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Perceptual-Psychomotor Tests in Aircrew Selection: Historical Review and Advanced Concepts

By
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Lockheed-Georgia Company

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AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
Lackland Air Force Base, Texas

NOTICE

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FOREWORD

This work was performed under Project 7719, Development of Procedures for Increasing the Efficiency of Selection, Evaluation, and Utilization of Air Force Personnel; Task 771904, Development, Analysis, and Improvement of Tools and Techniques for Officer Performance Evaluation and Measurement.

The research was carried out under the provisions of Contract AF 41(609)-2796 by the Lockheed-Georgia Company. Dr. George E. Passey was the principal investigator. Dr. Leland D. Brokaw acted as contract monitor for Personnel Research Laboratory.

This report has been reviewed and is approved.

James H. Ritter, Colonel USAF
Commander

ABSTRACT

This report reviews the literature reflecting the employment of perceptual-psychomotor tests for selection of aircrew members since World War II and provides behavioral concepts for consideration as possible future test development areas. The review considers the use of flight experience as well as perceptual-psychomotor screening devices and comments on the results of the programs in which such experience is intentionally used. The fundamental importance of criterion definition to development and validation of selection devices is discussed. Recent research is reviewed leading to the derivation of behavioral concepts recommended for consideration as principles on which new perceptual-psychomotor tests may be based. The merits of simple tests as opposed to complex tests in which numerous facets of performance are concurrently assessed are considered and the latter approach is recommended. References are included in support of the review and critical items are annotated.

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I. INTRODUCTION

This report provides a review of recent practice in the use of perceptual-psychomotor tests for selection of aircrew members and considers in concept several areas in which tests might be developed in order to extend and improve testing procedures. The review of the literature is placed in historical perspective, though the emphasis is contemporary. The review is supported by annotated references which reflect literature dealing with perceptual-psychomotor testing practices in aircrew selection, as well as pertinent literature in the areas of perceptual-motor functioning, perception, information processing, memory, motor skill acquisition, vigilance, environmental effects upon performance, and measurement methods. Particular attention has been directed toward changes in the state-of-the art since World War II, and the reviewers have attempted to be comprehensive in their coverage of the literature since the publication of the Army Air Forces Psychology Program Research Reports subsequent to World War II.

The procedure followed with respect to literature appearing prior to issuance of the Army Air Forces Psychology Program Research Reports has usually been by citation only. For numerous reasons much research which was accomplished during World War II outside the United States was not reported in time for the editors of the Reports to consider it and in such instances rather complete annotation was believed to be essential to our purpose. In preparing the review a thorough search of the literature was carried out leading to initial consideration of approximately 3,500 titles dealing with aircrew selection and with research in the perceptual-psychomotor area. The titles selected for consideration in the review were those considered by the authors to be germane to the issue of the development of concepts useful in further test development. Literature covering specific areas of behavioral functioning which could be more precisely or more economically assessed by other than apparatus tests was not included. The review does not intentionally reflect the current thinking or methodology concerned with personality, physiological, and intellectual assessment except as incidental accompaniments to achievement of the stated goals.

In the area of utilization of perceptual-psychomotor tests for selection of aircrew members the attempt has been to provide as complete coverage of the literature as possible. Much of the foreign literature is relatively inaccessible and failures in coverage, though not intentional, are undoubtedly present. In dealing with the literature leading to the derivation of suggested concepts the coverage is not intended to be exhaustive but representative and comprehensive in cross-section.

II. PERCEPTUAL-PSYCHOMOTOR TESTS IN AIRCREW SELECTION

Through World War I

Attention to the selection of pilots by the military of the United States began with the publication of instructions for the first physical examination for flying in 1912. The examination provided for determination of the medical status of individuals rather than examination of their aptitude in the sense in which we now use the term. This state of affairs with some refinements and a gradually developing specificity in the medical examination existed for several years. At the end of World War I the screening examination for flying did not include any systematized psychological assessment and the neurological and psychiatric examinations were quite superficial. An early laboratory manual indicates that although psychology had not made a noticeable contribution at that time, its potentiality was recognized for, as Burwell (1957) points out, it held that psychology could make a contribution to the efficiency of the Air Service in eight areas:

- Perception
- Control of voluntary activity
- Maintenance of equilibrium and orientation

- Memory
- Associative thinking (judgment, decision, inference)
- Emotional response
- Attention
- Habit formation or learning

The manual goes on to point out that the psychological requirements for aircrew members were at that time not known and while various opinions had been expressed, psychologists as a group were convinced that systematic observation and experiment must be undertaken in the establishment of these requirements. The need for practicable selection tests was emphasized. A good deal of experimental work did go on, however, both in the United States and abroad. An interesting summary of this work has been provided by Viteles (1942). In reviewing the early work he pointed out that the employment of perceptual-psychomotor procedures for the selection of aircrew members had, since its inception, utilized numerous techniques from elicitation of the simplest of motor reactions and reflex responses through such complex reactions as those imposed by the Ruggles Orientator.

The Italian psychologists of the World War I period were distinguished from their colleagues in other countries by their approach to test selection. These workers instituted a procedure for job analysis and, though present day techniques are different from theirs, the summary they provided gave them some insight into possible behavioral functions which a prospective pilot should possess. They described the job of the pilot in this fashion:

> "A good pilot is one who to a sufficient speed of perception and to a notable degree of extension and distribution of attention, adds constancy, precision, coordinating ability of the psychomotor activity, and who possesses a sufficient inhibitory power of emotive reactions not to be disturbed in the above functions on account of emotional stimulus." (Viteles, 1942, p. 3)

Their approach required development of tests for all of the functions indicated, though they paid particular attention to speed of reaction and calmness in emotion-provoking situations. They introduced a test similar in principle to the complex coordinator and utilized the psychograph in representing the standing of candidates on the traits measured. The usual tendency in these times was to select tests based on the hunches of those responsible for testing and the principal requirement was that it appear to have some relationship to the job of flying rather than be the outcome of a rational analysis such as the Italian psychologists employed. The chief contribution of the American psychologists in these early days is considered to be their insistence upon empirical demonstrations of validity prior to use of a test as a screening device and a further plea for the necessity of cross validation. Most of the work on psychomotor tests concerned either simple or complex reactions in which time and errors were measured. Combinations of tests were better than single tests, though the criteria employed were of doubtful value.

Between the Wars

During the period from the end of World War I to 1939 little interest was evidenced in aviation psychology in the United States. Burwell (1957) noted that during the period between the two World Wars the principal reason for elimination of pilot candidates from the flying training program was flying deficiency and that with the efficiency of the physical examination apparently adequate to its task, the real need was for a reliable estimate of flying aptitude. A significant event during this period was the further development of the principles underlying the complex coordinator.

In 1939 there was no program of research in aviation psychology within the United States and few, if any, psychologists with experience in the varieties of research necessary to a program in aviation psychology. In 1939 the Civil Aeronautics Authority, in conjunction with its pilot training program for civilians, and with the cooperation of the National Research Council, set out to remedy this deficiency. Through the joint efforts of these two agencies, especially the National Research Council's Committee on the Selection and Training of Aircraft Pilots, there were by 1941 at least 100 psychologists who had acquired relevant experience according to the estimate of Viteles (1942).

While the Committee felt that the problems involved in selection and training were in need of attention, it gave serious consideration to the problem of performance assessment in flight. With the interest in military flying which developed just prior to the outbreak of World War II, the Committee concerned itself with assisting the military in addition to its primary mission and continued to do so throughout the War in a program complementary and often closely related to the work going on in the military establishment.

World War II

Although the actual outbreak of World War II did not occur until the end of 1941, the military flying training program had expanded considerably during 1940 and the early part of 1941 and there was great concern in both the Army and Navy with regard to the attrition rates which they were experiencing in flying training. At approximately the same time in the summer of 1941 both the Army Air Forces and the Navy created organizations of specialists in aviation psychology and one of their primary concerns was selection and classification. These organizations made a monumental contribution to the entire military establishment, though in the area of perceptual-psychomotor testing the contribution of the Army Air Forces' program is of greatest import. The accomplishments of the aviation psychology program of the U. S. Navy are covered in a series of articles by Jenkins (1945; 1946) and Fiske (1946; 1947) though these reports are descriptive in nature as compared with the technical reports produced by the Army Air Forces.

The realization of the need for a more objective means of selecting functions for testing was noted by both Melton (1947) and Miller (1947). At the beginning of World War II it was possible to borrow some concepts from the past, but the emphasis was on empirical determination of behavioral functions likely to be effective in differentiating potentially successful from potentially unsuccessful aircrew candidates. Analyses of the records of eliminees from pilot training yielded information as to the principal stated reasons for failure of the student, and interviews with failing students were used to verify these reasons. A summary of the reasons which were given for elimination is contained in Table 1.

The following factors were cited as important to success in flying training: (a) motivation and emotional adjustment, (b) ability to divide attention, (c) capacity for rapid perceptual judgments, (d) good muscular coordination, and (e) good judgment.

Table 1

Deficiencies Listed as Reasons for Elimination From Primary Flying Schools in 1941[a]

Intelligence and Judgment	Coordination and Technique
Judgment	Coordination
Foresight and planning	Appropriateness of controls used
Memory	Feel of controls
Comprehension	Smoothness of control movement
	Progress in developing technique
Alertness and Observation	**Personality and Temperament**
Visualization of flight course	Absence of tenseness
Estimation of speed and distance	Absence of confusion and nervousness
Sense of sustentation	Absence of fear and apprehension
Division of attention	Suitable temperament
Orientation	Motivation and attitudes
Speed of decision and reaction	

[a] Adapted from Miller (1947, p. 42-43)

The use of these data and the information concerning validity of the tests in the classification procedure led to rather frequent modification of the testing battery in the early part of World War II, but as the war progressed changes became less frequent. The perceptual-psychomotor tests used in the program through the end of World War II are shown in Table 2.

These tests were described in detail by Melton (1947) and some of the more recent modifications of the tests are described briefly in the Appendix.

Our allies were less active in aircrew selection and classification. Both the French and the Philippine governments benefited directly from efforts of the Army Air Force's program, as described by DuBois (1947). The Royal Air Force Program has been described by Vernon and Parry (1949) and Parry (1947). In 1939, within the Royal Air Force, the medical examination was supplemented by two interviews, the first of which was relatively unimportant since it eliminated only the extreme cases and a second which was given by relatively unqualified personnel. In 1940 Professor F. C. Bartlett had been asked to prepare some short tests, though these were administered by untrained examiners and were for the most part ineffective. By 1941 the large proportion of failing trainees gave pause to those concerned and since the training was to take place overseas, the problem became even more important because of the logistics involved. Of those chosen for training by the interview boards, who had available the scores on Bartlett's tests, one in four failed through lack of flying skill. A work sample flight test was then devised and a twelve hour flight training period was given prior to overseas shipment. Aptitude testing of the variety used in the U. S. Army Forces was not initiated until 1944 when a two-day testing program involving 18 paper and pencil and 5 apparatus tests was instituted. Differential selection for aircrew specialties was attempted but validity data were incomplete at the close of the War. The program in the Royal Canadian Air Force followed that of the Royal Air Force in many respects and the employment of the "grading" procedure developed by the Royal Air Force and the use of the Visual Link test have been described b ~'gnori (1949).

Table 2

Apparatus Tests U. S. Army Air Corps

World War II

February 1942

Coordination (CM10)

Finger Dexterity (CM20)

Feel of Controls (CM40)

Serial Reaction Time (CM70)

April 1942

Steadiness (CM103A)

Arm-Hand Dexterity (CM114A)

Finger Dexterity (CM114B)

Coordination (CM701A)

Speed of Reaction (CP611C)

May 1942

Finger Dexterity (CM20A)

Steadiness (CM103A)

Arm-Hand Coordination (CM113A)

Coordination (CM701A)

Speed of Reaction (CP611)

June 1942

Steadiness (CM103A)

Arm-Hand Dexterity (CM113A)

Finger Dexterity (CM116A)

Speed of Reaction (CP611D)

SAM Complex Coordination (CM701A)

August 1942

Steadiness-Under-Pressure (CE206B)

SAM Two-Hand Coordination (CM101A)

Speed of Reaction (CP611)

Finger Dexterity (CM116A)

SAM Complex Coordination (CM701A)

December 1942

SAM Complex Coordination (CM701A)

SAM Two-Hand Coordination (CM101A)

SAM Rotary Pursuit (CM803A)

SAM Discrimination Reaction Time (CP611D)

SAM Aiming Stress (CE211A)

Finger Dexterity (CM116A)

(Continued on next page)

Table 2 (Cont'd)

Apparatus Tests U. S. Army Air Corps

World War II

<u>July 1943</u>

SAM Aiming Stress (CE211A)

SAM Rotary Pursuit with Divided Attention (CP410B)

SAM Complex Coordination (CM701A)

Finger Dexterity (CM116A)

SAM Discrimination Reaction Time (CP611D)

SAM Two-Hand Coordination (CM101A)

<u>November 1943</u>

SAM Rotary Pursuit with Divided Attention (CP410B)

SAM Complex Coordination (CM701A)

Finger Dexterity (CM116A)

SAM Discrimination Reaction Time (CP611D)

SAM Two-Hand Coordination (CM101A)

Rudder Control (CM120B)

<u>September 1944</u>

SAM Rotary Pursuit with Divided Attention (CP410B)

Rudder Control (CM120B)

Finger Dexterity (CM116A)

SAM Complex Coordinatior (CM701A)

SAM Two-Hand Coordination (CM101A)

SAM Discrimination Reaction Time (CP611D)

<u>June 1945</u>

SAM Rotary Pursuit with Divided Attention (CP410B)

Rudder Control (CM120B)

Finger Dexterity (CM116A)

SAM Complex Coordination (CM701E)

SAM Two-Hand Pursuit (CM810A)

SAM Discrimination Reaction Time (CP611D)

Pedestal Sight Manipulation (CM824A)

The Germans and the Japanese appear to have been active in aircrew selection and classification. Fitts (1946) has reported psychological testing as requisite for officer training within the German military establishment in the late 1920's. Although testing had gone on prior to this time, it was essentially on an experimental basis. In 1939, the first year of the independent existence of the Luftwaffe, an independent program of aircrew selection was inaugurated though the program was discontinued in 1942. The opinion of the test administrator in evaluating the results and the subjective observations made of the candidate during the testing procedure were of greater importance than his scores. No attempts at validation were made; the rationale for choice of tests were drawn from theories concerning personality structure and from conclusions obtained from case studies of military heroes. Geldard and Harris (1946) have reviewed the selection and classification procedures employed by the Japanese Air Forces. As in Germany, there was a lack of standardization in interpretation of test results, and much depended upon the opinion of the interviewing psychologist. Three psychomotor tests, described by Geldard and Harris, involved motor coordination and recognition and were regularly given to applicants. The scoring system used and the weights assigned in final appraisal would, however, allow an individual to be selected for aircrew training independently of the score made on the psychomotor tests.

World War II to Date

Following World War II, and the resulting demobilization, military agencies charged with aircrew selection and classification of aircrew underwent reduction in size. The Army Air Forces' School of Aviation Medicine continued to function in test development and validation, though with the decreased pilot candidate population, classification testing for aircrew was discontinued except for experimental purposes in 1947. The Air Force program in pilot training was quite restricted in size during the early postwar years.

The flying training program in the Navy was of greater magnitude during the immediate postwar years than was that of the Air Force. With its relatively larger input of pilot candidates the opportunity for collecting validation data was attractive and a joint program between the Army Air Forces and the Navy known as the Pilot Candidate Selection Program was carried out. The essential findings of the program are described by Payne, Rohles and Cobb (1952) and Roff (1952b). It is of interest that a number of paper and pencil tests designed to measure perceptual-psychomotor functions were included in the selection battery and that these tests were eventually judged to be inadequate.

Lane (1947) reported results of an investigation on civilian flying training in which various tests were used in an attempt to establish their validity for flying training in light aircraft. Among the tests were several of the perceptual-psychomotor variety.

The Office of Naval Research sponsored a survey of techniques utilized in pilot candidate selection. This work was carried out by Kelly, Bishop, Beum,and Dunlap (1951) and, in addition to a survey of techniques in use, these authors made recommendations for implementation of a selection program in Naval aviation. They suggested that both paper and pencil tests and perceptual-psychomotor tests should be employed and made specific recommendations for the content of a selection test battery.

While aircrew testing was not being used for classification within the Air Force, the work was carried forward on an experimental basis and a review of that work covering the postwar period through 1949 was prepared by Dailey and Gragg (1949). At this time the functions formerly carried out by the Air Force School of Aviation Medicine were transferred, in large part, to the newly organized Human Resources Research Center though the School of Aviation Medicine continued in its role with respect to the Navy project. The Korean conflict with its demands for larger numbers of aircrew personnel and the increasing number of volunteers led to the decision to reinstate aircrew classification testing within the U. S. Air Force. A conference for the purpose of considering revisions in the Aircrew Classification Battery was held early in 1951 (Dailey, 1951). Changes recommended in the battery by this conference were minimal, but it is interesting to note that in regard to perceptual-psychomotor testing, the Perceptual and Motor Skills Laboratory of the Human Resources Research Center reported that little had been done in investigating possibilities for new perceptual-psychomotor tests for selection purposes. Between April 1951 and July 1955 Aircrew Classification Tests were administered and perceptual-psychomotor tests were retained as a part of the test battery. Because of the dispersal of the volunteers to be tested and the logistic problems involved in apparatus testing, it was decided in July of 1955 to discontinue the use of apparatus tests. (The perceptual-psychomotor tests included in the Aircrew Selection Battery during its evolution in World War II were previously noted.) The changes in this portion of the Battery since World War II are summarized by listing the various perceptual-psychomotor tests utilized in subsequent revisions of the Aircrew Classification Battery. These data are contained in Table 3.

After World War I a lapse in selection and classification activity was noted, and while the reduction in activity immediately after World War II was mild compared to the decline following World War I, it does represent a considerable reduction. Factor analyses of data collected during the war were carried out by Dudek (1948; 1949), Michael (1949) and Roff (1951). A factor analytic study of the data collected in the joint Air Force-Navy program was also performed by Roff (1953a). An analysis of the validity of the Aircrew Classification Battery for differential prediction for the two stages of flight training and for differences between officer and cadet student pilots was carried out by Zaccaria and Cox (1952a; 1952b). No differential validities were found. Despite the activity brought about by the reinstitution of aircrew classification procedures in 1951, little was done in the development of new or revised perceptual-psychomotor tests save the work of Fleishman and his co-workers in the early and middle 1950's.

Table 3

Apparatus Tests Used by the U. S. Air Forces

Since World War II

June 1945

SAM Rotary Pursuit with Divided Attention (CP410B)

Rudder Control (CM120B)

Finger Dexterity (CM116A)

SAM Complex Coordination (CM701E)

SAM Two-Hand Pursuit (CM810A)

SAM Discrimination Reaction Time (CP611D)

Pedestal Sight Manipulation (CM824A)

February 1947

SAM Rotary Pursuit with Divided Attention (CP410B)

Rudder Control (CM120C)

Finger Dexterity (CM116A)

SAM Complex Coordination (CM701E)

SAM Two-Hand Coordination (CM101B)

SAM Discrimination Reaction Time (CP611D)

April 1951

SAM Rotary Pursuit (CM803B)

Rudder Control (CM120C)

SAM Complex Coordination (CM701E)

SAM Discrimination Reaction Time (CP611D)

With the separation of the Air Force from the United States Army, the flying program remaining within the Army was one of some contrast with that which the Air Force represented. The emphasis on smaller air vehicles and especially those of the rotary wing variety presented unique classification problems within Army aviation. After reporting little success with the traditional paper and pencil tests (Zeidner, Goldstein, Sprunger & Karcher, 1956), the Army has given only perfunctory attention to perceptual-psychomotor tests (Zeidner, Martinek & Anderson, 1958a) although it has attempted to produce such tests in paper and pencil variety (Zeidner, Martinek & Anderson, 1958b).

Reports on the use of perceptual-psychomotor tests in the selection of aircrew members abroad have not frequently appeared in print although it is suspected that there may be more activity than the small number of publications would indicate. In Spain, the U. S. Air Force's Aircrew Classification Battery was used with a group of 120 cadets at the Air Militia University. The Battery was modified and only three perceptual-psychomotor tests, the Two-Hand Coordination Test, the Rotary Pursuit Test, and the Visual Discrimination Reaction Time Test, were used. The results reported by Germain (1961) demonstrated validites in keeping with those found in the United States.

While details of the selection system in use in the United States were made available to Great Britain and Australia toward the end of World War II, administrative difficulties precluded the use of these techniques until 1955. Prior to 1955 intelligence testing and interview procedures were utilized. Want (1962) likened the procedure to local industrial practice and indicated that there was no attempt to predict flying aptitude as such. While both Naval and Air Force trainees receive their instruction from the Royal Australian Air Force, each service selects its own pilot candidates. In 1955, the Royal Australian Air Force began using tests based on those which had been developed for selection in the United States Air Force, though the Naval selection system remained unaltered. The only psychomotor test being used was one developed from the South African Arm-Leg Coordinator.

Dzhamgarov (1963) has reported four series of experimental investigations in the Soviet Union between 1959 and 1963. He indicated that the method involved the study of selected motor abilities and individual psychological traits which were believed most conducive to successful flight training. His communication points out that the examination program for the candidates utilized data derived from an analysis of reasons for failure in flight training. The motor abilities studied included speed of reflexes to complex signals and delicate coordination of movement, which was studied in conjunction with diversion of attention and artificially simulated emotional stress. The criteria used in validation were indexes of performance in initial flight training.

The most active region which we have identified during the postwar era has been South Africa. The South African Air Force has in the past decade, particularly, been carrying out numerous validation studies utilizing perceptual-psychomotor tests. The work has been carried out principally by de Wet (1959; 1960a; 1960b; 1961; 1962a; 1962b; 1963; 1964), who has developed some ingenious tests, though his rationale for the development has not been stated in any publications seen by the reviewers and the number of cases utilized in his validation samples has been undesirably small. His work is described in detail in the annotated references accompanying this review because of the general unavailability of the literature in question. The studies which have attempted to provide information on the validity of perceptual-psychomotor tests in selection and classification of aircrew since World War II are few in number. The studies which have been reviewed and the perceptual-psychomotor tests which were employed are listed in Table 4.

Table 4

Perceptual-Psychomotor Tests for Which

Aircrew Validity Data Have Been Recently Reported

Source	Test
South African Air Force	
de Wet (1959)	Coordination and Floating Effect
de Wet (1960a)	Hand-Foot Reaction
de Wet (1960b)	Steadiness
de Wet (1961)	Handlebars (two-hand coordination)
de Wet (1962a)	Variable Coordination (hands, hand-foot)
de Wet (1962b)	Flicker Fusion
de Wet (1963)	Roundabout
de Wet (1964)	Speed of Perception and Span of Attention
Royal Australian Air Force	
Want (1962)	Arm-Leg Coordination
U. S. Army	
Zeidner, Martinek & Anderson (1958b)	Rotary Pursuit
	Rudder Control
	Direction Control
	Complex Coordination

(Continued on next page)

Table 4 (Cont'd)

Perceptual-Psychomotor Tests for Which

Aircrew Validity Data Have Been Recently Reported

Source	Test
Royal Canadian Air Force	
Signori (1949)	Visual Link
Navy-Army Air Forces - U. S. Air Force Joint Project	
Payne, Rohles & Cobb (1952)	Plane Control
	Multidimensional Pursuit
	Rate Control
	Finger Dexterity
	Rotary Pursuit with Divided Attention
	Discrimination Reaction Time
	Two-Hand Coordination
	Complex Coordination
	Rudder Control
	Direction Control
	Single-Dimension Pursuitmeter
	Compensatory Balancing
	Controls Orientation
	Pursuit Confusion

(Continued on next page)

Table 4 (Cont'd)

Perceptual-Psychomotor Tests for Which

Aircrew Validity Data Have Been Recently Reported

Source	Test
Navy-Army Air Forces - U. S. Air Force Joint Project (Cont'd)	
	Rudder Reaction
	Complex Timing Reaction with Memory for Procedures
	Drift Correction
	Self-Pacing Discrimination Reaction Time
	Complex Multiple Reaction
Army Air Forces - U. S. Air Force	
Dailey and Gragg (1949)	Rotary Pursuit with Divided Attention
	Rudder Control
	Finger Dexterity
	Complex Coordination
	Two-Hand Pursuit
	Discrimination Reaction Time
	Pedestal Sight Manipulation
	Two-Hand Coordination

(Continued on next page)

Table 4 (Cont'd)

Perceptual-Psychomotor Tests for Which Aircrew Validity Data Have Been Recently Reported

Source	Test
U. S. Air Force	
Leiman and Friedman (1952)	Rotary Pursuit with Divided Attention
	Rudder Control
	Finger Dexterity
	Complex Coordination
	Two-Hand Coordination
	Discrimination Reaction Time
U. S. Air Force	
Fleishman (1953a)	Six-Target Rudder Control
	Dynamic Balance
	Complex Coordination
	Rotary Pursuit
	Discrimination Reaction Time
	Rudder Control

(Continued on next page)

Table 4 (Cont'd)

Perceptual-Psychomotor Tests for Which

Aircrew Validity Data Have Been Recently Reported

Source	Test
U. S. Air Force	
Fleishman (1954b)	Direction Control
	Compensatory Balance
	Complex Coordination
	Discrimination Reaction Time
	Rotary Pursuit
	Rudder Control
U. S. Air Force	
Cre[illegible]er (1957)	Rotary Pursuit with Divided Attention
	Rudder Control
	Finger Dexterity
	Complex Coordination
	Two-Hand Coordination
	Discrimination Reaction Time

(Continued on next page)

Table 4 (Cont'd)

Perceptual Psychomotor Tests for Which

Aircrew Validity Data Have Been Recently Reported

Source	Test
Royal Air Force	
Parry (1947)	Pilot Co-ordinator
	Control of Velocity
	Finger Dexterity (USAAF)
	Turret Manipulation
	Morse Record (U. S. Navy Modified)
Spanish Air Force	
Germain (1961)	Two-Hand Coordination
	Rotary Pursuit
	Discrimination Reaction Time
Civilian Pilot Training	
Lane (1947)	Mashburn Serial Reaction
	Two-Hand Coordination
	Judgment Reaction

III. PREVIOUS FLYING EXPERIENCE AND THE LIGHT PLANE AS SELECTION DEVICES

Experience in flying has been shown on numerous occasions to be of use in the prediction of success, especially in pilot trainees. In a sense this procedure utilizes a rather complex perceptual-psychomotor task, albeit an expensive one. The U. S. Army Air Forces carried out an experimental study of 1,000 applicants sent into pilot training in World War II. A biserial $\underline{r}$ of .29 was found between previous flying experience and success in pilot training (Flanagan, 1947). In 1942 the system of "grading" was introduced into the selection procedure in the Royal Air Force (Royal Air Force, 1945). This system assumes that there is a relationship of sufficient magnitude between rate of learning and subsequent performance. Its introduction was followed by a reduction in flying deficiency eliminations to about half the previous level. Essentially it involved a twelve-hour dual flying training course in which assessments of student pilot proficiency were given in the 7th and the 11th hours; these were later changed to 5½, 8½, and 11½ hours. In addition to the reduction of flying deficiency eliminations, it had the effect of reducing eliminations for other causes. For a sample of 923 cases Parry (1947) has reported a correlation between performance on the RAF selection battery and "grading" equal to .47. Signori (1949) in reporting the results of the Arnprior Experiment indicated that the correlation between "grading" and rank standing in Elementary Flying Training School for 342 trainees was .46 and with the composite pass-fail in Elementary and Service Flying Training School for 330 trainees was .52. Instructor's ratings during Initial Flying Training (the same program as that used in "grading") given at the end of 1½, 3, 5, 7, and 11 hours of training yielded correlations of .42 and .47 against the same criteria.

