplishment. During pre-solo training, the student pilot becomes familiar with how he must handle the aircraft controls to satisfy the requirements of his various training maneuvers. Typically, the student learns to control his aircraft through use of the method of trial and error, and typically his instructor pilot aids his learning by pointing out his errors as he makes them. Thus, the instructor reinforces the notion that the student's objective should be errorless aircraft control; that is, no errors of altitude, heading, airspeed, attitude, trim, position within the practice area, separation from other aircraft and clouds, and so on, in accordance with what the instructor has told the student to do.

Consequences of Inappropriate Error Consciousness

In his focus on errorless performance, the instructor aims at producing an error-conscious student who will look for, find, and correct his errors accurately and quickly. However, every pilot knows that at any instant his aircraft control may be generating an error that he will subsequently have to detect and correct. In an important way then, the student is being taught to be errorless, or perfectly accurate in his aircraft control, when in fact, perfection is not actually required and is seldom achieved in normal flight operations. Thus, the student is being misled, cognitively, with regard to his learning task requirements.

The goal of efficient, accurate and fast information processing to detect, interpret and correct flight control errors could be achieved if the instructor taught flight path error correction on the basis of errors being normal and their correction being the desired state, rather than perfect control the goal and errors of any sort indicating a kind of incompetence not socially acceptable among real pilots. Actually, a flight path error isn't really socially unacceptable, it's the length of time it remains undetected and uncorrected that's the problem rather than its existance in the first place.

Possibilities of Cognitive Reorientation

If the student was oriented appropriately with respect to the cognitive problem of dealing effectively with flight path error, then he would be cognitively better prepared later on to acquire the ability to prioritize requirements to insure mission success. Thus, the difficulty the competent professional pilot has in mastering the skill of accomplishing a mission, which involves being satisfied with adequate performance rather than seeking perfection, might be substantially reduced because of the different concept he acquired regarding error correction during his previous flying training experiences.

This kind of cognitively oriented training is often omitted in today's programs, leaving the development of the student pilot's understanding of what flying is all about up to him with the result that completion of his cognitive learning requires more time and is less efficient. If the cognitive model can be applied as this example suggests, such omissions and consequent inefficiencies may not remain indefinitely in future flying training programs.

Qualifications, Limitations and Prospects

The cognitive model of what is learned during flying training represents an integration of the author's experiences as a student of flying and of the psychology of learning. As such it is likely that it is incomplete and probable that it errs. The present portrayal of the student pilot's cognitive growth was generated to document what most pilots have known all along but which had not previously been reported or otherwise conceptually organized. Whether or not this idea has any more to offer than the older concept of flying as hand-eye coordination, will depend on what new understanding it stimulates which leads to improved flying training.