The United States Air Force conducted a well-controlled experimental program to evaluate the light plane training as a preprimary selection and training device for students drawn from Classes 53-D, 53-E, 53-F, and 53-G. The experiment involved 25 hours of flight training and effective matching with controls who did not receive the training. A number of indexes thought to be useful as predictors were collected. Boyle and Hagin (1953) have described the program and presented evaluative data which demonstrated the effectiveness of the procedure as a training device. A more detailed analysis of these initial findings was carried out by Sutter, Townsend, and Ornstein (1954). Flyer and Bigbee (1954) have evaluated the findings in terms of prediction of success in both Primary and Basic Single-Engine Flying Training. All of the measures taken were predicted significantly by the Pilot Stanine. For instructor's prediction of the overall flying grade in primary training, the highest validity coefficient was found for the 25-hour prediction and was .46, while the Pilot Stanine yielded a coefficient of .30 and the check pilot's prediction at 25 hours was .37. These data were based on an N=97, which represented those students who graduated from Primary Flying Training. For those graduating from Basic Single-Engine Flying Training (N=72), the 15-hour instructor's prediction yielded the highest validity with a coefficient of .39, the check pilot's 25 hours prediction was .34, while the Pilot Stanine was .17. The low validity found for Pilot Stanine was judged to be due to the fact that it is maximally predictive of flying deficiency eliminations rather than grades as such. When graduation-elimination from pilot training was considered, the validity of the Pilot Stanine was .40, that for the 25-hour instructor's prediction was .42 and that for the 15 hour check pilot's prediction was .47 for an N=112, who were graduates of the Light Plane Phase. Tucker (1954) has shown that when the Aircrew Classification Battery of 1947 was used with the General Information and Rudder Control tests omitted, the use of previous flying experience information may add significantly to the efficiency of prediction. Flyer and Bigbee (1955a) have also shown that the validity of the light plane grade for Classes 54-A, 54-B, and 54-C was .54 and the Pilot Stanine, .36 (N=269) for predicting flying deficiency elimination. For prediction of [illegible]er than flying deficiency elimination, coefficients of .35 and .11, respectively, were obtained. All except the last coefficient were [illegible] at the .01 level.

Rosenberg, Kaplan, and Skordahl (1961) reported that 94 percent of those with ROTC training completed Army Flying Training while only 72 percent of a comparable group lacking flying training were graduated. Berkshire and Ambler (1963) indicated that a group given indoctrination flights prior to preflight training and compared with a matched control yielded differences, though small, in favor of the indoctrinated group in the g[illegible] earned during flying training. Ambler (1955) had earlier found that previous flight experience was related to success in the Naval flying training program. The contribution of passenger experience was found negligible and when the overlap with the aptitude test scores was considered, the advantage of previous flight training other than passenger experience as a predictor was not significant. Flyer and Bigbee (1955b) reported data on 130 Air Force ROTC students in Pilot Classes 55-J through 55-Q who received light plane training. They indicated that the validity of the AFOQT Pilot Stanine was .58, the light plane check pilot's grade .29, and the light plane instructor's grade .48 for graduation from Basic Flying Training. If these predictors are used together, the validity coefficients show a slight elevation.

No cost effectiveness studies utilizing light plane training as a screening technique were found in the literature, but it appears doubtful that this technique is a useful one for selection unless it also provides some transfer of training for those who eventually graduate from the pilot training course. There is some evidence that elimination in primary training takes place later for those who receive the light plane training (Boyle & Hagin, 1953) and further that the beneficial effects for those receiving the light plane training tend to disappear by the time the trainee has completed 60 hours of Primary Flying Training (Sutter, Townsend & Ornstein, 1954).

IV. CRITERION DEFINITION

The development of adequate criteria for aircrew jobs is essential in the validation of selection and classification procedures as well as in the evaluation of training methods. In addition to these obvious needs for criterion specification it is largely from the procedures of job analysis, essential to criterion definition, that those charged with the development of screening devices should draw their critical behaviors which permit identification of the functions which will be represented in their testing procedures. Despite the need for such data, the whole issue of criterion development as regards aircrew members has been disappointingly neglected.

In recounting the difficulties besetting those responsible for the selection of candidates for pilot training in World War I, Viteles (1942) indicates that the task was a difficult one for many reasons, but salient among these was the embarrassing realization that none of the test developers knew very much about the qualifications of a good pilot. Although the techniques of job analysis were beginning to be applied in industry, they had not at that time been applied in the aviation setting. He indicates that some work on job analysis for the pilot had been carried out in Italy and that the psychologists there had attempted to differentiate between three quality levels in pilots. These early workers were not concerned with validation as we think of it today. They were essentially concerned with the development of tests on a rational basis and regarded the initial development as the end of their efforts. Validity was assumed as a consequence of careful development.

Henmon (1919), in what was probably the first attempt at cross-validation in the flight training situation, provided for the testing of cadets at two different locations in ascertaining the predictive efficiency of a simple reaction time test. His criterion was essentially a threefold classification involving the extremes in performance and a third group whose proficiency was unknown. His classification was arrived at from examination of officer's ratings and report cards. The test failed to make suitable predictions, though the failure could have resulted from defects in the criterion.

On the eve of World War II, job analysis for aircrew positions was still being neglected. There were no trustworthy techniques available for rating or measuring pilot performance; therefore the value of tests in selecting candidates for pilot training could be determined in only a crude fashion. In fact, there had been no really adequate research aimed at validation of selection techniques.

Early in the work of the NRC Committee on the Selection and Training of Aircraft Pilots, the Committee concerned itself with criteria of pilot proficiency (Viteles, 1945). Rating and grading methods of instructors and inspectors in the Civil Aeronautics Authority program for training civilian pilots were evaluated. Assessment of pilot performance prior to the work of the Committee was limited largely to the assignment of ratings on individual maneuvers considered as basic units and grades on overall flight performance without detailed or controlled reference to specific aspects of performance. The preparation of Standard Flights and the development of the Ohio State Flight Inventory were pioneer efforts in the standardizing of procedures for recording observations on specific items of pilot performance and in derivation of objective methods of scoring such observations. The Purdue Scale for Rating Pilot Competency was developed, and a subsequent factor analysis of this scale indicated that three factors, "skill," "judgment," and "emotional stability" were being assessed. This Purdue Scale was later adapted for use in Naval aviation and by Northeast Airlines. Photographic and graphic methods of recording pilot performance were also evaluated under the sponsorship of the Committee although the results were not encouraging.

Analysis of the methods in use by the Civil Aeronautics Administration tended to show rather low correlations between instructors' grades and those assigned by inspectors and also rather low observer reliabilities between pairs of instructors and pairs of inspectors. With reduction in incidence of failure as selection procedures improved, sensitive and more objective means than a subjective pass-fail criteria appeared to be called for.

Krumboltz and Christal (1957) and Want (1959) have effectively demonstrated that, despite protestations of those judging flight performance to the contrary, the observer judgments are relative to the particular students to whom the judge is exposed at the moment. A student of moderate ability stands out in a group of low aptitude students but is likely to be judged unsuitable for further training if he has the misfortune to be grouped with other students of outstanding aptitude.

Miller (1947) and his collaborators have summarized work within the U. S Army Air Forces aimed at providing reliable and valid indexes of pilot performance. At the end of World War II an instrument flying proficiency measure showed considerable promise with a reliability coefficient between different check pilots of .46 and a coefficient of .51 between the total score assigned by the two check pilots and ratings made by the student's instructor prior to the check rides. Flanagan (1947) indicated that he thought it possible to develop practical measures for use in all pilot training schools. In the same period the Royal Air Force developed a criterion involving standard flights and a method of recording student performance. Frisby (1952) reports that the first step was to demonstrate the unreliability of the former subjective methods of assessing performance followed by the introduction of the objective system. One type of checklist reduced flight exercises to a detailed list of objectively observable items while a second involved a simpler and shorter form on a point scale and required judgments for selected aspects of the exercise. The fact that the shorter form yielded higher reliabilities tends to confirm the suspicion that one may go overboard in requiring more observations than can reasonably be made in the time available. The detailed lists may represent an evolutionary step in the development and can be simplified when those indexes critical to assessment have been identified.

Following World War II, the Civil Aeronautics Authority continued its efforts in the development of objective proficiency measures for pilots. The literature on pilot proficiency measurement covering the period from

World War I to 1950 is summarized by Ericksen (1952b). A more recent bibliography of the literature on proficiency measurement for aircrew has been prepared by Buckout (1962). Smith (1964) prepared a bibliography on proficiency measurement for training quality control and Smode, Gruber, and Ely (1962) have treated aircrew proficiency measurement in synthetic ground environments.

An objective flight check for light plane flying was developed by Ericksen (1951) for the Civil Aeronautics Authority. With the increasing demand on air transport within the country, work was also sponsored by the Civil Aeronautics Authority on the development of objective flight checks for the job of airline pilot. The work of Gordon in identifying the critical elements of the airline pilot's job (1947; 1949a) and his later development of the objective flight check (1949b) are worthy of note, as are those of his successor in this area, Nagay (1949; 1950a; 1950b). While these workers obtained adequate reliability with their rating systems, Zeidner, Martinek and Kleiger (1958) reported difficulty in predicting pass-fail in flying on the basis of ratings given in Army aviation and suggested that the reliability of the grading system was probably low. Wilcoxon, Johnson, and Golan (1952) reported little success with an objective grading system in Naval aviation training and received comments to the effect that the use of their system created a hazard, since the rater was unable to fulfill his function as a safety pilot. Frisby (1952) experienced similar problems with the system tried in the Royal Air Force, but, as was previously indicated, reliability improved markedly with reduction in the number of items to be observed and simplification of the rating forms.

As a basic tool for use in pilot training research, the U. S. Air Force through its Human Resources Research Center and its successor organization carried out a great deal of work in methodology for objective recording of flight performance. Ornstein (1957) provided concise summaries of much of the work in his annotated bibliography. Among the more important contributions from the point of view of criterion development were the objective methods for recording flight performance which were developed in an extensive job analysis by Smith, Flexman, and Houston (1952). These techniques were later utilized as tools in the evaluation of performance in primary flying training by Houston, Smith, and Flexman (1954). With the employment of light plane training in connection with the Air Force ROTC program and questions concerning the usefulness of this training as a selection device, Ericksen (1952c) developed a light plane proficiency check based on the specialized maneuvers to be included in the syllabus for this training. A start was made on objective proficiency measurement in single-engine jet flying training by Neville, Holloway, and Lumpkin (1952) and for multi-engine training by Shafer and Nichols (1953), but the use of these analyses in the development of objective flight checks is not reported in the literature. With regard to the assessment of instrument flying proficiency, Henneman, Hausman, and Mitchell (1947) have reported useful findings and Holdredge (1953) prepared an objective flight check utilizing both forced-choice and checklist rating scales. The emphasis in the work that has been recounted has been more upon the development of criteria for judgment of the competence of the student pilot and deals with an immediate rather than an ultimate criterion. Melton (1947) pointed out that this immediate criterion was the predictive goal for the test developers of World War II. In addition to its being an accessible criterion, the conditions under which criterion measurement were carried out were likely to be more reliable than the fluctuating operational situation with which those concerned with the ultimate criterion must deal. The first step must be to predict this training criterion, since those who do not meet it do not progress further. Jenkins, Ewart, and Carroll (1950) emphasized the need for a combat criterion, yet the work which they carried out was little more than a gesture in this direction. McGehee (1951) found that criterion measurement was a serious problem in Naval aviation and that improvement of selection procedures, training, equipment assessment, and personnel assignment were dependent upon it. He indicated that the use of pass-fail criteria within the Naval aviation program was a serious impediment to improvement of the service. Berkshire (1960) recently argued that successful completion of flight training should not be the sole objective of selection techniques. None would dispute the desirability of this distal prediction, but in view of the lack of success in defining the proximal criterion, to date, one might still argue for prediction of the successful completion of training as an initial goal and the need for the development of an adequate grading system at this level as requisite to its attainment.

Since World War II there has been some development of criteria for positions other than pilot. Murray (1951) performed an analysis of the job of the aircraft navigator-bombardier and provided some useful data on the attributes required for successful performance. Daniel, Eason, and Lick (1957) devised a map-match method for assessing navigator performance in radar bombing. Christensen (1949; 1950a) surveyed the inflight activities of navigators and recommended a sampling technique for use in activity analysis (Christensen, 1950b). Wagner (1951) attempted the development of standardized procedures for the definition of aircrew jobs in terms of testable traits. Critical proficiency requirements for B-29 combat crews were surveyed by Marley (1952).

Although the activity in criterion development has been minimal, none of the work which has been done appears to have been adopted by using agencies and we are still, by and large, attempting to predict success versus failure in training. The criteria of success in training are somewhat varied but largely qualitative in nature and probably of relatively low reliability. The studies utilizing perceptual-psychomotor tests as predictive devices in the post World War II period have been reviewed in order to ascertain the criteria used in validation studies. These studies are summarized in Table 5.

Since it appears that predicting a proximal criterion such as training success may involve use of different behavioral functions as predictors than those required for predicting success in operational aircrew assignments, consideration should be given to the selection of the criterion to be predicted in view of its possible impact upon the behavioral functions selected for assessment in the selection and classification program.

Table 5

Some Criteria Recently Employed in Validating Perceptual-Psychomotor Tests for Aircrew Selection

Source	Position	Criteria
South African Air Force		
de Wet (1959)	Pilot	Wings Test (rating)
		General Flying (rating)
		Night Flying (rating)
		Pilot Navigation (rating)
		Instrument Flying (rating)
		Dual hours prior to solo
		Flying Training (pass-fail)
de Wet (1960a)	Pilot	Flying Training (pass-fail)
de Wet (1960b)	Pilot	Flying Training (pass-fail)
de Wet (1961)	Pilot	Flying Training (pass-fail)
de Wet (1962a)	Pilot	Flying Training (rank)
de Wet (1962b)	Pilot	Flying Training (pass-fail)
de Wet (1963)	Pilot	Flying Training (pass-fail)
de Wet (1964)	Pilot	Flying Training (pass-fail)
Royal Australian Air Force		
Want (1962)	Pilot	Pass-fail (all causes)
		Flying Training (pass-fail)

(Continued on next page)

Table 5 (Cont'd)

Some Criteria Recently Employed in Validating Perceptual-Psychomotor Tests for Aircrew Selection

Source	Position	Criteria
Spanish Air Force		
Germain (1961)	Pilot	Flying Training (pass-fail)
Russian Air Force		
Dzhamgarov (1963)	Pilot	Flights prior to solo
		Dual hours prior to solo
		Flight progress
		Instructor opinion
		Dismissal for unsuitableness
U. S. Army Aviation		
Zeidner, Martinek, and Anderson (1958b)	Helicopter Pilot	Preflight (pass-fail)
		Percent satisfactory flight grades
		Flying Training (pass-fail)
		Final course grade (includes academic and flight grade)
		Warrant Officer Candidate ranking

(Continued on next page)

Table 5 (Cont'd)

Some Criteria Recently Employed in Validating Perceptual-Psychomotor Tests for Aircrew Selection

Source	Position	Criteria
Royal Canadian Air Force		
Signori (1949)	Pilot	Initial Training School (rank)
		Elementary Flying Training School (pass-fail)
		Elementary and Service Flying Training School (pass-fail)
		Elementary Flying Training School (rank)
		Elementary Flying Training School ground (rank)
U. S. Naval Aviation		
Payne, Rohles, and Cobb (1952)	Pilot	Academic (pass-fail)
		Flying Training (pass-fail)
U. S. Air Force		
Dailey and Gragg (1949)	Pilot	Basic Flying Training (graduation versus total elimination)
		Basic Flying Training (graduation versus flying deficiency elimination
		Basic Flying Training (graduation versus all nonflight proficiency eliminations)

(Continued on next page)

Table 5 (Cont'd)

Some Criteria Recently Employed in Validating Perceptual-Psychomotor Tests for Aircrew Selection

Source	Position	Criteria
U. S. Air Force (Cont'd)		
		Basic Flying Training (graduation versus combined eliminations for death, discharge, age, and marriage during training)
Leiman and Friedman (1952)	Pilot	Basic Flying Training (pass-fail)
Fleishman (1953a)	Pilot	Primary Flying Training (pass-fail)
Fleishman (1954b)	Pilot	Primary Flying Training (pass-fail)
Creager (1957)	Pilot	Basic Flying Training (graduation versus flying deficiency elimination)
		Basic Flying Training (graduation versus motivational elimination)
		Basic Flying Training (graduation versus physical deficiency plus administrative elimination)
		Basic Flying Training (graduation versus total eliminations)
Civilian Pilot Training		
Lane (1947)	Pilot	Ratings by CAA-Flight Inspector, Instructor, Check pilot, and Student's log book

V. TEST CONCEPTS

General Considerations

It should be possible to determine the behavioral functions critical to success in various aircrew positions through reference to job analyses of aircrew positions and to criterion data for these positions. Unfortunately, while great progress has been made in the development of flight hardware, the whole issue of job analysis and criterion definition has shown little advancement since World War I. Indeed, since the state-of-the-art in hardware design has moved exceedingly rapidly and progress in job analysis has moved so slowly, the deficit appears to have been a cumulative one.

As indicated previously, the analysis of reasons for failure as reported in Miller (1947) provided the basis for the choice of perceptual-psychomotor test concepts during the early days of World War II. The critical incident approach might have been expected to yield useful data, but in its application the emphasis has been such that it has failed to yield much in the way of applicable information. The employment of this technique by Marley (1952) with respect to the B-29 combat crew contains examples typical of those derived by the procedure and which unhappily provide no guidance for the present work. The application of the critical incident approach by Ronan (1954) with regard to emergency procedures represents one of the more fruitful uses of the technique. Working with the job of airline pilot, Gordon (1947) also made effective use of the technique in deriving a number of characteristics or abilities which were consistently judged as more critical than others. These characteristics were: (a) intelligence, thinking and learning capacity; (b) lack of nervous behavior; (c) ability to get along with others; (d) favorable attitude, interest; (e) attending, remaining alert; (f) initiative, aggressiveness, forcefulness; and (g) industry and effort.

Ericksen (1952a) classified the critical comments in basic grade slip folders into (a) personal attitude and motivation, (b) learning and retention, (c) planning and judgment, (d) division and distribution of attention, (e) "feel" of the ship in flight, and (f) coordination. Two-thirds of the critical comments referred to the performance of students who were later eliminated for flying deficiency.

Factor analytic approaches have been used in analysis of the criterion measures as well as analysis of aptitude test batteries. One could hope for a correspondence of factors isolated from the two sets of factor analyses and could argue that the battery possesses construct validity and should be effective to the extent that the factors obtained are in agreement. Factors not represented in the test battery but present in the criterion would represent omissions in the battery. The analysis of the instrument flight check battery by Butler, Bamford, Kautz, and Ornstein (1954) is essentially a criterion analysis. They carried out a cluster analysis of pilot proficiency measures leading to the derivation of 5 clusters and 23 residuals. Unfortunately, they were unable to identify these factors in any meaningful behavioral terms. Fleishman and Ornstein (1960) in a factor analytic study of flight maneuvers were able to isolate the following factors:

- Control precision, called Coordination I or fine control sensitivity
- Spatial orientation, involving judgment of one's position in three-dimensional space
- Multilimb coordination
- Response orientation, ability to make rapid response decisions under rapidly changing stimulus conditions
- Rate control which involves responses to anticipations of velocity and rate changes
- Kinesthetic discriminations which are involved in maneuvers emphasizing stalls and slow movements of the aircraft

Fleishman and Hempel (1956) carried out a factor analysis on 23 tests, including 16 apparatus tests developed in the World War II program of the Army Air Forces and 7 printed tests which were used in the joint Air Force-Navy Pilot Candidate Selection Project. The first five factors isolated by Fleishman and Ornstein (1960) were found in this laboratory analysis of perceptual-psychomotor tests. The kinesthetic discrimination factor found in the analysis of flight maneuvers did not emerge in the laboratory evaluation. In addition, the laboratory analysis yielded factors of perceptual speed, manual dexterity, visualization, and integration, which had no counterparts in the analysis of flight maneuvers. All of the factors isolated by Fleishman and Hempel (1956) had factor loadings on the apparatus tests except for perceptual speed, which was apparent only in the printed tests.

McGehee (1951) frequently found that aviation personnel felt it was easier to fly jet aircraft than propeller-driven aircraft and that the only difference reported was in demand upon the pilot in terms of higher speed. He suggests that research is necessary to establish whether there is increased demand upon the perceptual and psychomotor activities of aircrew members and raises the issue of the need for differential assignment to aircrew duties in terms of these demands. He notes an absence of data on what pilots must do in various types of instrument flying.

Cassie (1962, p. 95) in a paper delivered at the NATO Conference on Defense Psychology made the following comments about the job of the military pilot:

> "Within the last twenty years the role of the pilot has changed. In 1940 he took his aircraft into battle, and thereafter was his own tactician, who depended on his own skill entirely. Later, he was directed by a controller to his target. The tactical decision was partly removed from him, but his own skill at control was still essential. Now, in the latest generation of highly sophisticated aircraft, he has under his surveillance an enormous complexity of mechanically and electronically generated information points but his power of physical control is being taken over by automatic systems. At many critical states of his task his function is that of a monitor; he is a form of "stand-by" brain and decision taker, and this is far removed from the earlier but still conventional view of the pilot. Also, it is perhaps not so very different from the task of the astronaut whose task is likely to be primarily a monitoring one."

Cassie views the aptitude battery of the future as one which emphasizes the intellectual and the perceptual processes though he also notes that coordination will still be a requirement. He suggests that it may be necessary to rework the concept of pilot aptitude. Fitts (1962) in another paper in the same symposium commented similarly on the changing nature of the role which man must play. These are analyses of the armchair variety and the empirical data from which a test developer might gain useful information is not supplied.

The possibility of treating the individual aircrew members in terms of job specialties does not seem possible in light of the information available, except for the job of pilot, which seems to have been the prime interest of the majority of workers in the field. In view of these difficulties we have chosen to view the problem of the aircrew member as the human participant in a complex high-speed man-machine system and to draw upon the functions required of man in such a system as potential sources of critical behavioral functions. Although many workers have attempted to categorize the performance requirements of military man-machine systems, Alluisi's (1964, p. 216) statement appears to cover the ground rather well. He points up the following categories:

"(1) attentive functions, including the monitoring of both static (discrete) and dynamic processes (continuous), (2) sensory-perceptual functions, including discrimination and identification of signals, (3) memory functions both short- and long-term, (4) communication functions including the reception and transmission of information, (5) intellectual functions, including information processing and decision making, (6) perceptual motor functions . . . necessary to the operation of the system and, perhaps, (7) procedural functions that include such things as interpersonal coordination, cooperation, and organization."

This list of behavioral functions undoubtedly represents those required in the successful operation of many high-speed military systems. These classifications are valuable and comprehensive but are not of sufficient detail to allow specification of the critical behaviors required in aircrew performance.

In the work edited by Barbour and Whittingham (1962), the issue of human problems related to supersonic and hypersonic flight is treated. Majendie (1962) pointed out that men provided with too much information will be unable to perform adequately on their jobs in this new and demanding type of flight, and Smith (1962) indicated that the loose coupling of visual flight with manual control must be superseded by other modes of operation at these increased velocities. Brown (1963) has treated the issue of selection of aircrew personnel for the supersonic transport.

Bartlett (1962) has dealt in depth with the requirements to be imposed on man in complex man-machine systems. He held that the requirements in future systems will include rapid decisions and execution, endurance and alertness required over extended periods of operation, consistency in performance, and adaptation to unusual conditions. The most outstanding characteristic of endurance will be the ability to maintain a reliable level of performance with alertness for relevant but intermittent indicators of the state-of-the system. Reliability of human performance will be of more importance than extreme precision. The magnitude of translation characteristics and complexities of current and future weapons systems will in all probability bring about changed operational requirements. Decisions for specific courses of action will have to be made within the confines of the system. Therefore, it is necessary to direct more attention to high-level and more complex modes of behavior than has been required with current systems.

In summary, it appears that the behavioral characteristics central to the successful operation of high-speed airborne vehicles of the complex varieties likely to be encountered in a modern air force will probably be as follows:

Adaptability to changing situations - The requirement will provide for situations for which training has not been specifically given, in addition to those emergencies for which anticipatory training has been provided. These critical situations may occur only once in the experience of the operator, but they must be met adequately if the system is to survive. Adaptability also includes flexibility in the transfer of training involved in transition to new types of aircraft, displays and/or control mechanisms.

Capacity for integration and processing of information - Performance of several different types of tasks concurrently or in rapid succession will be involved. Attention must be shifted rapidly from one task to another or attention will need to be focused upon a single aspect of the overall situation. Separation of the relevant from the irrelevant inputs must be accomplished prior to the making of decisions which must be followed or accompanied by precise motor activation of the control systems in order to allow implementation of the decisions taken.

Storage, reorganization, comparison, and combination of data inputs - The operator must identify similar patterns of attitude, rate, velocity, and direction in apparently dissimilar situations and must be capable of modifying his behavior on the basis of these inputs within relatively short time spans. Filtering of input data will be an essential operation.

Endurance - The ability to maintain a high level of performance and alertness under relatively demanding environmental conditions will be required.

In the quest for behavioral functions involved in aircrew performance, we have discovered an abundance of generalities and a dearth of specifics. The task of carrying out detailed job analyses for the many aircrew positions is beyond the scope of the present effort. Until adequate job analyses for aircrew positions become available, the determination of critical behavioral functions involved in aircrew performance will have to be generated from rational analyses of the kind cited with augmentation through inputs from knowledgeable aircrew members.

Critical Behavioral Functions

In deriving the concepts which will serve as a point of departure in the further development of perceptual-psychomotor testing, an attempt has been made to select behavioral functions which are believed critical to success in performance of aircrew assignments. This procedure has necessitated some arbitrary decisions in definition of functional categories and, while it was the intent of the authors to use mutually exclusive categories, it has not always been possible to achieve this goal. For each of the areas which are suggested as concepts from which tests might be developed, the relevant literature in support of the concept is cited. While many sources, formal and informal, served as stimuli, only the principal written sources recognized as stimuli by the authors have been cited and should thus be regarded as representative and not exhaustive for any functional category.

Motor Skill Acquisition Rate -- The training cost of producing skilled aircrew members is considerable, and some emphasis should be given to the selection of personnel who can modify their behavior in the desired direction in a minimum of training time. Fleishman (1953b) has indicated that learning rate should be recognized as a potential predictor in the selection process. Individuals differ widely in their rate of progress in aircrew training and prediction of differences in rate is a desirable outcome of the use of perceptual-motor tests. Ericksen (1952a) found that in some cases the eliminated students did not have as many opportunities to be rated on some maneuvers as those who were graduated since, on the average, the unsuccessful student progressed less rapidly and was eliminated prior to being rated on the more advanced maneuvers. Adams (1964) pointed out that behavioral laws for a specific function may not hold across all species and that it is much more realistic to expect that the initial level of performance, the slope, and the asymptote for a function will differ from subject to subject. Seashore (1951) has indicated that the initial rate of progress in motor skills is significantly and positively correlated with the ultimate performance level. The justification for the assessment of skill acquisition rate is further substantiated by the change in factor structure of complex psychomotor tasks as function of practice (Fleishman & Hempel, 1953) and evidence that measures of the initial performance on complex psychomotor tasks are not valid predictors of final performance or performance on a criterion task (Adams, 1953; Smith & Gold, 1956; Parker & Fleishman, 1960). Fleishman and Rich (1963) stated that individuals who have superior sensitivity to kinesthetic cues should be superior to others at the advanced stages of learning of a complex motor task, but they may not excel during the initial stages.

Adams (1957) concluded that the change in rank order from initial to terminal trials on the discrimination reaction time test could be attributed to aptitude or capacity of the subjects. He believed that the initial level was a function of extra-experimental experience and that practice permitted initially poor performers to attain levels of performance equal or superior to those of the initially proficient.

Mukherjee (1959) in an investigation of two-hand tracking performance found that subjects with superior initial ability on the skills required by the test reached criterion sooner and retained their superiority throughout training. This finding is somewhat at variance with the inability to predict terminal performance from initial performance found in other studies; yet the finding that initially superior individuals learned more rapidly is of considerable interest. The acquisition of relatively gross motor skills, such as those involved in ballistic-type movements and tension-type movements, have shown wide individual differences in rate and level of acquisition (Hollingsworth, 1948).

A work sample method involving 12 hours of flying training with two, and later three, standard flying tests given during the twelve-hour period was used as a selection procedure in the Royal Air Force (Vernon & Parry, 1949). The student pilots were ranked in order of merit and the lower-ranking individuals were eliminated from further training. This system is based upon the assumption that there is a substantial correlation between speed of learning and subsequent performance.

<u>Automatization of Response</u> - The human operator has the capacity for integrating sense experiences and this integration may proceed on a somewhat involuntary basis. Slivinske (1953) found that increasing the amounts of practice on a patterned component of a complex task increased the efficiency with which the total task was performed. He postulated that there was a shift of response control from stimulus to verbal and,

later, from verbal to internal response control. He designated these control modes as environmental stimulus control, mediated stimulus control and response stimulus control, respectively. In effect, it was the utilization of proprioceptive stimuli from a preceding response as stimuli for a subsequent response which permitted the shift to response control.

Bahrick and Shelly (1958), using different levels of redundancy of the criterion task and a concurrent auditory task, found that performance interference under the dual task conditions was inversely related to the degree of redundancy of the criterion task. They suggested that redundancy in the criterion task permitted a shift from exteroceptive stimulus control to interoceptive stimulus control and that the ability to timeshare may serve as an index of automatization.

Gibbs (1954) indicated that skilled movements of short duration may be continuously regulated by proprioceptive feedback. In the early stages of skill acquisition, monitoring of this feedback is probably supplemented by visual or other sensory inputs. As the integration of sense data proceeds, less and less dependency is placed upon specific central monitoring of the response. According to Fitts (1954), the hypothetical fixed information capacity of the operator is no longer completely required for the monitoring of the behavior and a portion of the unused central capacity thus freed may be employed elsewhere.

In contact flying the pilot must divide his attention between internal and external references. In many instances manipulative responses must be made accurately in the absence of visual monitoring. The degree to which automated movement has been acquired and the degree of confidence in this capability may mean the difference between skilled, unhurried performance and an overload condition in which gross errors are more likely to occur. It is believed that,as in all skilled behaviors, individuals differ in degree with regard to this aptitude. The contribution of this capacity to sequential organization of behavior, motor skill acquisition and retention, and anticipatory behavior is well recognized. Because of the pervasiveness of this characteristic throughout skilled performance, it is important to consider the assessment of this function.

Paced and Unpaced Performance - It must be recognized that individuals differ widely in the quality and quantity of their past experiences. This variation in background has undoubtedly served to produce behavioral patterns and modes of responding in at least some individuals which may be antagonistic to those required in the paced performance encountered in some aptitude tests. In many investigations concerned with ascertaining the maximum operating capacity of an individual, the characteristic temporal organization of that individual has been neglected.

There may be no single best way to accomplish an assigned task despite care in arranging the configuration or requirements of the task. The paced task may contribute to a decrement in performance which is not indicative of the aptitude level. An unpaced task, sampling the same abilities, may permit individual organization of responses so that optimum performance can be demonstrated and may possibly allow for greater consistency in response.

Scheier and Ferguson (1952) in a discussion of the effects of previous experience on facilitation or inhibition in the learning of a new task indicated that differential performance of individuals may not result from differences in ability but from interference by mutually antagonistic motor skills.

Fleishman (1953b) suggested that it might be interesting to test the hypothesis that individuals have general methods of attacking problems and that the work habits utilized might be predictive of success in complex motor tasks. He also pointed out that efficient work methods may be identical with efficiency of learning and that speed of learning may be predictive of future complex motor learning. It is important to note that he holds that muscular coordination may best be considered as a training issue rather than a selection issue. Such a possibility is further supported by the work of Mowbray (1960) and Mowbray and Rhoades (1959), who showed a decrease in choice reaction time with practice, irrespective of the alternate choices provided. Leonard (1959) found no systematic differences between 2, 4, and 8 alternate choices in tactual reaction time following practice. While even a relatively simple motor response appears subject to change with practice, it is not known whether a decreased reaction time in a choice condition results from increased rapidity of the processing rate in the central translating mechanisms or from changes in the effector system.

Rimoldi and Cabanski (1961) state that the spontaneous speed of an individual may give important information as to the temporal limits within which the individual functions optimally. From the results of their investigation they concluded that the optimal rate of responding remains constant within individuals though it varies among individuals. Freschiesen-Kohler, as reported by Rimoldi and Cabanski, concluded that there was a general factor of "personal tempo", which she interpreted as general personality characteristic and which is relatively stable within individuals.

Beck (1963) found that shorter reaction times resulted when measured in an unpaced condition, and Conrad (1960) that self-paced letter sorting yielded higher outputs. Kalsbeek (1964) noted considerable individual variation in performance on an unpaced task relative to performance on paced tasks, and it seems that self-pacing may reveal individual differences not found with paced tasks.

It is not suggested that unpaced tasks should be employed to the exclusion of paced tasks, but that some representation of both in any testing situation would be desirable. In addition to organization of behavior and indications of the "personal tempo" of the individual in the unpaced situation, some indication of the degree of cautiousness may be gained which may have value in prediction of pilot training success (de Wet, 1960b). Inclusion of a task performed under both paced and unpaced conditions may be effective in indicating performance capacity, resistance to operational stress, and temporal organization of behavior.

Resistance to Prolonged Operation - There has been a continuing interest in the effects of prolonged operation of man-machine systems on aircrew performance, inasmuch as missions of long duration are no longer atypical. As noted previously, the ability to undergo prolonged missions while maintaining high alertness and reliable performance is of more importance than extreme precision (Bartlett, 1962).

The issue of prime importance is not the detection of the decremental effects by prolonged operation but determination of the individual's susceptibility to the decrement producing conditions. Bartlett (1951) in his discussion of the effects of flying pointed out that although the manifest load has been reduced through self-regulator instruments, the latent load has possibly been increased. This increase in latent load may lead to deterioration of performance at critical periods.

Individual differences in susceptibility to factors which affect endurance in the performance of psychomotor skills was demonstrated by Payne and Hauty (1955). They found significant individual differences in latency, rate, and extent of performance decrements. Siddall and Anderson (1955) found considerable individual variability in the number of errors and mean time per error in a compensatory tracking task over extended time intervals. However, those subjects who did best in the first half-hour maintained their superiority during the four half-hour test periods.

It is unnecessary to conduct tests of long duration in order to assess an individual's susceptibility to decrement under prolonged operation. A performance continued for a relatively short period under high load stress may give valid indications of the endurance factor. Kalsbeek (1964) described his subjects as exhausted and tense after only six minutes of dual task performance. It is generally believed that this factor is not a major function of physical fitness, since measurements of the energy expended in overt work-output are often of small magnitude.

Performance Consistency - Performance variability among individuals is as well established a phenomenon as is behavioral oscillation within an individual. Variability is characteristic of performance for most tasks of the aircrew variety. Performance may vary within a single trial, among trials, and among a series of trials. At the outset the individual may show variability about some ideal or some mean performance level with significant changes in variability over time without shifts in mean performance.

Little research has been conducted to explore the use of variability in performance as an index for prediction of success in aircrew operations. Simmonds (1963), in observing pilot skill in instrument flying on two separate occasions for the same pilots, found that the more experienced pilots showed less variability in performance from occasion to occasion than did the less experienced pilots. He concluded that consistency in flying performance shows some promise as a measure of flying proficiency. In a study (Reese, Volkman. Rogers, & Kaufman, 1948) of the estimation of angular orientation of a line on a circular display, wide individual differences were found in accuracy and variability and these differences were little affected by the length of the bearing indicator. The most accurate estimators tended to be the least variable.

Lewis (1956) found that consistency of performance in automobile driving over a standard course was a characteristic of skilled drivers but not of relatively unskilled drivers. The unskilled showed frequent reversals in their approach acceleration patterns. He attributed the possible cause of this behavior to improper anticipation or lack of anticipation. He suggested that use of consistency measurements in early stages of training might be useful in predicting eventual skill level. Fitts (1954) believed that the information capacity of the motor system could be inferred from the variability of successive responses.

This aspect of performance has possibly been neglected in the past because of the difficulty involved in data collection and processing. Instrumentation for automatic response recording and computer processing which are now available will permit collection of consistency indexes with little additional effort during the administration of perceptual-psychomotor tests. This promising aspect of performance evaluation should no longer be neglected.

Resistance to Distraction - The aircrew member functions in an environment which is characteristically rich with stimuli of infinite variety. If he is to satisfactorily perform his crew member duties, he must ignore the irrelevant stimuli and on many occasions must extract relevant stimuli from noisy surroundings. If the aircrew member is unable to exclude the irrelevant or extraneous stimuli, his performance will suffer in proportion to his inability or incapacity for rejection of these signals. Some tasks assigned the aircrew member may be relatively insensitive to perturbation while others are extremely sensitive to almost any extraneous stimulation.

Hack, Robinson, and Lathrop (1965) exposed twenty subjects to 60 db. of thermionically produced noise which was interrupted for 1/3 of each second and simultaneously required them to perform on a two-axis compensatory tracking task. There was an initial decrement in performance on the tracking task, but adaptation was evidenced after five one-minute trials. Jerison (1959) found changes in alertness, time judgments, and complex effects on a mental counting task in subjects exposed to 110db. of noise. In a task in which a stylus must be made to follow an irregular path through manipulation of two-hand wheels, decrements in performance for response time and the number of patterns completed within a specified time were found under conditions of exposure to narrow band noise (Grimaldi, 1958). Crawford (1962) concluded that the presence of irrelevant lights in the proximity of warning signals could be detrimental to an operator's efficiency. The aircrew member who is able to reject irrelevant or extraneous stimuli and readily adapt to the distracting conditions should be more proficient, other things being equal, than the member lacking the necessary facility.

Adaptive Capacity - The stressfulness of the environments encountered by aircrew members is generally recognized. Fear, anxiety, and load and speed pressures are frequently reported by those engaged in both operational and training missions. Melton (1947) reported little increased validity in attempts to utilize performance in the presence of synthetic stresses as predictive measures in aircrew selection. More recently, however, de Wet (1960b; 1961) has noted that threats of electric shock or actual application of electric shock during selection testing on perceptual-psychomotor tasks altered the predictive efficiency of his indexes in a positive fashion. Particularly when he considered performance under stress versus performance without stress on the same task, he found that individuals showing the smallest stress-induced decrement were most successful in pilot training. A wide variety of conditions may be used to induce stress and individual reaction to the particular condition used is varied. In aircrew function one of the more commonly encountered stress conditions involves high load or high rate of incoming signals. When signals occur at a rate or load under which the crew member is unable to carry out adequate processing, undesirable changes in behavior may occur and the duration of these effects often extends in time beyond the termination of the stressful condition.

In addition to the sort of adaptation required in response to a stressful condition such as that elaborated above, one may also use the term to describe the ability to modify or change behavior which is no longer appropriate to the stimulus situation. The converse may involve regression to a previously adequate response. Mental inertia in switching from one kind of activity to another, continuation of inappropriate motor behavior, and failure to apply previously learned behaviors to unfamiliar but related conditions are other manifestations of nonadaptive capacity. This interpretation is closely related to the definition stated by Honkavaara (1958) for the term "perseveration."

Kleemeier and Dudek (1950) prefer the term flexibility which they define as the ability (a) to shift from one task to another or (b) to break through an established set in order to perform a task. Ritter (1958) uses the term "adaptability", in which perseveration comprises habit interference, proactive inhibition, negative transfer, and psychological rigidity. He hypothesized that this form of behavior was inconsistent with the ability to adapt to the demands of military aviation and held that the Controls Orientation Test (CP638A) warranted further investigation as a potentially useful device for adaptability screening. The degree of susceptibility to perseverative or regressive behavior under frustration, interference, or high demand situations would be central to transition from one system to another and, more specifically, in emergency or operational situations of high load demand.

Smode, Beam, and Dunlap (1959) listed four types of behavior in which nonadaptability is manifested: (1) difficulty in learning new responses to stimuli previously connected with other habitual responses, (2) difficulty in the ability to perform previously learned responses due to the interpositioning of newer and somewhat related responses, (3) regression to older modes of behavior, especially under emergency situations, and (4) persistence in non-adaptive responses. Beier (1951) points out that, although the term "stress" is a collective name for many factors such as anxiety, fear, and frustration, individuals behave in a non-normal fashion when exposed to stressful conditions. The resulting disorganization of behavior may be revealed in losses of abstract ability, ability to generalize, ability to perceive the essence of a situation, or ability to shift from one activity to another. Jones (1954) used an insoluble maze problem as a frustrating condition in an investigation of the effects of frustration on behavior and found that there was a subsequent increase in time required to learn a soluble task and increase in stereotypy of behavior. Cowen (1952) found that psychological stress produced a greater tendency to problem-solving rigidity.

Loveless (1962) stated that even if an established habit can be completely reversed under normal conditions through training, it can be predicted on theoretical grounds that habit regression will occur when the operator's motivation is decreased, when he is fatigued, and when he is subjected to any novel change in the working situation.

Deese & Lazarus (1952) stated that signs of emotional disruption and anxiety may not have much predictive value in terms of an individual's ability to hold up under stress; yet Voas, Bair, and Ambler (1955) found that cadets who had displayed anxiety reactions under exposure to a simulated altitude of 20,000 feet in a decompression chamber were more often eliminated during basic flight training than those not displaying such reactions. Individuals who demonstrate fear in one threatening situation appear more likely to develop incapacitating anxiety when exposed to danger stress in other situations. The realism and appropriateness of the pressure chamber exposure may have accounted for the findings in this study.

The emergence of nonadaptive behavior may result from internal or external factors and persist for varying periods of time from individual to individual. The persistence of the decremental reaction to a frustrating work situation or the rate of individual recovery would seem to be an important characteristic which can be assessed under high work load conditions.

Although no general adaptive capacity has been isolated, tests of flexibility, interference, transfer of skills, and effects of frustration should be given serious consideration for inclusion in further developments in perceptual-psychomotor testing.

Kinesthetic Discrimination - The role of kinesthetic sensitivity in acquisition and retention of perceptual-psychomotor skills has recently received attention and appears to possess implications for the aircrew selection procedure. The degree to which individuals differ in kinesthetic sensitivities and ability to utilize kinesthetic cues has not been fully explored nor has the importance of this factor to complex motor task performance been assessed. The awareness of and utilization of kinesthetic cues in aircrew operation has become increasingly important, not so much from the standpoint of "seat-of-the-pants" flying but from the needed precision and accuracy of control manipulation under conditions in which constant attention is required elsewhere.

Hellebrandt (1953) held that the key to the mastery of a motor skill resides within the act of moving. The individual acquires manipulative skills without being aware of the full complexity of the patterning of afferent sensory impulses.

Fleishman and Rich (1963) stressed the contribution of kinesthetic factors to the learning of a complex motor skill. They found that as practice continued on a two-hand coordination task, correlation of the performance measure decreased with a spatial ability criterion and increased with an index of kinesthetic sensitivity. Kinesthetic sensitivity was identified as an important ability variable which was effective in predicting proficiency levels in psychomotor performance for late states in training. Espenschade (1958) concluded from her experiment on the motor performance of blindfolded subjects that the improvement in performance resulted from a clean concept of the task rather than an awareness of movement. No designation of specific kinesthetic cues differentiating good or bad tosses were made by her subjects. It would seem that there may be an ability to profit by kinesthetic cues though they produce no awareness in the central nervous system.

Proprioception, according to Adams and Creamer (1962b), serves as a motor regulatory function and also as a mechanism for time perception. Proprioception apparently assists in the anticipation of temporal regularities in stimulus events. The results of an investigation on the transfer of anticipatory training encouraged the interpretation of the loci of temporal anticipation in terms of a mediated response rather than peripheral-motor (Adams and Creamer, 1962a).

Briggs, Bahrick, and Fitts (1957) found that force and amplitude cues improved performance on a tracking task but had little or no effect on rate of improvement. Fleishman and Ornstein (1960) found kinesthetic discrimination of the feedback from control manipulation to be important in a number of aircraft maneuvers.

The apparent importance of kinesthetic discrimination as a component of complex motor skills warrants consideration of the inclusion of a means of assessing this function.

Psychomotor Ability - There are specific aspects of psychomotor performance which tend to be important in the task accomplishment of aircrew members. The literature reviewed in this effort has tended to confirm the hypothesis that pure psychomotor tests are not the most valid predictors of aircrew success. Craik (1948) in the presentation of the theory of the human operator in a complex control system stated that the problem is to discover in detail the characteristics of the human link, its time-lag, distortions, flexibilities, and self-modifying properties. For Craik, the most important points at issue are (a) natural responses, (b) time required to reach a behavioral steady state, and (c) the limits and defects of performance when the steady state has been attained. These aspects are interpreted by the authors as the organization of behavior, the rate of acquisition, and the limits of capacity under various environmental conditions, respectively. In addition, Craik emphasized that the human response frequency was not limited by sensory organs or muscles and limbs but by central processing mechanisms where the control and activation processes are presumably integrated.

It has been apparent in many complex man-machine systems that the occasions on which split second reaction or extreme precision in control manipulations will result in success or failure of the mission are usually infrequent. The skilled operator must be able to foresee the development of a change in condition, prepare for, and take the corrective steps long before action seems mandatory. At a later point in time many actions which would previously have been effective are in fact ineffective.

Skilled performance arises from the adequate interpretation and anticipation of the state-of-the-system displays relative to the objectives of the man-machine system. The aircrew member is presented with continuously changing information relevant to the system which must be perceived, interpreted, filtered, stored, organized, and responded to with varying degrees of speed and precision. Conrad (1951b) noted that the skill of weavers did not rest on their ability to tie broken threads or to re-shuttle quickly but upon the ability to determine from the available cues when these operations needed to be carried out. Effector organs are activated by impulses from a central mechanism which determines the coordination and phasing of muscular action, according to Welford (1960). The times consumed by the several central processes are the important issues. Specific types of motor movements may have to be observed in order to assess the motor integration capacity of central processing, and this capacity may be difficult to observe by other methods.

Fleishman and Hempel (1956) carried out a factor analysis of 16 apparatus tests, which had previously been shown to possess validity for aircrew selection. Among the factors isolated were two psychomotor coordination factors which they designated as Psychomotor Coordination I, described as representing coordination of fine highly-controlled adjustments and Psychomotor Coordination II, which they identified as representing the coordination between muscles in more gross adjustments where the concurrent use of more than one member of the body is required.

Speed of movement required in aircraft operation would be generally confined to hand-positional movements in various planes. It is doubtful that assessment of pure speed of limb movement without consideration of acceleration, deceleration, perception, and other control factors would allow for an increase in selective efficiency. Limb speed assessment is further complicated by the differences in speed from limb to limb, direction of movement, and duration of movement. Lotter (1960) indicated that 15 percent of the common variance in movement could be ascribed to a speed of limb factor. He further held that individual differences in making fast movements are quite specific to the particular task. Henry, Lotter, and Smith (1961), in their factor analysis of individual differences in limb speed, reaction, and strength, concluded that the factor of limb speed is unrelated to the reaction factor; is characterized by relatively low saturation; and is related to the particular limb and/or limb action that is measured. Fleishman (1954a) isolated limb speed factors associated with wrist-finger and rate of arm movement. A third speed factor, psychomotor speed, was deemed too broad and thus of limited usefulness.

In a factor analysis of dexterity tests, Fleishman and Hempel (1954) isolated a positioning factor which seemed to be involved in precise localized responses. This factor appears to be similar to that defined by Brown, Knauft, and Rosenbaum (1948) as a "positioning reaction," which they described as involving the movement of an articular member from a position of rest to terminal position in space. A somewhat comparable factor was isolated by Fleishman (1953c) and characterized as "Precision Movement Under Speed Conditions." The ability to perform positioning reactions without the aid of visual or auditory cues would seem to be of importance in the absence of illumination or under conditions in which attention must be directed away from the positioning reaction. Positioning reactions are not normally performed in isolation, and the assessment of the discrimination of direction and extent of movement under conditions of variable task loading would be desirable.

In summary it is suggested that consideration be given to the use of an apparatus test or tests involving fine highly-controlled adjustments, multilimb coordinations, and positional movements.

<u>Concurrent Information Processing</u> - The emphasis in dealing with this concept in the context of present interest is essentially one of the measurement of reserve capacity, the ability to organize and adequately carry out multiple tasks, and the interference effects of work load on performance. It is believed that the complexity of airborne system operation involves capacity for the performance of a number of tasks more or less concurrently and in the maintenance of a reserve capacity

for higher-than-normal-work loads or for emergency conditions which may arise. Individuals differ in ability to perform adequately under high load conditions without consequent behavioral disorganization or failure in task performance. Assessment of differences in this ability should be of value in the elimination of potentially marginal aircrew men. Concurrent multiple test administration may also be valuable as a means of assessing an individual's ability to perform operational functions for extended periods.

Brown (1964) has proposed a method involving performance on two or more tasks concurrently as a means of assessing the perceptual load and/or reserve capacity of individuals. Although the major emphasis of his work was directed to the assessment of interaction of man-machine systems, certain points are important to the present objectives. He suggested that in the measurement of reserve capacity, the difference between capacity and the perceptual load imposed can be appraised by arranging to have the combined load in dual tasks exceed the capacity of the performer so that deficiencies in performance will occur. There are several ways in which the additional tasks may be used: (a) as loading tasks for the purpose of assessing individual differences in resistance to distraction; (b) as subsidiary measuring tasks; (c) as dual purpose secondary tasks; and (d) as stressing tasks. Pure stressing tasks, however, have limited usefulness, inasmuch as full utilization of a sensory or motor channel will give no indication of reserve capacity. Dual tasks on which no instructions are issued concerning the primacy of each task are also of dubious value as different individuals may bias their response in different directions. Loading tasks may, however, enable the determination of work stress on specific systems and permit some observation of the effectiveness of information transmission.

A number of investigators have successfully used the concurrent task method in analysis of performance. Conrad (1951a) investigated the breakdown in skilled performance under the environmental effects of speed and load. The results of this study indicated that performance was affected by speed and load but neither of the effects were proportional to the increases in either speed or load. Timing of response was influenced by load but speed was not affected.

Griew (1959) required subjects to perform on a continuous pursuit tracking task and to respond concurrently to auditory signals. The performance on the dual task as compared with performance on single tasks showed a rise in errors on the auditory task, an increase in amplitude of tracking error, but no increases in timing errors for the tracking task. In instances where the individual was given directions to respond to auditory signals, there was an increase in the amplitude of tracking error, though no auditory signals were actually delivered.

Disintegration of behavior under dual task conditions in terms of a shift to lower levels of organized behavior has been described by Kalsbeek (1964). Errors which occurred on both tasks when choice of response had to be made were thought to represent attempts to make two simultaneous decisions, resulting in failure to achieve a stable, temporal patterning of behavior. Considerable individual variation was noted in the unpaced-choice condition. However, some of the subjects were unaffected as evidenced by the adequate maintenance of performance.

Schouten, Kalsbeek, and Leopold (1962) concluded that individual perceptual capacity is limited and that two different tasks, each requiring full capacity, could not be performed simultaneously in an optimal fashion even though the sense organs and motor organs involved were different. In some instances the two tasks were not performed simultaneously but rather in an integrated pattern of alternating behavior. Many everyday skills depend upon facility of adequately timing a number of actions in response to almost simultaneous stimuli, and stress may result when the individual attempts to achieve simultaneous processing and responding.

Trankell (1959) reports on pilot selection for the Scandinavian Airlines System, where emphasis has been placed upon a synthesis of statistical and clinical methods. Tests are used but their interpretation by a dynamic process is stressed. Motor skill is assessed by means of a tapping test with the level of difficulty manipulated through speed load. Simultaneous performance capacity is assessed by means of an intellectual problem administered concurrently with the motor test. The results of the Simultaneous Capacity Test yielded a biserial $\underline{r}$ of .42 with success in training.

In an analysis of decision taking among student pilots, flight instructors, and jet pilots, Adiseshiah (1957) found that when more than six decisions per minute were required, performance broke down sharply for the student pilots and somewhat less abruptly for the jet pilots until the requirement reached ten per minute. The performance of flight instructors was midway between student pilots and jet pilots. In addition to the relation of his findings to the effects of load on performance, he stated that more instances of exaggeration were observed in the student pilots. This exaggeration may be indicative of the potential value of a measure of "carefulness" in aircrew selection procedures.

However, adaptability to work load in monitoring tasks was evident in the results obtained by Wiener (1964). He found that practice on either 1, 2, or 3 stimulus channel load showed no difference among groups when they were subsequently required to monitor a two-channel stimulus system. There were, in the initial sessions, decrements in performance over time (64 minutes), irrespective of the number of channels being monitored.

Anticipatory Behavior - The term "anticipation" may be indicative of a very complex cognitive response behavior or a somewhat less complex anticipation of the next stimulus in a non-random time sequence. There appears to be a high premium on anticipatory behavior in optimum aircraft operation. The pilot must anticipate the response of the aircraft to specific manipulations of controls in order to perform precisely. More importantly, he must predict the outcome of an action if permitted to continue in the same pattern. As previously stated, speed of movement and reaction is not sufficient to alleviate an emergency condition when it is occurring; it is mandatory that the operator anticipate the condition prior to its development and prepare to correct it.

In respect to less complex anticipatory behavior Poulton (1957) lists effector, receptor, and perceptual anticipations as three varieties involved in skilled movements. Effector anticipation is required in predicting the nature and size of muscular contractions, receptor anticipation in prediction of the duration of the response, and perceptual anticipation in prediction of the outcome upon completion of the response movements.

Temporal expectancy, or the learning of when stimuli will occur, is one of the most striking and least studied aspects of skilled performance, according to Adams (1964). Through anticipatory timing an individual can get his response under way before the actual occurrence of the stimulus. The importance of anticipatory behavior was further emphasized by Adams and Chambers (1962), who found that temporal anticipation is a key factor in the individual's capability for processing dual stimulus sequences in a complex task.

The relationship of anticipatory behavior to other functions of the human operator is readily apparent. If the stimuli are delivered in completely random sequence, systematic effective anticipation is not possible. If successful anticipatory behavior is to occur, there must be a degree of redundancy in the stimulus presentation and the operator must perceive and retain the patterning or temporal relationship. Thus learning, retention, and temporal estimation are fundamental to successful anticipatory behavior. Inasmuch as this aspect of behavior is central to efficient and safe aircraft operation, assessment of the function for selection purposes should be considered.

Rigidity - Our choice of the term "rigidity" may be an unfortunate one, since many definitions have been offered for the term and its employment leads to much controversy. It is entirely possible that the confusion has arisen from attempts to treat rigidity as a general factor. Scheier (1954, p. 157) defined a "rigid" person as "one who lacks the ability to perform overlearned operations in an unusual or unaccustomed manner, e.g., he might be expected to have difficulty in writing backwards or doing arithmetic backwards." Cattell and Tiner (1949) emphasize two types of rigid behavior. The first they liken to perseveration in stressing the aspects of inertia or momentum which resist change, and the second is characterized by a resistance to forces which might normally be expected to produce learning.

For our purposes behavioral rigidity is evidenced when an individual does not perceive changes in the stimulus environment, such as stimulus intensity or patterning, which require, under normal circumstances, a change in the response behavior. The inability to perceive changes in the environment is related to the individual's fixation of attention on characteristics of the stimulus situation which have not been altered although these characteristics of the stimulus may have become irrelevant.

Vaandrager and Ide (1962) have held that the rigid individual has no place in the flight station of an aircraft, particularly a supersonic or hypersonic aircraft. Proficiency of the aircrew involves the ability to improvise, utilizing previously acquired skills in new ways, when required by the changing conditions and in emergencies. Often many aspects of the environment may remain unaltered and the cues signalling the need for unusual response may be minimal.

In a factorial study of rigidity, Scheier (1954) was not able to isolate a cognitive or a motor rigidity factor. He found that so-called cognitive rigidity tests were largely measures of other mental abilities and motor rigidity tests were largely measures of motor speed. Where overlearned motor or cognitive factors were concerned, the ability to perform backward was closely related to ability to perform in the normal manner.

Scheier and Ferguson (1952) had, in a previous study, isolated a reasoning factor, a motor speed factor, and non-motor rigidity factor. They did not find a positive rigidity factor common to the cognitive and motor abilities in the tests which they employed.

The isolation of a "rigidity" factor has presented great difficulty, yet in view of the comments encountered in many sources as to its pertinence we are reluctant to discard it. It may well be that some measures of ability to adapt by learning new procedural applications, such as in transfer of skills from one test condition to another, will reflect this factor adequately for purposes of aircrew selection.

Short-Term Memory - The role of short-term memory in the acquisition and retention of perceptual-motor skills has not been accorded the attention it deserves. The effectiveness of kinesthetic feedback and the retention of the results of specific movements are largely dependent on short-term storage. If learning is to occur, effective movement in terms of duration, direction, and temporal organization must be stored for subsequent recall or for comparison of the current movement characteristics with the stored characteristics which have been perceived as effective.

The role of short-term memory in perceptual motor skill is reflected in the work of numerous investigators. Crossman (1964) pointed out that the functions of perception or programming of motor activity are concerned with the storing and processing of information. Fitts (1954) felt that the fixed informational handling capacity of the motor system was probably a reflection of the fixed capacity of the central mechanisms for monitoring and organizing the ongoing motor behavior. Short-term memory involvement in motor skills was demonstrated by Poulton (1963), who found that accuracy over the receptor-effector span was a function of time. This finding agrees with predictions based on a decay theory of immediate memory.

Fitts (1964) noted that continuous and serial tasks often provide an opportunity for measuring the lag, and hence the memory load, between sensing and output responses. Crossman (1959) suggested that the demonstrated proficiency of experts seems to stem from their knowing exactly which method to employ in a given situation rather than in their having superior coordination, acuity, or timing. Individuals adopt procedural combinations from choice or habit and, apparently on some occasions, by chance. In successive cycles there are modifications of the behavior through alterations in the patterning and direction of movements with the addition and deletion of functions. Loss of functions is probably a result of forgetting in at least some instances.

The relationship of motor memory to verbal short-term memory has not been, to the authors' knowledge, fully explored. Fitts (1964) expresses the belief, however, that the processes which underlie skilled perceptual-motor performance are very similar to those which underlie language behavior, problem solving, and concept formation.

Perceptual Speed - Perceptual speed is usually defined as the ability to recognize or compare rapidly. Daniel, Eason, and Dick (1957) in the investigation of navigator performance found that human perceptual factors are the most important sources of error. After learning what to look for, targets must be recognized and identified and the information utilized. It is difficult to conceive of an operational or training situation in which speed of perception is not a major factor in behavior.

The perceptual speed factor has been elusive in previous analyses of the apparatus tests used by the U. S. Air Force. Fleishman (1953b) indicated that a perceptual speed factor was found in some test analyses conducted by the Air Force but did not appear in others. In the Fleishman and Hempel study (1953) a significant perceptual speed factor was found only in early stages of practice. Roff's (1953a) factor analysis of a battery of 70 Air Force printed and apparatus tests indicated 17 tests which had loadings above 0.30 on the perceptual speed factor; this factor occupied a central position in a group of eight perceptual factors. The relationship of perceptual speed to motor speed was investigated by Wierman (1951) in an attempt to verify the hypothesis that individuals whose perceptual speed is equal to or faster than their motor reactions are less prone to accidents and that those with motor reactions more rapid than their perceptual speed are more likely to be "accident prone." He concluded that his results tended to confirm the hypothesis that those individuals who reacted more quickly than they perceived had a greater incidence of accidents in their histories.

Evidence that an individual's perceptual speed is directly related to behavioral efficiency when a specific sense modality is utilized was presented by Dinnerstein, Blitz, and Lowenthal (1964). Speed of vision was significantly correlated with a visual naming task. Speed in vision was also correlated significantly with measures of resistance to visual distraction, and auditory perceptual speed was correlated with resistance to auditory distraction.

While the perceptual speed factor has not uniformly appeared in analyses of apparatus tests, we have no explanation for this omission. We are convinced, as are others, that it is an extremely crucial function and that with perseverance on the part of test developers it can and should be measured.

Attention - There are a number of areas and conditions in the operation of aerospace systems in which attention plays an immediate role in the level of performance, including all varieties of estimation, search, monitoring, and other observing behaviors. Attentional behavior is not considered as a unitary function, for it is fundamental to perception, scanning, monitoring, memory, time-sharing, and other behaviors. There are, however, four specific aspects of attention which need to be recognized in test development. They are (a) attention span, which is defined as the number of discriminations which can be made in short perceptual exposures; (b) duration of attention, which is important in situations in which the critical signal is short and any fluctuation in attention may result in omission of signal reception; (c) fixation of attention, in which attention is focused on a specific stimulus source to the exclusion of other relevant or irrelevant stimuli; and (d) the shifting of attention from display to display or from channel to channel as required.

The relative importance of attentional behavior in aircrew operation was noted by Ericksen (1952a), who found that a critical comment directed toward student pilots concerned their inability to divide and distribute attention, and by Gordon (1947), who found inability to attend or remain alert and inability to divide attention as frequent critical comments directed toward ineffective airline pilots. Fixation of attention may be manifested to a greater degree in anxiety or under conditions of fear or overload.

Gibson (1947) presents data on two tests of attentional behavior which were administered to aircrew candidates during World War II. These tests were the Flexibility of Attention Test (CP411E) and Integration of Attention Test (CP415A) and were found to have validity coefficients of .15 and .13, respectively, in predicting elimination from elementary pilot training. Both tests were administered by means of motion picture techniques.

Estimation - Precise estimation of time, velocity, extent, and direction is important to aircrew members in many judgments of the state-of-the-system with respect to system objectives. This is particularly true of the pilot in contact flight in takeoff, landing, and terrain-following operations.

Time judgments play an integral part in practically all skilled behavior. In the temporal organization of complex motor skills, anticipatory behavior, time-sharing, and in estimation of duration and the temporal point of initiation of system control movements, precise discrimination of time is required. Previous research has shown that the reliability of time estimates is fairly low (Bakan & Kleba, 1957; Strunk, 1960) and that the reliability decreases with increasing temporal extents (Doehring, 1961). Separate observation of time estimation need not be made, since temporal estimation is an integral factor in the performance of complex motor skills; however, should it appear worthwhile to obtain such information, it can be easily observed.

Angular estimations are often required of aircrew members in pursuit of their assigned duties. Judgments with regard to interception and glide and climb angles are typical examples. Garvin (1964) in an investigation concerned with individual differences in the ability to estimate angular extents found that he could dichotomize his sample by using indexes of accuracy and bias. The low-accuracy group performed better in the 45° quadrants from the 12 o'clock position and the error size and variability increased as the angular separation from the 12 o'clock position increased. This difference in accuracy was characteristic only of the low-accuracy group. Four methods of presentation of the task indicated that the high-accuracy group performed well throughout regardless of the conditions of presentation.

Brown (1961), from the results of observer estimates of airplane speeds and laboratory investigations, suggested that methods developed in the laboratory for estimating angular speed may be adapted for field use. It was found that an observer discriminated a constant percentage difference throughout the range of speeds studied. The results were compared favorably with the Weber fraction. Angular estimation is apparently affected by training, as highly trained observers can detect a smaller percentage difference in speed when two moving objects are viewed alternately.

Kolesnik (1958) in an investigation of training on linear interpolation found that training produced an immediate reduction in linear estimation error but it was temporary in nature, as evidenced by the posttest result. Variability was only slightly affected by training and individual differences in overall deviations and variability were apparent.

Fleishman and Hempel (1956) extracted a factor which they named Rate Control and which was common to their apparatus tests only. It was defined as the ability to make adjustments relative to changes in speed or velocity of an object. Fleishman and Ornstein (1960) isolated a similar factor in the analysis of pilot flying performance.

Interference - Interference may be of two major types. External - which would be related to environmental conditions producing distraction, discomfort, or physiological and psychological stress. Internal - which is related to habit interference, or inability to differentiate and effect appropriate action sequences. The present area of interest is in the individual's susceptibility to motor habit interference in the acquisition of new motor skills. Smode, Beam, and Dunlap (1959) state that interference may be of considerable significance in the learning and retention of motor skills requisite to human performance in military systems.

Speith and Lewis (1950) employed a two-hand turret pursuit apparatus and required their subjects to follow a schedule in which one trial on the standard task and three trials on the reversed task formed what they termed a three-one schedule. This combination of standard and reversed task performance retarded learning on the standard task but did not result in the absence of learning. They noted that the subjects demonstrated differences in susceptibility to interference in these mutually antagonistic motor tasks. Two-axis tracking involving reversal of the control function was found by Abbey (1962) to produce significant performance decrements. Shephard (1950) found significant effects of length of practice on interpolated learning (reverse) on the following relearning trials in the original or standard mode on the Mashburn Apparatus.

In the initial stages short-term memory storage is called upon to provide awareness of the altered procedure required for satisfactory performance. Interference with short-term storage presumably results in some capacity limitations. Any overload brought about by an increase in the amount of incoming information may interfere with short-term retention of the immediate requirement of an unusual mode of operation and indicate the degree of susceptibility to interference. However, the difficulties involved in the control of learning in studies designed to investigate individual susceptibility to associative motor interference have been emphasized by Adams (1949). The authors are confident, nevertheless, that a means for assessing susceptibility to interference, not dependent upon reversal of learning, can be devised.

Discrimination Reaction Time - The SAM Discrimination Reaction Time Test (CP611D) was used continuously from 1942 throughout the war in the selection and classification of aircrew candidates. The test was not heavily weighted for pilot selection because of the relatively high correlation with printed tests. In 1944 and 1945 it carried weight in the selection of fighter pilots and bombardiers but not for bomber pilots or navigators. The Discrimination Reaction Time Test measured the speed of differential response to visual stimulus patterns. The reliability was considered adequate and the test showed high validity for prediction of elimination from flight training (Melton, 1947).

Adams (1957) stated that the total response on the Discrimination Reaction Time Test (CP611D2) could be reduced to three principal components: (a) perceptual response, which entails speed of pattern recognition; (b) visualization response, which entails learning the relevance of stimulus and response pairs; and (c) reaction time.

Simple reaction time has not proved to be of value in any aircrew selection procedures found in the literature. Mowbray and Rhoade (1959) found that differences between two-and-four choice reaction time disappeared with extended practice. This finding tends to support the view that this aspect of the discrimination reaction time test is probably a training issue.

Fleishman and Hempel (1956) demonstrated that the Discrimination Reaction Time Test had factor loadings in Spatial Relations I (stimulus interpretation), Spatial Relations II (response orientation or choice), and Factor VIII, Manual Dexterity. A relatively high degree of correlation of test scores on the Discrimination Reaction Time Test with scores on the printed tests of Dial and Table Reading and Instrument Comprehension was noted by Melton (1947). Additionally, Michael (1949) has shown that the spatial relations factor can be represented adequately in paper and pencil tests. In light of these findings it would seem that justification for considering discrimination reaction time as a function to be tested by use of apparatus tests must be found elsewhere. This function should, in our opinion, be included within the context of other test procedures rather than be employed as a separate test. However, there may be justification for its incorporation in order to provide an additional index of the spatial function and, perhaps, be particularly useful where paper and pencil tests cannot be readily employed.

Visualization - The ability to mentally manipulate objects in space in the process of recognition, comparison, and spatial prediction seems to be particularly relevant to man-machine systems which present the operator with a continuously changing perceptual field for interpretation. In factor analytic studies of the apparatus and printed tests employed by the Air Force, a visualization factor has been extracted. Hempel and Fleishman (1956) noted that this factor was distinguishable from spatial relations. Also, they found that the two apparatus tests, Direction Control Test (CP650A) and the Controls Orientation Test (CP638A), had heavy loadings on this factor.

Fleishman (1957) isolated a visualization factor which indicated high loadings on printed tests of Spatial Visualization (configuration of unfolded sheets of paper), Formation Visualization (airplane view manipulation), Pattern Comprehension (visualization of relationships between components of solids and their flat projections), and a Mechanical Principles Test (comprehension of leverage and rotation principles). The relative ease with which this function could be precisely and reliably assessed in an apparatus test makes it an attractive candidate for test development.

In summary, it is recommended that consideration be given to the design of assessment methods for the preceding list of behavioral functions which are believed to be critical for optimum aircrew performance. It is believed that aptitudes relating specifically to the recommended behaviors can be adequately assessed for the selection of potentially successful candidates.

In some cases the recommendations refer more specifically to methods of assessment rather than specific behaviors (Paced-Unpaced, Concurrent Information Processing); however, since the method of assessment plays a vital role in maximizing the return from behavioral observations, some consideration need be given to assessment methods. The major implication, however, is on the assessment of differential innate capacities, skill acquisition rates, and differential limits of ability under various environmental conditions.

For convenience of the reader the recommended functions are listed below in the order they appeared in the text:

- Motor Skill Acquisition Rate
- Automatization of Response
- Paced and Unpaced Performance
- Resistance to Prolonged Operation
- Performance Consistency
- Resistance to Distraction
- Adaptive Capacity
- Kinesthetic Discrimination
- Psychomotor Ability
- Concurrent Information Processing
- Anticipatory Behavior
- Rigidity
- Short-Term Memory
- Perceptual Speed
- Attention
- Estimation
- Interference
- Discrimination Reaction Time
- Visualization

VI. DEVELOPMENTAL PRINCIPLES

It is the purpose in this section of the review to set forth recommendations concerning employment of those concepts which represent behavioral functions believed to be crucial to success in aircrew performance and which may be selected for inclusion in perceptual-psychomotor tests to be designed. At the outset it appears reasonable, in light of the consensus in the literature and in our conversations with those charged with aircrew selection, to adopt a number of assumptions on which the exposition will be based. These assumptions are as follows:

> There is communality or overlapping of behavioral requirements for successful performance of all aircrew members, irrespective of the specific operating station or functions. The specific levels of functioning required are the distinguishing characteristics between jobs.

> Individuals differ from one another in terms of aptitude for specific behavioral functions, skill acquisition rates, and patterns or combinations of behaviors.

> There is a limited supply of potentially qualified people and it is essential that the selection process accurately distinguish between potential successes and potential failures.

Effective perceptual-psychomotor testing procedures can be devised which will provide valid and reliable indexes within relatively short behavioral samples.

An important characteristic of human behavior that has directed the present thinking is that human behavior is integrative and that man's capabilities are not utilized in isolation but that they operate in combination and concurrently. The conclusion that it is not advisable, or even possible, to limit those functions to be considered within the restricted context of the category "perceptual-psychomotor" seems inescapable. The importance of assessing the interaction effects of complex intellectual, sensory, motor, and perceptual functioning in concert dictates that measurement of central and peripheral system integration must be achieved if one would predict performance in a task which involves such interaction as does that of the aircrew member. Hence, it is not proposed that specific functions be isolated and assessed out of context but that tests be devised which allow component measurement within complex behavioral tasks.

The integrative behavior required of and displayed by the operator in a complex man-machine system makes it doubtful that performance on isolated pencil and paper tests can alone provide the predictive efficiency required in the selection of aircrew members. There is an integration of intellectual, sensory, and motor behaviors which is necessary for effective performance and which cannot be assessed adequately by the available pencil and paper tests. The combination of discrete performance measures may indicate a potential level of operation that is greater or less than the actual integrative requirement in an operational situation. In a complex man-machine system the operator is subjected to multiple stimuli of varying intensities and varying rates which require filtering, queuing, interpretation, and response in a sequential or concurrent series of functions. It is assessment under similar conditions which will eventually produce the indexes that will enable a high degree of efficiency in predicting aircrew success.

In the assessment of the individual's potential for participation in the successful operation of a complex man-machine system, the operator should be observed as an entity. The human operator as a part of the system receives, processes, and transmits information at the same time that he is performing motor functions. The motor skills cannot be divorced from reception and the central translation mechanisms. In the final analysis, the performance required is selected and directed from a central source. Vince (1953) argues convincingly that the complex relationship between motor and intellectual activity cannot be adequately observed in isolated assessment of either activity.

A number of investigators have indicated the importance of an integrative approach to assessment procedures. Brown (1964) has pointed out that much of the research data on skills has been obtained from experiments using only one or, at most, a limited number of variables. He observed, with regard to man-machine integration, that components of a man-machine system may permit optimal performance when operated in isolation but may interact unfavorably when brought together in the complex. This is equally applicable to the selection test process. Wrigley (1952) has expressed doubts that an aptitude as complex as flying skill can be satisfactorily predicted by any single index and recommended that a multi-test approach would be more appropriate for assessment. Ornstein (1954) has shown that the pilot stanine does not predict performance on all flight maneuvers in the training syllabus equally well.

Melton (1947) in his summary of experimental data from the study of compensatory visual-motor reaction tests stated that in general (1) subjects seem to respond less consistently to more complex tests, (2) tests that involve complex psychomotor performance seem to be better predictors of success in elementary pilot training than are less complex tests, (3) tests that are sensitive indicators of learning are better predictors of success than those tests which are less sensitive indicators of learning. Manning and Yellowlees (1949) further emphasized the apparent need in the selection procedures for aircraft pilots to assess the ability to perform complex mental and motor tasks simultaneously under condtions of stress. They hypothesized that many failures in flying training occur from a disorganization of motor and intellectual functioning under high load conditions. Wilson (1959) reports the use of the Complex Behavior Simulator developed by Hartman and McKenzie (1960) for selection of astronauts.

Fleishman (1953b) and Adams (1956) question the possibility of accounting for the variance in a complex psychomotor test by any number of tests of simple motor ability. Fleishman (1953b) further stated that factorially pure psychomotor tests are not necessarily simple motor tests. He does believe, however, that it is possible to predict complex performance from combinations of tests involving basic functions, though he does not take a position with regard to concurrent assessment of several functions.

Jackson (1958) emphasizes that a pilot is continuously being presented with variable information which requires perception and manipulation of specific controls and that several tasks must be accomplished concurrently. Conrad (1951a) further emphasizes the integrative and complex approach in the statement that behavior must be determined by the perception of a series of concurrent stimuli to the same and different sensory modes.

Fleishman (1953b) indicates that success in complex motor skills may depend upon nonmotor as well as motor factors and that the patterning of movement may be of greater significance than the particular sense modality of musculature involved. This concept was further reiterated by Parker and Fleishman (1960) when they argued that "purely motor abilities do not determine individual differences in advanced tracking proficiency. The important abilities appear to fall within the areas of 'Observing Responses' and, probably to a greater extent, 'Predictive Responses'."

In view of the foregoing we would recommend that consideration be given the development of a single test unit containing tests representing a number of behavioral functions. The developed battery of tests should permit the administration of more than one test concurrently to provide a more precise estimation of individual capacity. Predictive indexes for aircrew selection should be developed employing complex behavioral tasks involving intellectual, sensory-motor, and perceptual components.

The capacity of a test to differentiate between individuals is the basic reason for the test administration in the selection process. The differentiation must be accomplished so that the differences in ability observed are real rather than solely functions of the test or testing situation. The variations observed must be meaningful in terms of capacity. In other words, the difference must make a difference. The behaviors assessed must be valid predictors of the criterion.

Differentiation among individuals may be obtained by making the test so difficult that only a select few will be able to meet the criterion established and all others cast in one large undifferentiated group. One criterion of a good test is to enable the ranking of all individuals on the basis of performance. This implies that the test indices would have an infinite number of possible ranks. In applied testing situations, such fine discriminations of ability levels are usually not possible or required. It is necessary, however, to establish the difficulty of a test at a level which will permit a practical discrimination among individuals.

It is unfortunate that most of the research on psychological processes is concerned primarily with group rather than individual differences. However, it is assumed that the individual differences on most experimental variables are somewhat normally distributed and that tests which yield performance shifts in the presence of changes in the independent variables will be sensitive also to individual differences. Poulton (1965) has listed the methods of obtaining sensitive measures of performance which are briefly summarized here:

- Adjust the difficulty of the task so that the average performance expected is about 50%.
- Increase work load where it is impractical to vary the difficulty.
- Use a task with which no subject has had previous experience.
- Measure variability of performance; mean performance may show stability over time but variability in performance may change.
- Examine performance at times in which specific events are predicted to occur rather than averaging all performance over time.
- Examine component measures. Changes in overall performance may not be indicative.
- Channel two dimensions of variability into one (i.e., paced as opposed to unpaced tasks).

The tests should be relatively unique in order to minimize the effect of past experience and should not be of such nature as to penalize testees whose previous learning results in habit interference. Crossman (1964) indicates that in order to interpret a given pattern of behavior correctly, it is necessary to refer to the complete history of the individual. He indicates that this difficulty may be overcome to some extent by the selection of tests insensitive to past experience or the negation of the past experience effects by extensive practice.

It is believed that tests for the selection processes should not simulate the criterion environment but should be used to magnify individual differences on those behavioral factors which are central to operational success. Reliability should be attainable in short testing periods and programming should provide for adequate number of stimuli to allow alternate forms for repeated administration if required.

In view of the need for minimum cost, portability, and maintainability, a number of fundamental design considerations should be emphasized.

- Standard off-the-shelf components and equipment should be used wherever possible to reduce initial cost and maintenance cost.

- Components should be selected on the basis of function, stability of functioning, and expected reliability under the anticipated environments in which the equipment will be used or transported.

- Solid state circuitry and components should be used wherever possible to increase stability, reliability of functioning, and to decrease weight and volume for maximum portability.

- Multiuse displays and response mechanisms, appropriate to the behavioral functions being assessed, should be used where feasible to insure minimum volume and weight and, more importantly, to enable the assessment of many different behavioral functions within the confines of a single test device.

Flexibility with respect to stimulus and response characteristics should be incorporated in order to permit an empirical determination of optimum stimulus and response characteristics and permit adjustment where required without apparatus modification.

Automatic stimulus programming and response recording should be employed in order to minimize data loss, increase standardization, decrease cost of administration, and increase the comprehensiveness of the observations.

Automatic programming of test indicator, warning, response, and test cessation signals should be incorporated in order to minimize data loss and variation resulting from experimenter introduced variance in test administration.

VII. ANNOTATED REFERENCES

This section of the report contains annotations of certain references selected from those cited in the literature review. Approximately 80 percent of the titles considered relevant by the reviewers were acquired. All documents dealing with perceptual-psychomotor tests in selection of aircrew since World War II were annotated. Additionally, annotations are provided for literature crucial to concepts for future test development. The literature annotated in support of test concepts is representative and not comprehensive in coverage. In several of the references the tests used were developed in the Army Air Forces program and are identified by code. Tests identified in such a manner are described in detail in the Appendix, along with procedure for administration and scoring.

Adams, J. A. The problem of controlling level of learning in studies of associative interference in psychomotor performance. U. S. Navy, Special Devices Center, Technical Report SDC 57-2-9, 1949.

This report discusses the issues involved in controlling level of learning on a psychomotor task. Comparison is made with verbal learning in which the criterion is usually below the asymptote. In much motor learning the criterion of a common level of performance for all subjects on a standard number of trials is likely to lead to erroneous conclusions in studies of associative interference as the amount of decrement at the outset of relearning may be as much a reflection of level of learning as it is of the subject's proneness to interference. A method suggested is that in which a fixed number of trials is given, extrapolation is carried out to the asymptote, and subjects given the additional trials necessary to reach a predetermined level equal to some fraction of asymptotic performance. Vincentizing would be necessary in arriving at group curves.

Adams, J. A. The prediction of performance at advanced stages of training on a complex psychomotor task. USAF Human Resources Research Center, Research Bulletin 53-49, 1953.

Purpose: To determine the effectiveness of printed tests, briefly administered simple psychomotor tests, and complex psychomotor tests in predicting performance on a complex psychomotor criterion test at advanced stages of training.

Apparatus: Complex psychomotor battery: Complex Coordination Test (CM701E), Rotary Pursuit Test (CM803B), Unidimensional Matching Test, Two-Hand Matching Test, Discrimination

Reaction Time Test (CP611D2), Kinesthetic Coordination Test, and the Plane Control Test (CM817B).

Simple Motor battery: Nut and Bolt Test, Ball and Pipe Test, Simple Reaction Time Test, Eye Board Test, Pin Punch Test, Track Steadiness Test, Pin Board Test, Hex Nut Steadiness Test, Dowell Manipulation Test, Rate of Gross Movement Test, and the Backward Jump Test.

Procedure: 197 basic airmen were used as subjects. Scores on 34 printed tests were obtained (a number of scores on the tests were available from airman records) in addition to performance on the apparatus tests over a three day period. Considerable practice was given on the complex apparatus tests while a single performance was required on the simple tests. On the Complex Coordination Test (the criterion test) 16 trials were given each morning and each afternoon of days two and three, giving a total of 64 trials.

Indexes: Test scores and number of matchings per trial on the Complex Coordination Test.

Results: Printed tests, simple psychomotor tests, and measures from early practice on complex psychomotor tests predict initial performance on the criterion task better than they predict final performance on the criterion task. Measures from final stages of training on complex psychomotor tests predict final stage performance on the criterion task better than they predict performance in the initial stages. Detailed correlational data are provided.

Adams, J. A. The relationship between certain measures of ability and the acquisition of a psychomotor criterion response. Journal of General Psychology, 1957, 56, 121-134.

Purpose: To determine from the acquisition of a psychomotor response (a) what is the nature of acquisition curves for subjects having different levels of initial ability in the task and (b) how well can performance at various stages of training be predicted from intra-task measures, measures from other psychomotor tests, and printed test scores.

Apparatus: A four-unit Discrimination Reaction Time Test (CP611D2) and a test of simple reaction time to the onset of a light where the subject had to move his hand a distance of 2¼ inches.

Procedure: Experiment I: 860 basic airmen given 160 continuously presented settings.

Experiment II: 197 basic airmen given the Airman Classification Battery, a Discrimination Reaction Time Test, consisting of three blocks of eight trials each with a 2 minute rest between blocks (a trial is defined as 10 settings), and a simple reaction time test.

Indexes: Scores on tests of the Airman Classification Battery and reaction times.

Results: Experiment I: Trial 1 score is predictive of final level of attainment and when divided into deciles, mean performance curves generally maintain their rank order throughout training.

Experiment II: Ability to predict discrimination reaction time by printed tests of the Airman Classification Battery decreased from initial to final stages of training on the Reaction Time Test, while simple reaction time increased in predictive efficiency.

Discrimination reaction time total response can be grossly reduced to three principal component responses: (a) the perceptual response which entails speed of stimulus pattern recognition, (b) the visualization response which requires the learning of the meaning of any pair of stimuli for a particular response, and (c) the speed of execution of the required movement.

Adams, J. A., and Chambers, R. W. Response to simultaneous stimulation of two sense modalities. Journal of Experimental Psychology, 1962, 63, 198-206.

Purpose: To determine the fundamental load-carrying capacity of the human subject.

Apparatus: The device consisted of a visual display of three jeweled lights mounted horizontally. The lights were red, white, and green with a neon light below each stimulus light to indicate the position of a 2-inch control stick. The auditory dimension consisted of tones, 600, 800, and 1,000 cps transmitted by earphones. The control stick manipulated both displays, and a duplicate stick was mounted for left hand operation when the bisensory condition was programmed.

Procedure: Forty-eight subjects were randomly assigned to three groups: Group A, auditory condition; Group V, visual condition; Group AV, auditory-visual conditions simultaneously. Further, stimuli events were either certain, 68% redundancy, or uncertain. In the bisensory condition (AV) the certain event in the auditory mode was paired simultaneously with a certain event in the visual mode or, conversely, the uncertain auditory events were paired with uncertain visual events.

Each trial was 100 sec. in duration and consisted of 50 2-sec. events or in Group AV, 50 pairs of 2-sec. events. Sixty practice trials were given, 20 on each of three different days.

The subject was required to move the controller in discrete steps to match the position of the stimulus light or to match the tone. A mismatched tone would result in a complex tone of two of the three frequencies. The stimuli were programmed in a probalistic defined sequence and were the same for all subjects except in respect to unisensory or bisensory conditions.

Indexes: Time-on-target for each of the six stimulus events. On trials 56 and 57, response times were analyzed into (a) time between onset of stimulus and onset of the response, (b) number of control movements in the wrong direction, and (c) duration of each error before correction.

Results: It was found that the response to "certain" visual events in the bisensory task was superior to that of the unisensory visual control group. This result was hypothesized to have occurred from the pairing with the normally faster response time to auditory stimuli. It was suggested that anticipation permitted the triggering of the response from within and freed it from the constraint of the visual S-R system.

When events were uncertain, the bisensory condition resulted in a slowing of the normally faster auditory response. Anticipation was absent, and the slower response governed the response movements. A significantly longer time was required to correct response movements to the auditory stimuli in the unisensory mode and this was not apparent in the visual condition.

The higher level of beneficial anticipation in the auditory condition in which the stimulus events were 68% redundant was attributed to the greater difficulty of the auditory task. This difficulty resulted in a higher level of anticipation in order to achieve a measure of success. An analysis of the time-on-target scores indicated that time on target for uncertain bisensory events was significantly poorer than uncertain unisensory events for both auditory and visual stimuli.

Adams, J. A., and Creamer, L. R. Anticipatory timing on continuous and discrete responses. Journal of Experimental Psychology, 1962, 63, 84-90.

Purpose: To determine the transfer of pretraining in perceptual anticipation on a nontracking response to a tracking criterion task and to determine whether the anticipatory mediating response was central-verbal or peripheral-motor in origination.

Apparatus: Experiment I

The basic task was a single-dimension pursuit tracking task. The signal to be tracked was a cam-generated red line on moving white paper. The input signal approximated a sine wave at 34 cycles per minute. The tracking was accomplished with a horizontal handle moved back and forth.

Experiment II and III

The apparatus consisted of a red, a white, and a green light horizontally placed with a corresponding neon feedback light for each stimulus light to indicate the position of the controller. The auditory task utilized the same controller but the signals were 600, 800, 1,000 cps pure tones. When the subject was on target, he heard a single pure tone and a complex tone of two of the frequencies when he was off target. Manipulation of the input was accomplished by means of a movable controller.

Procedure: Experiment I

Forty-seven subjects were randomly assigned to four groups: Group WT, given 10 whole-task trials with no anticipation training; Group V (Verbal) given 12 pretraining trials in verbally responding "Change" when the direction of the stimulus changed; Group CM (continuous motor) pretraining in turning a small crank to match the speed and direction of the pointer; and Group DM (discrete motor) pretraining in pressing a button when input direction changed. The subjects in the pretraining groups were instructed to anticipate the change in signal direction. Each trial was of 60 sec. duration. All groups were then given the whole task.

Indexes: Response time in seconds taken from the directional change of the input signal and the response movement of the subject.

Results: Experiment I

The pretrained groups, Verbal, Discrete Motor, and Continuous Motor, showed a greater decrease in response lag and percentage of beneficial anticipations than the untrained group but no differences were observed among the pretrained groups irrespective of method.

Procedure: Experiment II

The number of pretraining, whole-task trials, and trial durations were the same as in Experiment I. A control group, WT, had whole-task visual discrete tracking; group VV, a verbal response to the onset of each of the three visual signals; group AV, a verbal response to each of the three auditory signals; group VM, a visual-motor response of pressing one of three buttons to correspond to the visual signals; and group AM, a pushbutton response to the auditory signals. The whole-task was administered to all groups after pretraining.

Indexes: Time on target

Results: No significant difference was observed among groups.

Procedure: Experiment III

In contrast to Experiment II, feedback was given during the pretraining trials. The number of trials, duration of trials, and intertrial rest periods were the same as in Experiments I and II. Sixteen subjects were randomly assigned to two groups. Control group data (WT) from Experiment II was used for comparison. The two experimental groups were Group VF, visual tracking and feedback, and Group AF, auditory tracking and feedback during the pretraining trials. The criterion task was visual tracking with the stick control.

Indexes: Time on target and response time (beneficial anticipation index) defined as a response within + or - 76 msec. of the directional change.

Results: The mean percent time on target scores of the two experimental groups was significantly different from the control group beyond the .01 level. The beneficial anticipation scores were significant also beyond the .01 level. No difference was observed between the two experimental groups.

Feedback was found to be a necessary condition for the acquisition of beneficial anticipation. The results of pretraining encourages interpretation of the loci of anticipation in terms of mediated responses.

Adiseshiah, W. T. V. Speed in decision taking under single channel display conditions. Indian Journal of Psychology, 1957, 32, 105-108.

Purpose: To determine the average rate at which correct responses can be given by aircraft pilots to signals for action presented under single channel display conditions.

Apparatus: Six aircraft information symbols were presented on each of two cards. One card was stationary and the other was moved into the display window. The rate of display change could be varied from 1 to 20 cards per minute.

Procedure: The subject was required to tell how many symbols were common to both cards. The factor of speed stress was introduced by varying the duration of exposure of the cards. The tests were administered to groups of pupil pilots, fighter pilots, and flying instructors of the Indian Air Force.

Indexes: Number of errors under each of the different temporal conditions.

Results: Accuracy of decision breaks down seriously when speed in decision taking exceeds the rate of six decisions per minute. In the case of pupil pilots, the error rate tended to rise sharply and abruptly, once the rate of decisions exceeded six per minute. With jet fighter pilots, the increase in error rate was less abrupt and less sharp until the rate of decisions exceeded 10 to 12 per minute. Flying instructors stood almost midway between pupil pilots and fighter pilots. More instances of underestimation (less than the actual number of symbols in common) than exaggeration were observed. More instances of exaggeration were observed in pupil pilots. The experienced pilot seemed to take the test situation with greater calm and avoided hazarding wild guesses.

Bahrick, H. P., and Shelly, Carolyn. Time sharing as an index of automatization. Journal of Experimental Psychology, 1958, 56, 288-293.

Purpose: To determine the relationship of the degree of redundancy of a task to the degree of automatization or proprioceptive control through performance in a time-sharing situation. Both visual and auditory tasks were used.

Apparatus: The visual stimulus panel consisted of four 6-v. lights spaced horizontally at a distance of 1.75 inches and a fifth knowledge-of-results light. The response panel consisted of four telegraph keys spaced at 0.75-inch intervals mounted horizontally for operation by four fingers of the right hand. A stepping switch of 103 positions with 7 leads for each position activated the light sequences. Each stimulus was presented for 0.58 sec. If the appropriate response key (corresponding to the location of the activated light) was depressed, a hit was recorded.

Four versions of the task were used:

1. Repetitive Version (RP), the sequence repeated after every fourth stimulus (1, 3, 2, 4, 1, 3 --).

2. High Redundant Version (HR), all four lights occurred with equal frequency (25 times), but 4 digrams (1-3, 3-2, 2-4, and 4-1) each occurred 16 times, and the remaining 12 digrams each occurred 2 or 3 times.

3. Low Redundant Version (LR), all four lights occurred with equal frequency (25 times); the four digrams (1-3, 3-2, 2-4, and 4-1) each occurred 10 times and of the remaining 12 digrams each occurred 4 or 5 times.

4. Random Version (RA), each light occurred 25 times and each digram 6 or 7 times.

The relative redundance values were calculated to be 100%, 13%, 2%, and 0% for the RP, HR, LR, and RA task versions, respectively.

The auditory task consisted of numbers 1-5 presented over earphones at irregular intervals between 0.5 and 4.0 seconds. Each number occurred three times during a period of 46 seconds. The subject was required to depress the corresponding key to the number on a five-finger keyboard with the left hand. The intervals between stimuli were filled with white noise.

Procedure: Forty male and female students were randomly divided into four groups of 10 subjects each.

During the first session all subjects were given 10 trials on the visual task appropriate to the group. Each trial consisted of 100 stimuli. The second session was a duplicate of the first session. The third session consisted of four time-shared trials on the combined auditory and visual task. Tests under the time-sharing condition were administered four trials per session on sessions 3, 14, and 25. The sessions were given over a period of 6 weeks.

Indexes: The number of hits on the visual task and the correct responses, errors, and cumulative reaction time on the auditory task.

Results: The introduction of the auditory task caused significant interference effects which varied inversely with the redundancy of the task. Continued practice reduced the susceptibility of the task to interference, but not greatly beyond Session 14.

It was concluded that the interference effects produced by time-sharing were an inverse function of the degree of redundancy of the visual task. and these effects can serve as an index of the degree of automatization. The redundancy of stimulus sequences permits a change from exteroceptive control of responses to proprioceptive control.

Barbour, A. B., and Whittingham, H. E. (Eds.) Human Problems of Supersonic and Hypersonic Flight. London: Pergamon, 1962.

This book contains the proceedings of the 5th European Congress on Aviation Medicine held in London in 1960. The papers may be classified into six categories: (a) flying personnel research, (b) human efficiency related to flight performance and operational procedures, (c) human efficiency related to airborne systems, (d) flight environment and safety, (e) human efficiency related to ground control systems, and (f) miscellaneous papers. Papers of interest in the present review are listed in the references under the names of the authors.

Bartlett, F. The outlook for flying personnel research. In Barbour, A. B., and Whittingham, H. E. (Eds.) Human Problems of Supersonic and Hypersonic Flight. London: Pergamon, 1962, 3-8.

The author traces the changes in personnel research throughout the history of flying and suggests that, with increasing speed and the use of automatic devices, the human qualities required may be less specialized. He indicates that the required qualities are quickness of decision and execution, endurance, continuing alertness with the least possible variation during a duty period, and the ability to adapt rapidly to changing conditions. There is a greater need for human operators to be reliable in their performance rather than extremely precise. He points out that methods for identifying and measuring the traits of alertness, endurance, speed adaptability, and reliability within the human need to be developed, and he expresses confidence that they will be. Transfer of training is an important issue in readjusting to new situations. More attention will have to be given to the observation of high-level functioning and complex problems of behavior and their control.

Brown, J. G. Crew composition and selection for the supersonic transport. American Society of Mechanical Engineers, Paper Number 63-AHGT-84, 1963.

The selection of pilots for transition training for jet aircraft in domestic airlines has been principally based upon seniority. This practice has led, on some occasions, to discontinued training of some pilots who were not making adequate progress in the transition. In foreign airlines, the selection procedure has not been on the basis of seniority, according to the author, though he provides no details to support this assertion. He pointed out that the cost of training for supersonic flight will probably be excessive, and some attention to selection processes beyond that which is done currently will be required. Normal flight regimes in the supersonic aircraft will probably require no greater flight skills than are required today, but unusual, abnormal, or emergency situations may be far more demanding. Decision-making will be the crucial activity, but, with increasing automation, ground control may be expected to relieve the crew of some aspects of the decision process.

Brown, J. S., Knauft, E. B., and Rosenbaum, G. The accuracy of positioning reactions as a function of their direction and extent. American Journal of Psychology, 1948, 61, 167-182.

Purpose: To study the effect of plane of movement, direction of movement, and distance moved on the accuracy and variability of positioning reactions.

Apparatus: The apparatus consisted of a waxed-paper recording instrument connected to a movable slider which was manipulated by the subject. Two stimulus pointers, one in a fixed location and the other moved by the experimenter for each trial, were set against a millimeter scale. A 100-w. lamp was centered over the response panel. When this light was turned on, an electric timer automatically turned it off after 2.5 seconds. A one-to-one ratio of the pointer and slider was maintained for all trials. The apparatus could be placed for operation of slider in six directions of movements.

Procedure: It was planned to use 24 subjects for each of six experimental conditions, but after the first two conditions it became necessary to use most of same subjects for the rest of the conditions. The six experimental conditions were: (1)

Vertical plane-movement of slide from bottom to top, (V:BT); (2) Vertical plane-movement from top to bottom (V:TB); (3) Horizontal plane-outward movements to the frontal plane of the body (H:NF); (4) Horizontal plane-inward movements from far to near (H:FN); (5) Horizontal plane-outward movements from the center of the body to the right (H:CR); and (6) Horizontal plane movement from right to center (H:RC). Ten trials were given at each of four distances (0.6, 2.5, 10, and 40 cm.) under each condition. The subject observed the set distance for 2.5 seconds and then was required to move the slider to match the distance after the light went out. All movements by the subject were made in total darkness. The subject was required to hold the slider in the estimated position for approximately 2 seconds and then return it to the fixed position for the next trial. The subject closed his eyes when the experimenter was moving the pointer for the next series of trials at one of the other distances.

Indexes: Magnitude of error of each trial in centimeters.

Results: Subjects tended to overshoot the mark at the shorter distances and undershoot at the longer distances. Variability of positioning reactions increased with distance in all experimental conditions. Variability of positioning movements directed away from the body was greater than movements toward the body at distances of 10 and 40 cm. The relationship was reversed at 0.6 and 2.5 cm. Movements away from the body exhibit smaller percentage errors in positioning than do movements toward the body at comparable distances.

Conrad, R. Speed and load stress in a sensori-motor skill. British Journal of Industrial Medicine, 1951, 8, 1-7.

Purpose: To determine the effect of speed and load on performance on a task which required constant vigilance and adaptive responses to endless changes in critical stimuli.

Apparatus: The apparatus consisted of 2, 3, or 4 dials with pointers revolving at a constant speed but each pointer at a different speed. Six equally spaced target marks were placed on each dial. The subject's task was to turn the knob located beneath, and extending from, the dial every time a pointer coincided with a target mark.

Procedure: The subjects were 20 Navy ratings aged 19 to 23 years. Each subject was tested with five speeds (40, 60, 80, 100, and 120 signals per minute), and three loads (2, 3, and 4 dials). Thus, there were 15 conditions in all. Each subject did a 10-minute test under three conditions daily for 5 consecutive days. The test order was suitably randomized.

Indexes: Errors of omission (failure to respond to the critical signal) and time of response.

Results: Increasing the speed three times increased errors at least 30 times on the four-dial display. Errors were not directly proportional to speed at any load, with all loads extra speed significantly increased absolute errors and missed signals. It was found that load alone is an important factor in skill deterioration. A significant interaction effect indicated that speed has a more serious effect as the load increases. Variations in load affected the timing error; speed did not. In general, the results were stated to confirm previous work which indicated the independence of speed and load effects.

Creager, J. A. Validation of the February 1947 Aircrew Classification Battery for the 1950 pilot training classes. USAF Personnel and Training Research Center, Technical Memorandum 57-8, 1957.

Purpose: To examine the validity of the Battery for prediction of success in pilot training for classes 1950 A, B, C, D, E, F, and G.

Apparatus: SAM Rotary Pursuit with Divided Attention (CP410B), Rudder Control (CM120C), Finger Dexterity (CM116A), SAM Complex Coordination (CM701E), SAM Two-Hand Coordination (CM101B), and SAM Discrimination Reaction Time (CP611D).

Procedure: These tests were administered, using standard procedure within the context of a test battery containing other tests of the paper and pencil variety, to a sample of 2678 students entering training (complete data reported on this number though more were tested).

Indexes: Graduation-elimination in basic (later primary) flying training. The standard indexes for each of the tests were employed.

Results: Validities for flying deficiency elimination (N=2010)

Test	Biserial r
CP410B	.22
CM120C	.58
CM116A	.11
CM701E	.35
CM101B	.32
CP611D	.21

Dailey, J. T. Conference on revision of the aircrew classification battery. USAF Human Resources Research Center, Conference Report 51-2, 1951.

The conference considered aircrew classification testing in all of its aspects. Of particular interest in the present context was the recommendation that the six psychomotor tests of the 1947 battery be retained until better replacements were made available.

Dailey, J. T., and Gragg, D. B. Postwar research on the classification of aircrew. USAF Human Resources Research Center, Research Bulletin 49-2, 1949.

The authors review the work in aircrew classification demobilization following World War II through most of 1949. Data on testing for classes 49-A, 49-B, 49-C, and 50-A are reported. Early testing was with the June 1945 battery, which contained seven perceptual-psychomotor tests as follows: CP410B, CM120B, CM116A, CM701E, CM810A, CP611D, and CM824A. The battery was revised in February 1947 and effective on 1 April 1947 CM810A and CM824A were eliminated and CM101B added. Testing for other than experimental purposes was discontinued in October of 1947 and was not begun again within the period covered by this report (actually classification testing was not reintroduced until April of 1951). During this period, the stanine showed continuing validity in prediction of elimination for flying deficiency, but since eliminations for other causes showed an increase, the research effort was largely directed toward development of measures for prediction of elimination from these other causes. The need for mobile test facilities led to work in derivation of paper and pencil tests to replace apparatus tests, although none of the details of this effort were reported in the review.

de Wet, D. R. Co-ordination and floating effect. Journal of the National Institute of Personnel Research, 1959, 8, 28-38.

Purpose: To develop and validate a perceptual-motor test which presents the type of control relation as found in an elastic medium such as the response of the aircraft to its controls.

Apparatus: The test involves two tracks at right angles to each other in the same plane (horizontal), one above the other. Steel balls placed on the tracks are required to be maintained in a center position on each track. The mechanism provides tilt of the plane in two dimensions away from the horizontal, and the operator is required to counteract the tilt of the mechanism by tilt of the apparatus, which is gimbal-mounted on two axes utilizing a two-hand held control. (The apparatus bears some similarity to the SAM Rudder Reaction Test (CM507A2).) If desired, the handle could be modified to allow control on one axis only and a foot control supplied for tilt about the remaining axis as in the SAM Rudder Reaction Test. The investigation employed only the hand control.

Procedure: The starting position is always with the near end of one track and the end of the other track to the left of the operator in a down position. At the start of the trial, the operator is to bring the device to level position and attempt to compensate for the mechanism tilt by keeping the balls centered. Three 3-minute trials are given.

Indexes: Time on target. Criterion: ratings on Wings Test (final rating), General Flying, Night Flying, Pilot Navigation, Instrument Flying, dual hours prior to first solo, and pass-fail in training.

Results: Two samples were run, one in 1952 and one in 1955. The N's were 29 and 44, respectively, with corresponding eliminations of 4 and 11 students. Reliabilities across trials were on the order of .80, using intertrials correlations as indexes. The r's required at the .05 level are .38 for the 1952 data and .32 for the 1955 data on ratings. The 1955 r's are enclosed in parentheses.

RATINGS (N=25 and 33)	Trial 1	Trial 2	Trial 3	Trials 1, 2 & 3	Worst of 1, 2 & 3
Wings Test	.44 (.26)	.21 (.18)	.27 (.15)	.36 (.29)	.39 (.30)
General Flying	.36 (.32)	.22 (.16)	.38 (.03)	.34 (.20)	.30 (.34)
Night Flying	.27 (.11)	.20 (.02)	.48(-.10)	.29 (.05)	.27 (.13)
Pilot Navigation	.07 (.28)	.02 (.30)	.32 (.28)	.08 (.31)	.09 (.31)
Dual Hours Before Solo	.36	.21	.35	.32	.34
Instrument Flying	.30 (.26)	.17 (.28)	.35 (.13)	.28 (.25)	.35 (.28)
Formation Flying	(.30)	(.02)	(.06)	(.12)	(.25)
PASS-FAIL*					
(N=29 and 44)	.83 (.24)	.63 (.35)	.66 (.25)	.71 (.31)	

*Biserial r's reported for pass-fail. All other coefficients are product moment r's.

de Wet, D. R. A portable hand-foot reaction test. Journal of the National Institute of Personnel Research, 1960, 8, 106-116.

Purpose: To present the design and validity data for the hand-foot reaction test in prediction of success in pilot training.

Apparatus: The device utilized four controls, two hand- and two foot-controls. The subject is seated facing a vertical panel which contains four stimulus lights which are not symmetrically arranged. A single control activation is the adequate response for the occurrence of a single stimulus light. Lights are presented at random by a programming device. The task is self-paced.

Procedure: The subject is seated before the device and given instructions as to the specificity of control for a single light, though he must learn which control is appropriate to each light. He practices until such time as he can give 20 correct responses. A time limit of 15 minutes is imposed for learning. A buzzer sounds for each correct response, and the next stimulus is presented. In the second or speed part of the test he receives no buzzer corroboration. He is told to work as rapidly and accurately as possible. He is given a practice period of one minute and then performs a five minute run. If the subject depresses two response devices simultaneously, the apparatus is stopped and the subject must press a reset switch.

Indexes: During the learning phases, total time to reach the criterion and in the second or speed phase, correct and total count recorded for each half minute. Criterion: Pass-fail in flying training.

Results: Data are reported for two groups run in 1954 and 1955, the N's being equal to 38 and 47 respectively. For learning time the biserial r's were .31 and .52 and for the number of correct reactions .60 and .48, respectively.

The author reports that in a separate study by Van der Reis when a jeweled light located approximately centrally on the stimulus panel was substituted for the buzzer, neither part of the test showed a significant validity in predicting success in pilot training and a great number of subjects were unable to learn the task in the 15-minute time limit. The author does not indicate the number of subjects failing to learn in either his or the study by Van der Reis.

de Wet, D. R. An improved steadiness apparatus and its validity for air-pilot selection. Journal of the National Institute of Personnel Research, 1960, 8, 122-136.

Purpose: To describe a modification of the steadiness test previously used by the South African Air Force and to ascertain its validity in the prediction of success in pilot training.

Apparatus: The device consisted of a tracing board (a standard Whipple-board) in the form of a "T." There were two tracing paths in the cross of the "T"; one was a 90° zig-zag pattern, and the other was of a square wave form. The stem of the "T" contained a single straight path. The stem of the "T" was placed at right angles to the frontal plane of the subject.

A heel plate, upon which the subject rested his free hand, was provided to administer an electric shock if an error occured. A stylus was used to traverse the tracing paths. The apparatus is placed in a horizontal position on a table of convenient height and the subject performs in the seated position.

Procedure: Four trials are given and each trial follows a standard sequence. The stylus is drawn toward the subject on the Whipple-board twice, a rest is given with the subject performing eight simple additions. He then traces the distal zig-zag board from right to left immediately followed by tracing the proximal board from left to right. An interim eight additions are again performed and a subsequent trial begins. The subject is told that the first trial is practice. He performs the second and third trials without further instruction. Prior to the fourth trial the subject is told his average tracing time for the second and third trials and that he must try to finish within this time or he will receive an electric shock.

Indexes: Total time (time to complete a trial), Error Time (time in contact with sides of tracks), and Correct Time (total time minus error time). Criterion: Pass-fail in flying training.

Results: Data are presented on students entering training over a five-year period from 1954 through 1958; the N's are 38, 45, 41, 47, and 49, respectively. Indications of reliability for correct time revealed through inter-trial correlations averaged for the five years range from .79 to .95.

Biserial r's for error time with pass-fail are not significantly different from zero for all trials. Biserial r's for correct time and pass-fail are given for the various years below.

Trials	1954	1955	1956	1957	1958	Mean	p=
1	.42*	.32	.29	.06	-.10	.19	.021
2	.19	.25	.12	.02	.07	.12	.124
3	.20	.30	.05	.05	.06	.12	.124
4	.30	.44	.08	.15	.15	.22	.007

*A positive correlation indicates that the slow performance is related to success in flying.

de Wet, D. R. Handlebars: A self-paced test of two-hand co-ordination and some results on air-pilot candidates. Journal of the National Institute of Personnel Research, 1961, 8, 199-208.

Purpose: To describe the development of a two-hand coordination test based on a lever system rather than rotating handles because of the greater relationship to aircraft controls and to introduce a "steadiness" element not found in the typical two-hand coordination tests and to obtain validation data on pilot candidates.

Apparatus: The pattern to be traced is in its central portion similar to the usual five-pointed star traditionally used in mirror tracing experiments surrounded by an irregular pattern which must also be traced continuously as an integral part of the task. The track is 1/2-inch in width and is cut into a metal plate which is mounted on a sloping surface at table height. A compound scissors-like arrangement has its principal pivot outside the pattern and toward the subject. Linking bars are attached and pivoted at what would be the tips of the scissors, and these two linking bars are themselves coupled in a common pivot which contains the tracking stylus. Thus separating the handles will move the stylus toward the subject while bringing them together will move the stylus away from the subject. Lateral movement merely involves rotating both handl s to the right or left while maintaining their separation consta t. In order to follow the pattern, both movements are required concurrently. An electrical circuit through the stylus and track provided for time scoring and the activation of a buzzer when the stylus was in contact with the sides of the track.

Procedure: The peripheral track enclosing the star was traversed first and then the star. In the 1954 and 1955 groups 2 trials were given. In the 1956 group, 5 trials were given. The instructions were changed from the earlier ones which stressed careful and quick work and did not indicate that a second trial would be given. The instructions cautioned the 1956 group about working too fast and stressed precision on the first practice round, speed in the second round, the third allowing freedom to do it the easiest way, the fourth and fifth trial stressed speed. It was pointed out that the fifth trial counted most.

Indexes: Total Time (time to complete tracing), Error Time (time in contact with sides of track) and Correct Time (total time minus error time). Criterion: Pass-fail in flying training.

Results: Subjects were run in three groups during 1954, 1955, and 1956, the N's being 38, 43, and 41, respectively. Intertrial correlations served as indications of reliability and were for the three years .84, 96, and .84 (average), respectively. The mean correlation between Correct Time and Error Time was -.39, indicating that fast working tends to be associated with more error. The only validities possessing statistical significance were biserial r's for the first trial for the third group (1956) with a .32, p=.039 for Correct Time and .35, p=.030 for Error Time when one-tailed tests were used. Total Time and Error Time were correlated with Two-hand Co-ordination (Moede type), Hand-foot Reaction, and Steadiness. The r's for comparable measures of Steadiness were .532, p less than .001 for Total Time, and .404, p less than .001 for Error Time. The relationship with Two-hand Coordination was .152, p=.055 for Handlebars Total Time versus Two-hand Co-ordination Time, and .219, p=.006 for Handlebars Error Time versus Two-hand Co-ordination Errors. The intertest correlations were based on an N=161.

de Wet, D. R. A variable co-ordination test and its potentiality as a gauge of aptitude for airmanship. Psychologia Africana, 1962, 9, 86-99.

Purpose: To describe the development of a variable co-ordination test and to examine its validity for the selection of pilots.

Apparatus: A 12 inch diameter wheel with a 2¼-inch flat rim is mounted at table height. A ¼-inch irregular track around the circumference of the wheel is to be traced with a pointer mounted on a horizontal crossbar. The wheel shaft has cranks on either side for rotation by either or both hands. The crossbar can be manipulated with either hand or by the feet when stirrups are attached. The subject rotates the wheel and manipulates the crossbar to maintain the pointer on the irregular track. The task is self-paced. Electrodes are attached to the arms to provide shock to the subject during error periods. Torque loading may be provided by the attachment of a spring to one side of the crossbar.

Procedure: In the present study both hands were applied to the cranks and both feet to the crossbar without spring loading. A trial consists of a single revolution of the wheel. A click and a buzzer indicate when the subject is off the track during the first two trials. Shock is introduced on the third trial and doubled in intensity for the fourth trial. A 30-second rest is given between trials.

Indexes: Total Time (time to complete a revolution), Error Time (time off track), and Correct Time (total minus error time) for the test. Criterion: Rank in flying training.

Results: Forty-seven pilot candidates were used in the validation study. Intertrial correlations for both correct and error time served as indicators of reliability. The coefficients for correct time varied from .78 to .88, and those for error time varied from .44 to .73. Rank difference correlations reflect validity for both indexes.

Trial	Correct Time		Error Time	
	Rho	p	Rho	p
1	.34*	.03	-.23	.13
2	.28	.08	.09	.57
3	.42	.01	-.25	.11
4	.48	.002	-.14	.35

*Positive signs on Correct Time and negative signs on Error Time imply, respectively, that success in flying is associated with fast working and less error on the test.

The author also found that the smaller the increase in time under stress, the greater the chance of success in pilot training. No significant correlation was found for this test with learning time or speed on the Hand-Foot Reaction Test or fusion threshold on the Flicker Fusion Test.

de Wet, D. R. A compact flicker-fusion machine and its application to air-pilot candidates. Psychologia Africana, 1962, 9, 100-118.

Purpose: To investigate the predictive efficiency of flicker-fusion data in predicting success in flying training and to describe an apparatus possessing attributes of portability, reliability, and freedom from unwanted cues in the testing situation.

Apparatus: A device based upon operation of a constant speed phonographic turntable on which is mounted a stroboscopic disc is described. The device is calibrated and so arranged that the subject has access to a limited portion of the reflected light from the rotating disc. Both foveal and peripheral determinations are provided for.

Procedure: Twenty minutes of adaptation to indoor lighting conditions preceded testing. For foveal measurements the test begins with flicker and by the method of limits proceeds until the threshold is established with five determinations in each direction. Peripheral readings are taken with the subject fixating and following a moving dot with five readings taken in each direction, again a total of ten determinations.

Indexes: Critical Flicker Frequency. Criterion: Pass-fail in flying training.

Results: Data were collected with the test on 161 cases in 1956 and 149 cases in 1959. For correlational studies in reliability determinations and for relationship among tests these N's were used. For purposes of validation a total of 87 cases were available, with 40 coming from 1956 group and 47 coming from the 1959 group. The CFF obtained for foveal and peripheral stimulations differed significantly, thus the two indexes were considered separately. Odd-even reliabilities across trials were computed and the corrected reliabilities varied from .92 to .98. Correlation between foveal and peripheral CFF for the 1956 group was .67 and for the 1959 group, .79. A high CFF appears to be associated with success in flying training. The biserial coefficients obtained are given below, and are possessed of a p less than .01.

	1956 (N=40)	1959 (N=47)	Combined (N=87)
Foveal CFF	.55	.47	.50
Peripheral CFF	.46	.26	.35
Aggregate CFF	.56	.38	.46

Intercorrelations with other tests given the 1956 group (N=161) are given below: (none of these are statistically significant but are included to indicate other tests used by the South African Air Force)

Span of Attention	-.04
Speed of Perception	.10
Errors on Hand-Foot Reaction Test	.06
Learning on Hand-Foot Reaction Test	-.06
Motor Perseveration (speed)	-.13
Motor Perseveration (errors)	.01
Mental Alertness	-.02

de Wet, D. R. The roundabout: A rotary pursuit-test, and its investigation on prospective air-pilots. Psychologia Africana, 1963, 10, 48-62.

Purpose: To determine usefulness of a rotary pursuit test as a device for pilot selection.

Apparatus: A two-part apparatus consisting of a hand-held circular mortarboard and a rotary-pursuit tracking apparatus. The pursuit apparatus is mounted at table height and the subject is required to move about the apparatus in tracking, holding a stylus in one hand while balancing a steel ball held on the mortarboard held in the other hand.

Procedure: Trials are of 30 seconds duration. Tracking performance is scored only while the ball is retained on the mortarboard. Three types of trials are given. (a) continuous movement of tracking target in one direction; (b) reversal of target direction of 3, 6, 10, 12, 16, 19, 24, and 27 seconds; (c) reversal of target direction at 4, 11, 14, 21, and 27 seconds with stops and continuation in same direction at 7.5, 8.5, 15.5, 16.5, 23.5, and 24.5 seconds. Trials terminate whenever a ball falls from the mortarboard. Target rotates at 4 rpm. New trials always reverse direction of movement from previous trial. Four trials are given under condition (a), while three trials each are given under conditions (b) and (c).

Indexes: Correct time (total time minus error time), error time (time off target while ball is on mortarboard), total time (time that ball remains on mortarboard). Criterion: Pass-fail in flying training.

Results: Tested 161 subjects; validity data on 40 subjects; criterion was successful completion of course; 32 successes, 8 failures. Error time was the best predictive score. Biserial r for procedures (a) -.25 (p = .184); (b) -.33 (p = .078); (c) -.30 (p = .114) with aggregate r = -.35, (p = .066).

Intercorrelations with other tests evaluated by author are given. For error time no significant relationships were found for flicker CFF, Arm-Leg-Coordination, Manual Steadiness, or for Handlebars Coordination. For Hand-Foot Reaction speed r = .15, (p = .057) and for Two-Hand Coordination (Moede Type) r = .16, (p = .043) for time score. These data were based on scores of 161 subjects.

de Wet, D. R. Measures of speed of perception and span of attention on air-pilot candidates. Psychologie Africana, 1964, 10, 206-218.

Purpose: To determine the validity of tests of speed of perception and span of attention for predicting success in flying training.

Apparatus: A "fall" tachistoscope allowing for variations in exposure time using an adjustable counterpoise and cards containing appropriate stimulus material.

Procedure: <u>Speed of Perception</u>: Stimulus materials involved three symbols on each of 10 cards. The symbols were Roman capital letters, Arabic numerals, or used in combination. Ten exposure times were available. Each card was exposed individually, with the subject controlling the onset of the exposure. The cards were exposed for increasing durations until the subject was able to report the three characters on the card, or until the subject failed at the longest exposure time provided.

<u>Span of Attention</u>: Stimulus materials involved symbols of the same variety described above. Cards were exposed individually for approximately 1/25-second with one trial given for each card. Card 1 contained three symbols, cards 2 and 3 had four symbols, cards 4 through 7 had five symbols, cards 8 and 9 had six symbols, and card 10 had seven symbols. The subject reported the symbols recognized.

Indexes: A score of 10 was given for recognition of all symbols on the card at the most rapid presentation speed. The scores descended in value with each increased increment of exposure time with failure at the longest exposure time receiving a score of zero. Each card was scored separately, and the total for the ten cards determined. For span of attention, the number of symbols correctly recognized was tallied for each card and totaled to give the score for the test. Criterion: Pass-fail in flying training.

Results: Reliability data based on 161 subjects. Validity data were determined on 40 who entered training; of these 8 were eliminated from training.

Speed of Perception: Odd-even reliability (corrected) was .94. The difference in score between the pass-fail groups was not significant. This test does not differentiate among the groups.

Span of Attention: Odd-even reliability corrected was .81. The biserial r with the pass-fail criterion was .48.

Correlation between the two tests was not significant. Correlations with other perceptual-psychomotor and written tests are reported and, though small, suggest that speed of perception is related more to physical reaction and coordination and span of attention to intellectual activity.

Ericksen, S. C. Analysis of basic grade slip folders. USAF Human Resources Research Center, Research Note PILOT: 52-5, 1952.

Purpose: To identify pilot skills most important in determining initial success or failure of the basic student pilot (subsequently called primary).

Procedure: A set of categories was developed for classifying comments on grade sheets. Following the initial tabulation, the classification scheme was refined. In addition the maneuver grades were analyzed. Data were also obtained from advanced single-engine flying training.

Results: Critical maneuvers showing greatest differentiation between successful and unsuccessful students were identified. Analysis beyond the identification of specific maneuvers was not attempted. With regard to comments, the following were made more frequently about unsatisfactory students: Poor learning and retention, unable to divide and distribute attention, lacking "feel" of the ship in flight, and poor coordination.

Fleishman, E. A. An evaluation of two psychomotor tests for the prediction of success in primary flying training. USAF Human Resources Research Center, Research Bulletin 53-9, 1953.

Purpose: To evaluate experimental tests as predictors of pilot training success for classes 52D through 52F.

Apparatus: Six-Target Rudder Control Test: A revision of test CM120C. The task is self-pacing, requiring that the subject shift to a new target after remaining on target for 3 sec.

Dynamic Balance Test: Consists of a board mounted on an axle much as a teeter-totter. On the base is a box with two rows of five lights each. One row is red and controlled by programming mechanism. The task is to match the programmed red series. A new red light is illuminated after a 0.5 second continuous match has been achieved.

Procedure: Six-Target Rudder Control: Since the Standard Rudder Control Test is a part of the regular test battery within which the experimental tests were administered, it was necessary to test half of the subjects after and half before performance on the standard test. Four two-minute trials were given.

Dynamic Balance: Four two-minute trials.

The experimental tests were given as part of the operational Air Crew Classification Battery, which included the following perceptual-psychomotor tests: Complex Coordination (CM701E), Rotary Pursuit (CM803B), Discrimination Reaction Time (CP611D), and Rudder Control (CM120C).

Indexes: Six-Target Rudder Control: Number of targets achieved.

Dynamic Balance: (a) number of matches, (b) time in correct position. Graduation-elimination from pilot training and standard indexes for the tests. In calculating validity coefficients, graduation-elimination in flying training with non-flying deficiency eliminations excluded was employed.

Results: Biserial r's were obtained for Standard administered first r-.38 (N-448), and for the Six-Target Test administered first the r was .33 (N=285). Odd-even reliability for the standard was .93 (corrected), while that for the Six-Targe was .95 (corrected).

Dynamic Balance: Biserial r's were .12 (N=620) for number of matchings and .11 (N-613) for time in correct position. Odd-even reliability was .86 and .82, respectively, for the two scores when corrected.

Intercorrelations with the other four psychomotor tests were

	CM120C	Six-Target	Dynamic Balance, Matches	Dynamic Balance, Time
CM701E	.44**	.38*	.22	.13
CM803B	.38**	.38*	.17	.11
CP611D	.15**	.24*	.12	.11
CM120C	.58**	.44*	.05	.01

* = Six first ** = Standard first

Fleishman, E. A. A factor analysis of intra-task performance on two psychomotor tests. *Psychometrika*, 1953, 18, 45-55.

Purpose: To determine the stages at which ability or abilities shift in importance, to determine at what stage the test is most complex and at which stage the tests measure one ability at a time.

Apparatus: The Standard Rudder Control (CM120C) and the Experimental Six-Target Rudder Control Tests. In the Rudder Control Test, the examinee sits in a mock cockpit of an airplane. His own weight throws the seat off balance unless he applies correction by means of rudder foot-pedals. Pushing the right rudder pedal causes the apparatus to swing to the left. The task is to keep the cockpit pointed directly at one of three target lights situated on the front panel.

The Experimental Six-Target Rudder Control Test involves the same apparatus as the Standard model, except that the examinee is provided with a panel of six target lights to which he must successively shift the apparatus as each is presented.

Procedure: The Standard Rudder Control Test and the Experimental Six-Target Rudder Control Test were administered to 698 pilot-cadets. In 356 cases the Standard was administered before the Experimental Model. In 342 cases the Experimental Model was administered first. The eight-minute testing period for the Standard Model was divided into six one-minute trials separated by 30-second rest periods. The Experimental Model test period was divided into four two-minute trials with a 30-second rest period. Separate scores were recorded at the end of each trial for each test.

Indexes: The score derived from the Standard Model was the total time the apparatus was held on target by the subject. The score derived from the Experimental Six-Target Model was the number of targets achieved by the subject (self-paced). The apparatus had to be held on target steadily for three seconds before a new target was presented.

Results: Four factors were extracted from the matrix of inter-trial correlations obtained when the Standard Rudder Control Test was administered first: Factor I, Precision Movement Under Speed Conditions (highest loading on the four trials of the Six-Target Rudder Control Test); Factor II, Steadiness-Control (common only to the six trials of the Standard Rudder Control Test, with the highest loadings derived from the first three trials; this factor does not appear in the four trials of the Experimental Six-Target Test); Factor III, Strength (common only to the last three trials of the Standard Rudder Control Test); Factor IV is residual unaccounted variance. The analysis of the matrix on the inter-trial correlations obtained from the Six-Target Rudder Control Test confirmed the same factor pattern as was obtained in the previous analysis.

The same factor pattern is found for the two tests, regardless of their order of administration. The first three trials on the Standard Test provide the best measure of the "Steadiness-Control" factor.

Fleishman, E. A. A factorial study of psychomotor abilities. USAF Personnel and Training Research Center, Research Bulletin 54-15, 1954.

Purpose: To describe the construction and factor analysis of a battery of 34 specially designed apparatus and printed psychomotor tests.

Apparatus: The following apparatus tests were employed: Precision Steadiness, Steadiness-Aiming (CM103E), Track-Tracing, Two-Plate Tapping (CM202A), Key Tapping, Ten Target Aiming, Rotary Aiming, Hand-Precision Aiming, Visual Reaction Time, Auditory Reaction Time, Minnesota Rate of Manipulation (both placing and turning), Purdue Pegboard (left hand, right hand, and assembly), O'Connor Finger Dexterity, Santa Ana Finger Dexterity (CM116A), Punch Board, Pin Stick, Dynamic Balance, Postural Discrimination (both vertical and angular), Rotary Pursuit (CM803B), Discrimination Reaction Time (CP611D2), Complex Coordination (CM701E), and Rudder Control (CM120C).

Procedure: Each of the experimental apparatus tests was administered to a different sample of 200 basic airmen. The printed tests were administered to a single sample of 200 basic airmen. The entire battery was then administered to a new sample of 400 basic airmen, with half receiving inverted order of test presentation. The data were subjected to a factor analysis.

Indexes: Standard indexes on the apparatus tests and on the eleven printed tests that were held to be of psychomotor variety.

Results: Twelve factors were identified. They were wrist-finger speed, fine or finger dexterity, rate of arm movement, aiming, steadiness, reaction time, psychomotor speed, psychomotor coordination, spatial relations, postural discrimination, a doublet factor confined to error, and correct scores on the Hand Precision Aiming Test. Psychomotor speed and the doublet factor are questioned as independent factors as this time.

Fleishman, E. A. Evaluations of psychomotor tests for pilot selection: The direction control and compensatory balance tests. USAF Personnel and Training Research Center, Technical Report 54-131, 1954.

Purpose: To evaluate experimental tests as predictors of pilot training success for classes 52G, 52H, and 53A.

Apparatus: Direction Control Test: An upright display panel containing 64 lights arranged in an 8 x 8 square and a response panel containing four toggle switches and two buttons. Subject is required to activate two response devices to reverse direction of the four light target, which is in the form of a cross with short upper arm indicating travel direction. For movements in a direction parallel to the side of the target matrix a switch and button combination is activated, while for a diagonal movement indication two switches must be activated. (SAM Code CP650A)

Compensatory Balance Test: The subject is required to control the progress of a steel ball through a ten choice point alley maze. The maze is mounted on a platform and the subject in seated position controls left-right tilt of the platform with pedals and up-down tilt through use of a wheel. The ball is returned to the testee at the end of a successful negotiation of the maze pattern (SAM Code CM510A).

Procedure: Direction Control: Four demonstrations; question period; four 2 min. test periods. Compensatory Balance: Four 2 min. test periods. The experimental tests were given as part of the operational Aircrew Classification Battery, which included the following perceptual-psychomotor tests: Complex Coordination (CM701E), Discrimination Reaction Time (CP611D), Rotary Pursuit (CM803B), and Rudder Control (CM120C).

Indexes: Direction Control: Number of patterns completed.

Compensatory Balance: Number Correct: for a given trial, passage of a point counts once only. Errors Score: number of entries to blind alleys. (Each entry was counted, even though the same alley was entered more than once on a given trial.) Smoothness: amount of jerky movement of platform recorded.

Results: Direction Control: A biserial $r = .34$ ($N = 936$) for flying deficiency eliminations and .33 ($N = 968$) all causes, each with $p = .01$.

Compensatory Balance: Reliability coefficients for Corrects = .90, for Errors = .78, and for Smoothness = .94 ($N = 1130$). The biserial r's for flying deficiency eliminations were, respectively .30 ($N = 990$), -.23 ($N = 1004$) and .01 ($N = 979$), and for all causes .27 ($N = 1022$), -.21 ($N = 1012$), and .00 ($N = 1010$).

Intercorrelations with the other four psychomotor tests were

	CP650A	CM510A Corrects	CM510A Errors
CM701E	.36	.33	-.12
CM611D	.41	.22	-.11
CM803B	.20	.30	-.09
CM120C	.16	.24	-.15

N=1003

Fleishman, E. A. Factor structure in relation to task difficulty in psychomotor performance. Educational and Psychological Measurement, 1957, 17, 522-532.

Purpose: To study aptitude patterns related to proficiency on a visual discrimination-and-reaction-psychomotor task and to evaluate the effect of varying task difficulty on the aptitudes assessed by the task.

Apparatus: This apparatus, called the Response Orientation Test, consists of a circular pattern of 16 lights and a circular pattern of 16 switches of the pushbutton variety. The light panel is arranged in the vertical plane and the response panel in the horizontal plane at table height. Reference arrows on each of the panels provide an index point. The panels can be rotated to place the reference arrows in any desired position. It is required that upon appearance of a light, the subject depress the corresponding pushbutton. Combinations of lights can be used, and a sequential response may be required.

Reference arrows may be moved from response to response. In addition, the Discrimination Reaction Time Test, (CP611D), the Complex Coordination Test (CM701E), and the Direction Control Test (CP650A) were used.

Procedure: In the present study 200 basic airmen were required to perform on the three apparatus tests and printed perceptual, spatial, and visualization tests. These printed tests were Aerial Orientation, Formation Visualization, Instrument Comprehension, Printed Discrimination Reaction Time, Pattern Comprehension, Spatial Visualization, Mechanical Principles, Speed of Identification, and Hands.

In the present experiment the stimulus pattern of the Response Orientation Test was rotated so that its reference arrow relative to that of the response device was at 0, 45, 90, 135, 180, 225, 270, and 315 degrees. Of the 200 subjects, 25 started at each of the eight stimulus positions and moved in a clockwise direction, being given four one-minute trials in each of the eight positions.

Indexes: Number of correct responses for each of the eight stimulus conditions on the Response Orientation Test and scores on the other paper and pencil and apparatus tests.

Results: As the divergence between the reference arrows increases on the Response Orientation Test, the number of correct responses declines. A factor analysis was carried out and six factors were extracted, i.e., spatial orientation, and perceptual speed as defined by loadings on the printed perceptual, spatial, and visualization tests. The fifth factor seemed specific to the Response Orientation Test and the sixth factor was a residual and devoid of psychological meaning. Certain factors appear to fall along a difficulty continuum.

Fleishman, E. A., and Hempel, W. E., Jr. Changes in factor structure of a complex psychomotor test as a function of practice. USAF Human Resources Research Center, Research Bulletin 53-68, 1953.

Purpose: To investigate changes in ability patterns which occur with practice in a complex psychomotor test and to attempt to identify the factors involved at different stages of performance.

Apparatus: Apparatus was the same as that used by Adams (1953).

Procedure: The data on 197 basic airmen were collected by Adams (1953). The performance on the criterion task was sampled by drawing eight blocks of five trials each from the 64 trials given on Complex Coordination Test. Only certain of the printed and psychomotor test data collected by Adams were used in this analysis. The psychomotor test data utilized were taken from the Rotary Pursuit Test (CM803B), the Plane Control Test (CM817B), the Discrimination Reaction Time Test (CP611D2), and from Nut and Bolt, Reaction Time, and Rate of Movement.

Only 12 of the printed tests were considered. A factor analysis was carried out on the 26 variables.

Indexes: Standard indexes on the tests and scores for each of the eight blocks of five trials on the Complex Coordination Test.

Results: Nine factors were identified - psychomotor coordination, rate of movement, spatial relations, perceptual speed, visualization, mechanical experience, numerical facility, psychomotor speed, and a factor specific to the practice stages on the criterion test. Considerable change was noted in factor structure over the eight blocks of trials on the Complex Coordination Test. Non-motor factors were important at early stages and motor factors important at later stages. Factor structure becomes stable toward the end of training.

Fleishman, E. A., and Hempel, W. E., Jr. A factor analysis of dexterity tests. Personnel Psychology, 1954, 7, 15-32.

Purpose: To identify factors contributing to individual differences in manipulative skill evidenced in dexterity tests.

Apparatus: Ten apparatus tests: O'Connor Finger Dexterity, Purdue Pegboard-Right Hand, Purdue Pegboard-Left Hand, Purdue Pegboard-Both Hands, Purdue Pegboard Assembly, Minnesota Rate of Manipulation - Turning, Minnesota Rate of Manipulation - Placing, Santa Ana Dexterity, Punch Board, Pin Stick, and five printed tests; Tapping-Large, Tapping-Small, Square Marking, Tracing, and Marking Accuracy were used. The tests were given to a sample of 400 basic airmen.

Indexes: Standard indexes for each of the tests. All tests had time limits.

Results: Six factors were extracted from the correlation matrix by Thurstone's Centroid Method. Factor extraction was continued beyond the point where any meaningful factor variance was suspected to remain.

Interpretation of Factors

I. Finger Dexterity or Fine Dexterity - ability to coordinate finger movements in performing fine manipulations.

II. Manual Dexterity - ability to make skillful arm and hand movements.

III. Wrist-finger Speed - ability to make rapid wrist flexing movements and finger movements.

IV. Aiming - ability to perform quickly and precisely a series of movements requiring eye-hand coordination.

V. Positioning (tentative identification) - the distinction from the aiming factor is not clear. The ability seems to involve precision of single localized discrete responses.

VI. Residual Factor

The analysis confirmed previous findings of the distinction between the Finger Dexterity and Manual Dexterity and between Tapping and Aiming Factors. Pin Stick and Purdue Pegboard-Left Hand seem to be the best measures of Wrist-finger Speed and Finger Dexterity, respectively. The three printed tests, Square Marking, Marking Accuracy, and possibly Tracing seem to be better measures of Aiming. The Minnesota Rate of Manipulation subtests are saturated with Manual Dexterity. Performance on the Santa Ana Dexterity Test is determined by Wrist-finger Speed and Manual Dexterity. Low communalities of tests indicate that there is still unexplained variance contributing to these tests.

Fleishman, E. A., and Ornstein, G. N. An analysis of pilot flying performance in terms of component abilities. Journal of Applied Psychology, 1960, 44, 146-155.

Purpose: To ascertain the basic factors involved in performance of 24 flight maneuvers making up the syllabus in basic flying training in the T-6 aircraft.

Apparatus: T-6 Trainer

Procedure: Data for each of the 24 maneuvers were scored for each student pilot on four successive days. The score for each maneuver was the sum of scores for the four separate trials. Data were subjected to a factor analysis using the method of Thurstone for orthogonal rotation.

Indexes: Correct and incorrect items within a maneuver.

Results: Factor interpretations include loadings above .30.

Factor I — Control precision, originally called Coordination I or fine control sensitivity

Factor II — Spatial orientation, designated as judgment of one's position in three dimensional space

Factor III — Multilimb coordination, in previous studies called Psychomotor Coordination II

Factor IV — Response orientation, called ability to make rapid response decisions under rapidly changing stimulus conditions

Factor V — Rate control, involved in responses to anticipation of velocity and rate changes

Factor VI — Kinesthetic discrimination, involved in maneuvers emphasizing stalls and slow movements of the aircraft.

The factor content in terms of maneuvers and their loadings are given.

Fleishman, E. A., and Rich, S. Role of kinesthetic and spatial-visual abilities in perceptual-motor learning. Journal of Experimental Psychology, 1963, 66, 6-11.

Purpose: To test the hypothesis that as performance becomes habitual, kinesthetic cues are of prime importance in motor learning. Also, to test the hypothesis that early in learning spatial-visual abilities would play a dominant role but decrease in importance as practice continued.

Apparatus: (a) A set of weights 100, 102, 104, 106, 108, 110, and 112 grams of standard volume, (b) USAF Aerial Orientation Test, and (c) Two-Hand Coordination Test (CM101B).

Procedure: Forty male subjects had their DL (Difference Limen) for weights determined, took the Aerial Orientation Test and were given 40 1-minute trials on the Two-Hand Coordination Test. Trials were usually separated by 15-second rest, but a rest period of 1 minute was given after trials 8, 16, and 32.

Indexes: Time on target for Two-Hand Coordination Test, DL for lifted weights, and number right for the Aerial Orientation Test.

Results: Correlation between the DL and number right on the Aerial Orientation Test was not significant (r = .12). Both Aerial Orientation and DL were correlated with Two-Hand Coordination Score, being respectively .49 and .58. A multiple R of .73 results when the tests are combined in prediction of Two-Hand Coordination score. Correlations of Two-Hand Coordination performance decrease with the spatial measure and increase with the kinesthetic measure as practice accumulates.

Flyer, E. S., and Bigbee, L. R. Primary flying grades, pilot stanines, and preflight peer nominations as predictors of basic pilot training criteria. USAF Personnel and Training Research Center, <u>Technical Memorandum</u> 55-17, 1955.

Purpose: To assess methods of student appraisal during primary flying training through examination of relationships among primary phase grades and their validities for predicting performance during basic flying training.

Procedure: Collect primary flying performance data as obtained by the schools, intercorrelate these measures, and determine the validity of these factors, the pilot stanine, and peer nominations as predictors of basic flying grade and graduation versus elimination.

Indexes: Estimates of flying performance converted into stanine distributions to facilitate analysis.

Results: Data were available for 269 primary graduates, of whom 15 were eliminated in basic for flying deficiency and 31 for other reasons. Data for both single- and multi-engine were combined. Validities were as follows:

Primary Data: Pearson r's	Instructor Assigned Primary Overall Grade (N=269)	Check Pilot Assigned Primary Grade (N=228)
Pilot Stanine	.29**	.17*
Light Plane Grade	.42**	.15*
T-6 Grade	.72**	.29**
Instrument Grade	.67**	.24**
Acrobatic Grade	.62**	.13
Primary Overall Grade		.26**

Basic Data: Biserial r's	Total Elimination	Flying Deficiency Elimination
Pilot Stanine	.19*	.36**
Light Plane Grade	.41**	.54**
T-6 Grade	.31**	.40**
Instrument Grade	.35**	.47**
Acrobatic Grade	.11	.33**
Primary Flying Grade	.37**	.60**
	N = 46	N = 15

* p equal to or less than .05
** p equal to or less than .01

Flyer, E. S., and Bigbee, L. R. Light plane proficiency ratings as a selection device for AFROTC pilot trainees. USAF Personnel and Training Research Center, Technical Memorandum 55-38, 1955.

Purpose: To evaluate a light plane program as a predictor of success in primary and basic flying training in combination with AFOQT stanine for AFROTC pilot trainees.

Procedure: Light plane performance ratings were given by both instructor and check pilots at about the 20th hour of light plane training through use of a rating scale. The AFOQT was administered as part of pre-primary processing but was not used for selection purposes. Interrelationships among AFOQT pilot stanine scores, instructor, and check pilot light plane grades were obtained, as well as their validities in predicting graduation versus total elimination. Score combinations were also evaluated.

Indexes: Instructor and check pilot ratings for light plane training, AFOQT stanines, and elimination in either primary or basic flying training.

Results: Data were available on 130 AFROTC students who were given light plane training and subsequently entered primary flying training. Eleven students were eliminated in light plane training. Of the 130 students entering primary flying training, 101 graduated from basic training. The eliminees were distributed as follows: flying deficiency in primary training, 11; flying deficiency in basic training, 6; other types of elimination, 12. All eliminations are grouped for purposes of analysis.

Validities were as follows: $\underline{N} = 130$

Variables			Biserial r's
AFOQT Pilot Stanine[a]			.58**
Check Pilot Grade			.29*
Instructor Grade			.48*
Composite[b]	:	Stanine, Instructor and Check Pilot Grades	.62**
Composite	:	Stanine and Instructor Grade	.66**
Composite	:	Stanine and Check Pilot Grade	.58**
Composite	:	Instructor and Check Pilot Grade	.44**

[a]When the 11 light plane eliminees are added the $\underline{r}$ = .63

[b]Composites are unit weighted

Gordon, T. The airline pilot: A survey of the critical requirements of his job and of pilot evaluation and selection procedures. Civil Aeronautics Administration, Division of Research, Report No. 73, 1947.

Purpose: To obtain information concerning (a) the critical requirements of the job of airline pilot, (b) the methods of selecting airline pilots, (c) the methods of evaluating airline pilots, (d) the critical situations in airline flying and their causes, and (e) pilot fatigue.

Procedure: Survey methods utilized with pilots, CAA examiners, company check pilots, CAB accident reports, and airline company personnel files to determine critical incidents.

Indexes: Cumulative frequencies of critical incidents.

Results: Critical incidents elicited led to the specification of a number of traits which differentiated good pilots from poor pilots. While a wide variety of traits were given, certain of these traits appear to be factors of a perceptual-psychomotor nature. These features were (a) inadequate thinking and learning, (b) inability to attend or remain alert, (c) slow reaction, (d) carelessness and tendency to err frequently, (e) tendency to become confused, (f) inability to divide attention, (g) lack of coordination between knowledge and skills, and (h) lack of motor coordination. Evaluation of tests in current use by airline companies, none of which were of the perceptual-psychomotor variety, were found to be ineffective in distinguishing between eliminated and non-eliminated pilots.

Gordon, T. The airline pilot's job. Journal of Applied Psychology, 1949, 33, 122-131. Contains selected portions of Civil Aeronautics Authority, Division of Research Report No. 73 by the same author.

Jackson, K. F. Behavior in controlling a combination of systems. Ergonomics, 1958, 2, 52-62.

Purpose: To determine how alteration of the characteristics of the task affects the pattern of the operator's performance and how far and by what means he can overcome increases in the difficulty of the task by adaptation.

Apparatus: A test apparatus was designed to present 1-5 tracking tasks at a time. The console had five dials and five knobs. Each knob was a positional control for its corresponding dial.

Disturbances were simple harmonic misalignments of the pointers of one cycle per minute with maximum amplitude of ± two scale divisions or ± 4.5° of angular movement. The pointers had to be corrected to their center zeros by the subject. The disturbances were arranged to be out of phase with each other.

Procedure: Twenty subjects were tested. They controlled one, two, three, four, or five pointers at one time with one hand. The subjects were instructed to work systematically round the set of controls and dials in use, giving each equal attention and to try to keep the pointers at zero. Each subject after practice worked at each number of dials for five minutes.

Indexes: Measurements were made of the integrated mean error for the corrective movements and the interruption periods for each separate control system: duration of error, duration of corrective movements, and number of corrective movements made during each session were recorded.

Results: All measures differed significantly between different numbers of dials. The amplitude of control movements increased with the number of dials. The duration of the control movements decreased with more dials, flattening off between four and five dials. The average speed of control movement increased in direct proportion to the number of dials and showed no flattening. The duration of these movements decreased as the number of dials increased. The frequency with which both the control movements and movements from dial to dial were made also increased with the number of dials. Subjects operating on two or three dials had a tendency to anticipate the coming disturbance and allow for it in advance. As the number of dials to be controlled increased, this forward-looking behavior became less evident in the results. Speed of work as an adaptation process was not exhausted in this study inasmuch as speed of control movement showed no signs of falling off.

Kalsbeek, J. W. H. On the measurement of deterioration in performance caused by distraction stress. Ergonomics, 1964, 7, 187-195.

Purpose: To describe the deterioration in performance of complex behavior patterns caused by dual tasks involving different central and effector mechanisms.

Apparatus: The apparatus presented the subject with a series of two tones, 2000 cps. or 250 cps. to which he had to respond by pressing a pedal with the right or left foot, respectively.

The secondary task consisted of a metal plate containing five rows of twelve holes. Each row of holes was of a different diameter and, thus provided the following clearances between the hole and the rod which was to be inserted: 0.09, 0.57, 0.13, 0.20, and 0.21 mm. The rods were inserted in a different row of holes on each trial.

Procedure: Eleven subjects, five for Experiment I and six for Experiment II, who were postal employees ranging in age from 25 to 40 years were administered the tests under two conditions: unpaced and paced.

The tones were presented in random order either at regular intervals (paced condition) or with the new stimulus being presented immediately after the subject had responded to the previous one (unpaced condition). The subjects were instructed to give preference to the tone task when both tasks were presented simultaneously.

In Experiment I, Unpaced Condition, the primary task (tone task) was unpaced and three conditions of the secondary task (rod and plate task) were used: (1) remove the rods from the plate and place them in a box, hidden from view; (2) remove the rods from the box and place them in the plate (rods were prearranged in the box according to size); and (3) the procedure was the same as (2) but the rods were placed in the box at random. These conditions resulted in observations of (1) movement alone, (2) movement together with positioning, and (3) movements together with both positioning and choice.

Indexes: Increase in the time taken to handle the 60 rods, decrease in the number of responses per minute, and errors made in the tone task.

Results: Experiment I

Condition (1) Movement

Movement time was increased from 75 sec. to 103 sec. Decrease in the number of responses to tones from 68 to 58.

Condition (2) Positioning

Positioning time showed no significant difference with or without tone task. The number of responses to tones showed no decrease.

Condition (3) Choice

Choice time showed no significant difference with and without tones. The number of pedal pushings were decreased which provided more decision-free moments.

Experiment II

The same procedure was used as in Experiment I except the tone task was paced at the maximum which the subject could handle in condition (1) of the dual task without making more than two errors per three minutes. The speeds used were 36, 45, 45, 48, 55, and 55 tones per minute at uniform intervals.

The increase in time was significant for movement but not for positioning time or choice time. The errors plus omission scores showed a significant increase from condition (1) to (3) but not from (1) to (2) or (2) to (3).

The results were interpreted in terms of the "single channel" hypothesis, that decisions and the monitoring of movements have to take place successively. When both tasks require choices, it appears that extra time can no longer compensate for the difficulty and errors occur.

Kelley, C. R.; Bishop, E. W.; Beum, C. O.; and Dunlap, J. W. Pilot selection: An evaluation of published techniques. Office of Naval Research Contract N8onr-641, Task Order 06, 1951.

An evaluation of published techniques for the selection of pilots covering the period from World War I to date with emphasis on the decade from 1939-1949. Consideration is given to both printed and perceptual-psychomotor tests. The Rudder Control Test and the Complex Coordination Test are recommended for inclusion in a selection battery for use in Naval Aviation in addition to paper and pencil tests. Research necessary to the development of the test battery is outlined.

Kolesnik, P. F. Effects of extensive training on linear interpolation. Perceptual and Motor Skills, 1958, 8, 247-249.

Purpose: To determine the beneficial effects of extensive training on ability to interpolate linear extent.

Apparatus: A movable marker, which can be positioned on a 10 mm. scale by means of a knob, is moved by the subject. The linear distance that the marker is to be moved is given in tenths of total range. The position of the movable marker, in hundredths of mm., is indicated to the experimenter by the projection of a beam of light on a magnified scale.

Method: Twenty-one subjects were required to make 144 settings at each session, (16 at each tenth) in random order for the pretest. No knowledge of results was given in the two sessions. After the pretest six sessions of 144 settings were given to each subject over a three weeks' period with knowledge of results given after each setting. These sessions were considered as training sessions. The posttest session trials were identical to the pretest except the subjects were given five sessions of 144 settings, one session per week, without knowledge of results.

Indexes: Mean deviation for each of the nine positions (bias) and mean deviation for all positions (overall bias) in hundredths of mm.

Results: Practice without knowledge of results in the pretest produced no reduction in overall bias. The training sessions produced a reduction in bias which was immediate but temporary as evidenced by the posttest results. Variability was only slightly affected by training and individual differences in overall bias and variability were apparent.

Lane, G. G. Studies in pilot selection. I. The prediction of success in learning to fly light aircraft. Psychological Monographs, 1947, 61, 1-17.

The Mashburn Serial Reaction Apparatus, the Two-Hand Coordination Test, and the Judgment Reaction Test, supplemented by paper and pencil tests, were evaluated as predictors of success in light plane flying training under civilian auspices. Thirteen separate criteria were used and the multiple coefficients ranged from .512 to .707 for the tests used as a battery. Overall ratings in flight performance rather than ratings of individual maneuvers were predicted best.

Leiman, J. M., and Friedman, G. Validation of Aircrew Classification Battery against advanced flying training - single engine jet - criterion. USAF Human Resources Research Center, Research Note PERS: 52-2, 1952.

Purpose: To validate a battery of tests against advanced flying training - single engine - jet (this phase of flying training was subsequently renamed - basic).

Apparatus: SAM Rotary Pursuit with Divided Attention (CP410B), Rudder Control (CM120C), Finger Dexterity (CM116A), Complex Coordination (CM701E), Two-Hand Coordination (CM101B), and Discrimination Reaction Time (CP611D).

Procedure: These tests were administered in the context of a test battery containing other tests of the paper and pencil variety to an intake population of 894 students. Comparative data on another sample against basic (later primary) training is included.

Indexes: Graduation-elimination in jet flying training and the standard indexes for the tests.

Results: Of the 894 cases, 140 were eliminated for all reasons. Of these eliminees, 90 were for flying deficiency, 28 for motivational reasons, and 22 for miscellaneous reasons. In comparison with the basic sample the differences in beta weights would indicate that somewhat different abilities are involved in the two sorts of training.

	894 Jet Students		2644 Basic Trainees	
Tests	Biserial r	Beta weights	Biserial r	Beta weights
CP410B	.15	.09	.19	.03
CM120C	.18	.07	.47	.25
CM116A	.06	-.01	.12	.01
CM701E	.19	.02	.27	-.03
CM101B	.19	.06	.28	.04
CP611D	.16	.03	.22	-.03

Lewis, R. E. F. Consistency and car driving skill. British Journal of Industrial Medicine, 1956, 13, 131-141.

Purpose: To determine the consistency of performance of groups of skilled and unskilled drivers during a standard driving task.

Apparatus: The experimental car was a series E, 1947 Morris 10 Saloon equipped with a forward-facing single shot camera which took a picture of the road ahead, the dashboard instruments, and a Tapley accelerometer every five yards of distance travelled. The test course was an airfield with runways forming an equilateral triangle with 120° turns. The roadway lanes were 15 feet wide. At a point 150 yards before and after each corner, a recognizable mark was painted on the road surface.

Procedure: The subjects were ten skilled police driving instructors or motor patrol drivers, ten skilled rally drivers, not police trained, and ten unskilled drivers who had driven for at least three years and were considered to drive in a manner below average.

After a practice and car familiarization period, the subjects were instructed to negotiate two turns to the right, turn around and negotiate the two turns to the left, staying within the 15 foot roadway. Questions of speed and time were answered by stating that requirement was to drive "comfortably." All subjects were retested under the same procedure six weeks later.

Indexes: Difference between acceleration readings on test and retest trials.

Results: The film records of acceleration were analyzed frame by frame over 61 readings obtained over 150 yards before and 150 yards after each turn at five yard intervals. Over the test-retest trials, an analysis of variance showed significant differences (p less than .01) between the mean consistency scores for the three groups. No significant difference was observed between police and rally drivers. A further analysis of variance of inconsistency scores between consecutive corners within one day for the three groups revealed no significant differences between groups, although the unskilled drivers still appeared to be less consistent.

Differences in acceleration patterns were observed. The police drivers decelerated smoothly approaching the corner and accelerated around and away from the corner. The rally drivers were similar in acceleration patterns although they differed among themselves. The unskilled drivers showed frequent reversals in approach acceleration patterns which were believed to demonstrate the role of "anticipation" in skilled performance.

Majendie, A. M. A. Pilots and monitors, automatic and human. In Barbour, A. B., and Whittingham, H. E. (Eds.) Human Problem of Supersonic and Hypersonic Flight. London: Pergamon, 1962, 209-219.

Conventional subsonic aircraft have been provided with automatic systems which have been designed to ease the workload rather than be an extension of the operator's capabilities. Supersonic and hypersonic automatic aircraft systems will extend the capabilities beyond that of a human operator. Humans will then be required to (a) perform when extreme flexibility is needed and when the task cannot be adequately predicted, (b) when intervention not connected with the task is required and discretion must be exercised, and (c) when the automatic devices would not be economical. The author stresses the point that man may be provided with too much information to perform adequately and points out the incipient divergence which occurs in a pursuit as opposed to a compensatory tracking situation.

Manning, R. V., and Yellowlees, L. A. RCAF aircrew selection methods. Journal of Aviation Medicine, 1949, 20, 58-61.

A report concerning the selection procedures used in the period following World War II up to the date of the report. The Visual Link Test is cited as the largest component of the aptitude battery. The use of the test is defended by reference to World War II success and because it seems to possess potential beyond that previously in evidence. It is suggested that in the procedure of fractionating the tasks of aircrew and devising tests for them an important quality has been neglected - the necessity of performing complex motor and mental tasks concurrently in a stressful environment. Emphasis is placed upon the breakdown in the organization of performance. No data are reported.

McGehee, W. Survey of psychological problems and services in Naval Aviation. National Research Council Committee on Aviation Psychology, Report No. 12, 1951.

Report of an interview type survey concerning psychological services which are necessary to improvement of Naval aviation. Particularly of significance in the present context were his findings in the areas of proficiency measurement and job analysis. In each of these areas a dearth of information was found to exist and the author commented to the effect that improvement of selection and classification procedures and improvement of training were dependent upon the development of such information.

Mowbray, G. H., and Rhoades, M. V. On the reduction of choice reaction times with practice. Quarterly Journal of Experimental Psychology, 1959, 11, 16-23.

Purpose: To determine the reduction in choice reaction time with extended practice.

Apparatus: Ten small pea-lamps were spatially arranged on a display panel corresponding spatially to two groups of five pushbuttons, each appropriately spaced for a left-hand and a right-hand operation. Stimuli were programmed randomly by a tape transport mechanism under a restriction that each response was equally required within trials and no one response would be required more than three times in succession. The reaction times were recorded to the nearest 10 msec. There were 3000 reaction times per trial or a total of 45,000 reaction times for the entire experiment.

Procedure: Only one subject, 22 years of age, was used. The two-choice and four-choice reaction was presented alternately throughout the test sessions. No session lasted for more than an hour with frequent rest periods interspaced. The subject was instructed to react as quickly as possible.

Indexes: In analysis of the data only the reaction time from the index finger of the left hand was used. The number of wrong responses was also observed.

Results: Reaction time in both the two-choice and four-choice condition decreased as did the errors number (wrong response) and variability. After the thirteenth session no significant differences were observed between each condition. The two-choice reaction time decreased more rapidly than the four-choice.

It was concluded that choice reaction times are significantly affected by practice. Information theory concepts would predict that reaction time would increase with increasing number of alternatives and, therefore, no application seems to be apparent in the choice motor responses of this study.

Mukherjee, B. N. Learning efficiency in a psychomotor test as a function of initial skill. Engineering and Industrial Psychology, 1959, 1, 138-142.

Purpose: To determine how different measures of learning are related to the initial level of ability.

Apparatus: A two-hand coordination tracking test. The total length of the tracking path through which the testee had to move a pin was 18 cms. The movement was accomplished by rotating two crank handles.

Procedure: Sixteen college students were divided in performance level quartiles based upon scores on a 5-trial try-out session. Each subject received 20 trials on each of five successive days during the experimental period.

Indexes: Total time to traverse path and number of errors (pin touching the side of the path).

Results: The learning curves for the second and third quartile (middle ability groups) converged although they were initially separated. The group rates of learning varied unpredictably. It was found that subjects with superior initial ability on skills required by the test reached criterion sooner and maintained the highest level of proficiency at the end of the trial. Group learning rates converged. Final levels of performance for the four groups differed significantly at the end of the trials.

Nagay, J. A. The airline tryout of the standard flight-check for the Airline Transport Rating. Civil Aeronautics Administration, Division of Research, Report No. 88, 1949.

Purpose: To accomplish a tryout of the third revision of the standard flight-check.

Procedure: Each pilot was given two check flights, on successive days where possible. The first check flight was observed by two check pilots and the second flight by a third check pilot. All check pilots used the standard rating form. In addition to the check pilots, the first flight was checked by a Civil Aeronautics inspector or a designee while the second flight was checked by two qualified individuals.

Indexes: Ratings of flight performance by either the standard check or the usual Civil Aeronautics authority check.

Results: Thirty-two pilots were checked. Ride-ride reliabilities for the flight checks were $\underline{r}_t$ = .89 ($\underline{N}$=40) for the standard and $\underline{r}_t$ = .35 ($\underline{N}$=43) for the CAA flight test report.

Nagay, J. A. Revisions of the standard flight-check for the Airline Transport Rating based on the airline tryout. Civil Aeronautics Administration, Division of Research, Report No. 89, 1950.

This report presents a final revision of the standard flight-check resulting from suggestions made by participants in the airline tryout.

It led to the development of a user's manual and revisions to render the flight check suitable for operational use.

Nagay, J. A. A study of the semi-annual instrument check for airline pilots. Civil Aeronautics Administration, Division of Research, Report No. 93, 1950.

This report provided a review of the semi-annual instrument checks of 18 of the major airlines. It was found that there is little agreement among airlines as to what pilot skills need to be checked periodically. The procedures used in checking do not provide precise standards or clear instructions as to what is to be done.

Ornstein, G. N. Stanine as a predictor of pilot performance on specific maneuvers. USAF Personnel and Training Research Center, Basic Pilot Research Laboratory, Laboratory Note 54-1, December 1954 (Unpublished draft).

Performance scores on 44 maneuvers required in experimental Primary Pilot Training Program were correlated with the pilot stanine for each of the performers who were graduates of the program (*N*=63). Thirty of the maneuvers were of the contact variety and 14 were classified as instrument maneuvers. When the correction was made for the unreliability of the criterion and a perfect criterion assumed, the correlations showed a differential validity for the stanine in predicting maneuver performance.

Parker, J. F. Jr., and Fleishman, E. A. Ability factors and component performance measures as predictors of complex tracking behavior. Psychological Monographs, 1960, 17 (Whole No. 503).

Purpose: To investigate the relationships between ability variables and progress in learning a complex perceptual motor skill; and to compare the predictability of terminal performance from earlier scores.

Apparatus: A battery of 20 printed tests, 29 apparatus tests, and a criterion tracking task were used in this study. The criterion task required the subject to maintain a target dot at the center of an oscillograph with a control stick and the centering of a pointer on a voltmeter type display by means of foot-operated simulated rudder controls. All turning movements required coordinated action of the stick and rudder controls.

Procedure: The battery of tests were administered in 3 two-hour sessions for the printed tests and 5 one-hour sessions for the apparatus tests.

Each subject was given an indoctrination to the criterion task and allowed 5 to 10 seconds of practice. Each of the subsequent 17 practice sessions on the criterion tracking task consisted of 21 1-minute trials, making a total of 357 trials. For each session the scores of the first three trials were discarded to avoid warmup effect. The remaining eighteen trials were subdivided into three groups of six trials each for 51 time segments for the full period of practice.

Indexes: Fifty different scores were obtained on the Reference Battery Tests. The indexes on the criterion task were integrated absolute error score, azimuth (yaw) part score, elevation (pitch) part score, slideslip error part score, and time-on-target score.

Results: A factor analysis of the battery of tests resulted in the following factors:

Spatial Orientation, Control Precision, Speed of Arm Movement, Manual Dexterity, Reaction Time, Verbal Comprehension, Arm-Hand Steadiness, Perceptual Speed, Integration (Coordination of units to produce an integrated response), Pursuit Confusion Doublet (not interpretable), Mechanical Experience, Finger Dexterity, and Multilimb Coordination.

The abilities represented by the battery of tests accounted for only as much as 25 percent of the terminal tracking performance variance. The initial component measures of the criterion task were not predictive of final performance.

It was concluded that motor abilities alone do not determine differences in tracking proficiency and analysis of target motion and prediction of the appropriate response may be more important.

Parry, J. B. The selection and classification of R.A.F. aircrew. Occupational Psychology, 1947, 21, 158-167.

A summary of the program of the R.A.F. from 1939 through the end of World War II. The program was characterized by interviewing only in 1939, first testing in 1940, testing in a short flight course in 1942 (grading), aptitude testing for specialties in addition to those of pilot, using 18 paper and pencil and 5 apparatus tests in 1944. The tests are described by name only, and the Finger Dexterity Test is the only apparatus test for which direct credit is given the USAF, although the remaining tests appear from their names to be similar to those used in the United States. Validity data are sparse and incomplete.

Payne, R. B., Rohles, F. H., Jr., and Cobb, B. B., Jr. The pilot candidate selection program. IV: Test validities and intercorrelations. USAF School of Aviation Medicine Project No. 21-29-008 U. S. Navy Project No. NM001-057 Report No. 4, 1952.

Purpose: To evaluate experimental tests and the Air Force Aircrew Selection Battery tests as predictors of pilot training success in Naval flight training.

Apparatus: SAM Plane Control Test (CM817B), SAM Multidimensional Pursuit Test (CM813E), SAM Rate Control Test (CM825A), Santa Ana Finger Dexterity Test (CM116A), SAM Rotary Pursuit Test with Divided Attention (CP410B), SAM Discrimination Reaction Time Test (CP611D2), SAM Two-Hand Coordination Test (CM101B), SAM Complex Coordination Test (CM701E), SAM Rudder Control Test (CM120C), SAM Direction Control Test (CP650A), SAM Single-Dimension Pursuitmeter (CM801B6), SAM Compensatory Balancing Test (CM510A), SAM Controls Orientation Test (CP638A), SAM Pursuit Confusion Test (CM702B), SAM Rudder Reaction Test (CM507A2), Complex Timing Reaction Test with Memory for Procedures (CI511A), SAM Drift Correction Test (Paced) (uncoded), SAM Self-Pacing Discrimination Reaction Time Test (CP611E2), and Complex Multiple Reaction Test (CP612AX1).

Procedure: The experimental tests were given as part of a test battery containing other tests of the paper and pencil variety to an intake population of 2,126 midshipmen about to enter flying training. The standard test administration procedure for the tests was employed.

Indexes: Graduation-elimination from flying training (flying deficiency only) and standard indexes for the tests.

Results: The number of cases differs from test to test for various reasons, though intercorrelations on the apparatus tests are based on no fewer than 595 cases and many of the sample sizes run in excess of 1000 cases. All tests were not given to all examinees since two routes were used; thus the correlations were separated by route in order to eliminate any confounding effects.

Of the new tests, five showed some promise. They were CM817B, CP650A (correct score), CM510A (rights score), CM702B (time on target), and CI511A (gates and procedures scores). The validity of these tests, along with those perceptual-psychomotor tests used previously in the selection battery, are shown below as biserial r's.

	Route 1		Route 2	
	r	N	r	N
CM817B	.27*	636	.29*	667
CM116A	.11*	685	.05	678
CP410B	.37*	683	.26*	679
CP611D2	-.26*	658	-.24*	650
CM101B	.41*	674	.34*	660
CM701E	.45*	676	.32*	669
CM120C	.42*	681	.49*	668
CP650A	.31*	529	.28*	521
CM510A	.24*	518	.37*	510
CM702B	.35*	648	.26*	639
CI511A (gates)	.27*	668		
CI511A (procedures)	.30*	668		

*p equal to or less than .01

The attempt by use of Navy pencil and paper tests to accomplish measurement of perceptual-psychomotor functions yielded validities that were in the range from .08 to .18.

Poulton, E. C. On increasing the sensitivity of measures of performance. Ergonomics, 1965, 8, 69-76.

Purpose: To attempt to formalize the procedures of increasing the sensitivity of performance measures.

Summary: The methods by which the sensitivity of a performance test may be increased are listed below:

(1) Adjusting the difficulty of the task

The test should not be so difficult that performance measures are at a chance level nor so easy as to prohibit observation of enhanced behavior.

(2) Saturating the man's channel capacity

If the task is easy and the difficulty level fixed, a concurrent secondary task may be used providing that it is compatible to the sensory and response channels of the primary task and does not produce associative interference.

(3) Using an unfamiliar task

A relatively easy task may be used provided it is unfamiliar to the subject. It may require high-level organization of behavior.

(4) Measuring variability

The mean performance measure may not reflect changes in the independent variable, but the variability of the responses may have increased or decreased.

(5) Selecting specific events

Observation of specific events in performance rather than continuous observation may produce less contamination of the results.

(6) Examining component measures

Overall measures of performance may not reflect changes in component measures.

(7) Channeling two dimensions of variability into one

When errors are produced on two separate measures, neither may reflect the effect of the independent variable. The sensitivity of the task may be increased by channeling the error into one dependent variable.

The methodological difficulty in drawing inferences from changes in performance measures as a result of variation in the independent variable was discussed.

Rimoldi, H. J. A., and Cabanski, S. Temporal organization of behavior, Journal of Psychology, 1961, 51, 383-391.

Purpose: To investigate some characteristics of personal tempo (temporal pattern that subjects adopt spontaneously when engaged in performance of a task) in a restricted experimental situation.

Procedure: Fifteen subjects (11 males and 4 females) were given 5" x 7" cards containing patterns of dots varying from 1 to 10 dots with variable spacing. Seventeen cards were used, with 5 subjects given one order, 6 subjects given the inverse, and four subjects a random order. All subjects were given the single dot pattern first. Subjects were instructed to tap the pattern shown on a card in their most "natural" congenial manner and to continue tapping the pattern until told to stop. A telegraph key was employed and subjects' responses were recorded on a kymograph.

Index: Length between depressions which can be converted to time.

Results: The duration for tapping a group of dots increases as the number of dots in a group increases. Each dot appears to have a time value independent of the pattern in which it occurs. The separation between groups of dots remains constant, though the gaps between groups varied on the cards presented the subjects.

Roff, M. F. Personnel selection and classification procedures: Spatial tests. USAF School of Aviation Medicine, Project No. 21-29-002, Final Report, 1951.

Purpose: To carry out factor analyses (both orthogonal and oblique rotations) of tests which are concentrated in the spatial-manipulation-cognitive area as an aid to the use of these tests for selection purposes.

Apparatus: Rotary Pursuit (CP410B), Rudder Control (CM120B), Finger Dexterity (CM116A), Complex Coordination (CM701A), Two-Hand Coordination (CM101A), and Discrimination Reaction Time (CP611D).

Procedure: These tests were administered within the context of a battery of 65 tests of varieties other than perceptual-psychomotor. The standard procedure for administering the tests was employed.

Indexes: Graduation-elimination from flying training and the standard indexes for the tests were used.

Results: The Aircrew Classification Battery supplemented by experimental tests provided five test batteries. The Aircrew Classification Battery was given to 8,158 subjects and each grouping of experimental tests was used on slightly in excess of 1,500 subjects.

A psychomotor factor with the following loadings emerged: CP410B = .53, CM101A = .52, CM701A = .49, CM120B = .46, CM116A = .31, and CP611D = .20. Perceptual speed and complex reaction time factors emerged, though these were measured in the current context with paper and pencil tests.

Roff, M. The pilot candidate selection research program, V: A factorial study of the motor aptitudes area. USAF School of Aviation Medicine. Project Number 21-29-008. Report No. 5, 1953.

Purpose: To provide a factorial analysis of data collected under the combined Air Force-Navy selection research program and to supplement previous work involving factorial studies of space thinking and perceptual performance carried out by the same author.

Apparatus: SAM Plane Control Test (CM817B), SAM Multidimensional Pursuit Test (CM813E), SAM Rate Control Test (CM825A), Santa Ana Finger Dexterity (CM116A), SAM Rotary Pursuit Test with Divided Attention (CP410B), SAM Discrimination Reaction Time Test (CP611D2), SAM Two-Hand Coordination Test (CM101B), SAM Direction Control Test (CP650A), SAM Single-Dimension Pursuit-meter (CM801B6), SAM Compensatory Balancing Test (CM510A), SAM Controls Orientation Test (CP638A), SAM Pursuit Confusion Test (CM702B), SAM Rudder Reaction Test (CM507A2), Complex Timing Reaction Test with Memory for Procedures (CI511A), Drift Correction Test (uncoded), SAM Self-Pacing Discrimination Reaction Time Test (CP611E2), and Complex Multiple Reaction Test (CP612AX1).

Procedure: These perceptual-psychomotor tests were administered within the context of a battery of classification tests including some tests devised by the Navy, using the standard test administration procedure for these tests.

Indexes: Graduation-elimination from flying training and the standard indexes for these tests.

Results: Six factors defined by the perceptual-psychomotor tests emerged. They are integrated coordination, visuo-motor discrimination, anticipatory balancing reaction, eccentric pursuit, error and pursuit learning. Factor loadings are presented in the reference.

Shephard, A. H. Losses of skill in performing the standard Mashburn task arising from different levels of learning on the reversed task. Office of Naval Research Contract N9onr-93801, Technical Report SDC 938-1-9, 1950.

Purpose: To investigate the manner in which different levels of interpolated learning following a constant level of original learning affected subsequent performance on the Mashburn Apparatus.

Apparatus: A modified Mashburn Apparatus was used in this study. On a panel in front of the subject were three double banks of lights: a slightly curved upper bank, a vertical bank, and a lower horizontal bank. Each double bank consisted of two parallel rows of 13 red and 13 green pilot lamps. The red lights when lighted (one in each bank) served as stimuli with which the green lights were to be matched by manipulation of three simulated elevator, aileron, and rudder controls.

Procedure: Seven groups of male subjects (9 to 11 per group) were trained successively to perform the standard task (OL), the reversed task (IL), and again the standard task (RL). Original learning of the standard task continued until a criterion of 35 matches per two minute trial had been reached. The level of interpolated learning of the reversed task was different for each group (23, 27, 31, 35, or 39 matches). Two minutes after reaching the prescribed IL criterion, each subject in five experimental groups was given five relearning trials on the standard task. Fifteen relearning trials were given on the next day, and five additional trials on the following day. Two control groups, which were matched with two of the experimental groups in level of IL, were not given relearning trials until 24 hours after completion of interpolated practice.

Indexes: Performance was measured in terms of number of matches, number of errors (movement of the control in the wrong direction), and the ratio between errors and matches on each two-minute trial.

Results: The differences between the groups on the first RL trial following IL were significant on all three measures used and were directly related to the amount of IL given each group. An inverse relationship was found between skill in performance on the first trial of RL and subsequent rate of improvement but directly related to the rate of improvement during the RL trials.

Signori, E. I. The Arnprior experiment: A study of World War II pilot selection procedures in the RCAF and RAF. Canadian Journal of Psychology, 1949, 3, 136-150.

Purpose: To compare three procedures developed by the RCAF and the RAF for assessing flying ability in pilot training applicants and to assess the predictive efficiency of the RCAF selection battery developed during World War II.

Procedure: Applicants were given 5 paper and pencil tests, biographical, motivation and attitude assessments, and subjected to three psychomotor procedures. The psychomotor procedures are of special interest and involved (a) the RCAF Visual Link Test of Flying Aptitude, (b) the RAF "grading" procedure involving detailed assessments at the end of the first 7 and 11 hours of initial flying training by different grading examiners and (c) flying instructors' ratings by the flight instructor at the end of 1½, 3, 5, 7, and 11 hours of initial flying training.

Indexes: Scores in the three psychomotor procedures. Criterion: Initial Training School rank, Elementary Flying Training School rank, and pass-fail, Elementary and Service Flying Training School pass-fail, and Elementary Flying Training School ground rank.

Results: Zero-order validity coefficients for flying training deficiency are shown below:

Psychomotor Procedure	ITS Rank (N=366)	EFTS Rank-Standing (N=342)	EFTS Pass-Fail (N=342)	E and SFTS Pass-Fail (N=330)
Visual Link Test	.18	.57	.40	.47
Grading: 7 hrs.	.19	.39	.36	.46
11 hrs.	.22	.41	.40	.46
Instructor Rating:				
1¼ hrs.	.11	.21	.14	.17
3 hrs.	.13	.30	.30	.32
5 hrs.	.19	.33	.30	.34
7 hrs.	.16	.38	.34	.41
11 hrs.	.18	.41	.36	.45
Multiple R:				
Grading		.46		.52
Instructor Rate		.42		.47
All Psychomotor		.60		.58
All Tests		.62	.51	.59

Simmonds, D. C. V. An investigation of pilot skill in an instrument flying task. Ergonomics, 1960, 3, 249-253.

Purpose: To investigate the possibility of using consistency as a measure of skill in relation to an aircraft pilot's performance.

Apparatus: The flying tests were conducted in a tandem Chipmunk aircraft, the subject flying the aircraft from the front seat. Visual reference was restricted to the cockpit interior. Rear cockpit was occupied by the experimenter, who while acting as a safety pilot operated the controls of a camera (Bell & Howell A-4) which photographed the rear cockpit panel of instruments. The panel instruments consisted of an airspeed indicator, direction indicator, altimeter, and engine r.p.m. indicator (as on the standard panel), and, in addition, a vertical accelerometer, elevator angle indicator, and a clock. The panel was photographed twice a second.

Procedure: The flying task was divided into two sections:

(a) Fly straight and level for one minute at 85 knots; at the end of the minute carry out a climbing turn to the left (3^{o} per second) gaining 500 ft. during the one minute turn.

(b) Fly straight and level for one minute at 85 knots, and then carry out a standard rate descending turn to the right at 70 knots, losing 500 feet in altitude.

Each maneuver was carried out in succession four times on two different days. Recordings were taken during the fourth set of maneuvers. The subjects were 3 Air Squadron students, 7 R.A.F. students, 4 R.A.F. pilots, and 3 Air Squadron instructors with mean number of flying hours of 97, 144, 854, and 1,604, respectively.

Indexes: Each subject's performance was analyzed and plotted at 10-second intervals in terms of deviation from the perfect pattern readings from the airspeed indicator, direction indicator, and altimeter. Consistency scores were obtained by considering separately the difference in readings of each instrument from each flight. Each subject had six consistency scores, three for each instrument in the climbing and three in the descending turn on each day.

Results: A significant difference, p less than .05 between groups in consistency was found. A rank correlation of r=.51, p less than .01, was estimated between consistency scores and number of flying hours. The correlations for different instruments were not equal. Accuracy (in terms of absolute error) and consistency did not correlate significantly with flying hours.

The experimenter observed that the less experienced students tended to concentrate on one instrument for far too long a period so that errors built up on other instruments. The more experienced pilots were better able to interpret the general situation but showed a wide variability in ability to make corrections quickly. It was concluded that consistency in flying performance showed promise as measurement of flying skill.

Smith, H. P. R. The need for aircrew performance data. In Barbour, A. B., and Whittingham, H. E. (Eds.) Human Problems of Supersonic and Hypersonic Flight. London; Pergamon, 1962, 220-226.

The pilot is being removed from a position of skill to one of monitor and decision taker. There is already evidence of the pilot's ineffectiveness as a short-term computer, especially with reference to the take-off. The author agrees with Majendie that the contact analogue simulating visual flight is already outmoded. The loose coupling of visual flight with manual control will be inadequate for aircraft of the future.

Smith, J. F., Flexman, R. E., and Houston, R. C. Development of an objective method of recording flight performance. USAF Human Resources Research Center, Technical Report 52-15, 1952.

The objective of this work was to develop a technique for objective recording of pilot performance and to provide for the development of reliable and valid measures of pilot skill. The primary (previously basic) training syllabus was analyzed in order to define the pilot's job; following the analysis, the objective recording technique was derived and reliability between observers determined.

Vaandrager, K., and Ide, H. C. A new approach to pilot selection. In Barbour, A. B., and Whittingham, H. E. (Eds.) Human Problems of Supersonic and Hypersonic Flight. London: Pergamon, 1962, 29-34.

The authors concentrate on a clinical assessment for selection of pilots proceeding from the data on aircraft accidents which they indicate are primarily a result of pilot error. They stress the fact that not only must the pilot have mastered the flying technique but that he must be able to put it into practice in an emergency. The authors state that a rigid personality must be avoided in assignment to the cockpit and that a man with sufficient flexibility to adapt satisfactorily is required. Frustration-tolerance level should be determined in order to find out whether the candidate is prone to undesirable reaction under stress.

Vernon, P. E., and Parry, J. B. *Personnel Selection in the British Forces*, London: University of London Press, 1949.

Chapters 5 and 16 of this book are devoted to a discussion of the selection methods employed in the Royal Air Force during World War II and the findings concerning the validity of the methods employed.

Want, R. L. The validity of tests in the selection of air force pilots. *Australian Journal of Psychology*, 1962, 14, 133-139.

Purpose: To determine usefulness of tests as devices for predicting success in pilot training.

Apparatus: Developed from South African Arm-Leg Coordinator. A spot of light is reflected on a ground-glass screen, and the subject by manipulating a hand lever and pedals keeps the light on the center of the screen.

Procedure: Not given.

Other tests not of the perceptual-psychomotor variety were used in the test battery but not reported herein.

Indexes: Time off target

Results: Criterion I: includes academic as well as flight failures. Criterion II: utilizes flight failures only. Successful students all received wings. Biserial *r*'s corrected for restriction of range gave $r=.31$ ($p=.001$, $N=117$) for Criterion I and $r=.24$ ($p=.05$, $N=92$) for Criterion II.

Wilcoxon, H. C., Johnson, W., and Golan, D. L. The development and tryout of objective check flights in pre-solo and basic instrument stages of Naval Air Training. The Psychological Corporation under Contract Nonr-442 (00)(901) and U. S. Naval School of Aviation Medicine Project No. NM 001 058.24.01, Joint Project Report, 1952.

This study describes the development and tryout of an objective flight check for use in pre-solo and basic instrument flying in Naval Aviation. Comparisons are made with conventional rating schemes. The reliability of these objective flight checks was found to be low, and the judgment of those employing them was that they were hazardous to apply because the large number of items to be observed interfered with the instructor's role as safety pilot.

Wilson, C. L. Project Mercury candidate evaluation program. USAF Wright Air Development Center Technical Report 59-505, 1959.

This report describes the various tests involved in the Project Mercury candidate evaluation program. Particularly of interest in the present context were the psychological tests, specifically the employment of the Complex Behavior Simulator, a test providing for 14 different signals appearing in [illegible] order at increasing rates of speed. The test is thought to produce a maximum amount of confusion and frustration and to assess the ability to organize behavior and also requires the candidate to maintain emotional equilibrium under stress.

Zaccaria, Lucy, and Cox, J. A., Jr. Differential validity of the Aircrew Classification Battery (February 1947) for assignment to basic pilot training. USAF Human Resources Research Center, Research Note PERS: 52-38, 1952.

An investigation to determine if the tests within the battery and the stanines showed differential validity for prediction of success in basic pilot training (at this time what had been previously called advanced single-engine and advanced multi-engine training were renamed as varieties of basic training, and the old basic training designation was renamed primary). Although eight of the coefficients were significant at the .01 level, the highest biserial coefficient was equal to .18; thus differential prediction was not attained.

Zaccaria, Lucy, and Cox, J. A. Comparison of aviation cadets and student officers in primary pilot training. USAF Human Resources Research Center, Research Note PERS: 52-41, 1952.

Purpose: To compare elimination causes and rates and to examine validity of the Aircrew Selection Battery for aviation cadets and student officers for classes 51-E, 51-F, and 51-H.

Apparatus: SAM Rotary Pursuit with Divided Attention (CP410B), Rudder Control (CM120C), Finger Dexterity (CM116A), SAM Complex Coordination (CM701E), SAM Two-Hand Coordination (CM101B), and SAM Discrimination Reaction Time (CP611D).

Procedure: The apparatus tests were administered, in addition to the paper and pencil tests making up the Aircrew Selection Battery, to a sample of 1,016 aviation cadets and 547 student officers. The standard test administration procedure for these tests was employed.

Indexes: Graduation - elimination in primary (previously basic) flying training and the standard indexes for these tests were used.

Results: Large and statistically significant differences exist between student officers and cadets with respect to elimination from flying training. The officer group had 72% graduated, and the cadets had only 58% graduated. Overall differences in elimination rate are almost entirely the result of a greater frequency of motivational eliminations among the cadet group. (27% for cadets and 10% for officers.)

Validities were as follows: Cadets N=1016, Officers N=547

Tests	Biserial r Cadets	Biserial r Officers
CP410B	.16	.26
CM120C	.36	.25
CM116A	.11	.06
CM701E	.31	.36
CM101B	.27	.26
CP611D	.21	.27

Zeidner, J.; Goldstein, L. G.; Sprunger, J. A., and Karcher, E. K. Evaluation of fixed wing selection tests for predicting success in Army helicopter pilot training. U. S. Army Adjutant General's Personnel Research Branch, Technical Research Note No. 65, 1956.

Paper and pencil tests used by the U. S. Air Force and the United States Navy were applied to men involved in pilot training in helicopters in order to determine the adequacy of these tests for the helicopter training selection program. Those selectors showing most promise were (a) previous flying experience, (b) mechanical comprehension, (c) practical reasoning, and (d) certain personality characteristics. No perceptual-psychomotor tests were used in this study.

Zeidner, J., Martinek, H., and Anderson, A. A. Evaluation of experimental predictors for selecting Army helicopter pilot trainees: I. U. S. Army Adjutant General's Personnel Research Branch, Technical Research Note No. 99, 1958.

This was the first of the studies aimed at preliminary validation of selection tests for helicopter pilot trainees. This report did not evaluate any apparatus tests. A two-hand coordination test, a perceptual speed test of the paper and pencil variety, failed to correlate significantly with any of the five criterion measures employed.

Zeidner, J., Martinek, H., and Anderson, A. A. Evaluation of experimental predictors for selecting Army helicopter pilot trainees: II. U. S. Army Adjutant General's Personnel Research Branch, Technical Research Note No. 101, 1958.

Purpose: To evaluate tests as devices for pilot selection.

Apparatus: Rotary Pursuit: Prod-stylus and small metallic surface set into rapidly revolving disk. Subject required to maintain stylus in contact with target surface.

Rudder Control: Mock cockpit thrown off balance unless proper correction applied through foot pedals. Aim toward three targets required.

Direction Control: Manipulation of learned combination of switches and buttons in response to visual patterns differing from one another with respect to spatial arrangement of component parts.

Complex Coordination: Requires adjustments of stick and pedal controls in response to successively presented patterns of visual signals.

Procedure: <u>Rotary Pursuit</u>: Three 20-sec. trials

<u>Rudder Control</u>: One 90-sec. center target trial

One 348-sec. triple target trial

<u>Direction Control</u>: Self-paced, total test time, 8 minutes

<u>Complex Coordination</u>: Self-paced, total test time, 8 minutes

Indexes: <u>Rotary Pursuit</u>: Total time on target

<u>Rudder Control</u>: Total time on target

<u>Direction Control</u>: Number of patterns completed

<u>Complex Coordination</u>: Number of completed matchings

Results: Biserial *r*'s against a pass-fail criterion in flying, based on 159 subjects, were significant at the .05 level for Rotary Pursuit, Rudder Control, and Complex Coordination; the respective *r*'s were .30, .39, and .41. The *r* for Direction Control was .15. An additional subsample (*N*=90) was tested with Rotary Pursuit, Rudder Control, and Complex Coordination only. The biserial *r*'s for pass-fail flying training were .15, .10, and .19, respectively.

No reliability data are provided.

Other tests not of the perceptual-psychomotor variety were used in the test battery but not reported herein. A paper and pencil Two-Hand Coordination test was employed but did not show a significant relationship to flying training performance.

Zeidner, J., Martinek, H., and Klieger, W. A. Analysis of flight evaluations of Army helicopter pilot trainees. U. S. Army Adjutant General's Personnel Research Branch, Technical Research Note No. 93, 1958.

Purpose: To determine causes for failure in the training program.

Procedure: An analysis was carried out on three samples of students in the Army Helicopter Pilot Course involving the interrelations between pre-solo flight grades and population reference variables and between grades at various stages of training and end of course evaluations.

Results: Percentage of satisfactory grades had the highest relationship with pass-fail decisions. The biserial *r*'s were .92 (*N*=185), .94 (*N*=180), and .98 (*N*=122). There was a positive relationship between pass-fail and practical flight grade. The practical flight grade and the academic grade were unrelated, yet the final course grade was heavily weighted in favor of the academic grade. There are in effect two separate criteria to predict in selection for this training. Interrelationships between grades from one stage of training to another indicate a great degree of independence which may, in fact, be produced by the unreliability of the grading system.

APPENDIX

DESCRIPTION OF TESTS

The material comprising the Appendix was prepared to facilitate understanding of this survey and annotated references and in the interests of economy in presentation. It contains descriptions of perceptual-psychomotor tests which are frequently referred to in both text and references. The descriptions are taken principally from Melton, A. W. (Ed.) Army Air Forces Psychology Program Research Reports: Report No. 4, Apparatus Tests, and its supplement. The reader in need of a more detailed description for any test than that provided herein is advised to consult this reference. In the event that the test description came from another source, that source is identified following the test description.

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Complex Timing Reaction Test with Memory for Procedures (CI511A). In this test the examinee moves a "stick" to impart motion in the pitch and roll axes to a platform supporting a freely moving steel ball. The task is to control the attitude of the platform so that the ball is made to roll through successive gates located on the principal orthogonal coordinates of the platform. When negotiating the laterally placed gates, the examinee must depress the one of two switch buttons ipsilateral to that gate. Indexes: (a) each gate penetrated in correct order is counted and cumulated for four 2-minute test periods; (b) in addition, a procedure count is registered when a ball rolls through a lateral gate while the switch button ipsilateral to that gate is depressed. (On a procedure gate, one can obtain a gate count without receiving a procedure count, but not vice versa).

SAM Two-Hand Coordination Test (CM101B). This test is designed to measure the examinee's ability to coordinate the movements of both hands for the purpose of causing a pointer to follow a circular target moving irregularly at a varying rate in a clockwise direction. Simultaneous rotation of two lathe-type handles produces pointer motion in the plane of movement of the target. Time is recorded when the contact component of the pointer is on the target. Eight 1-minute trials, separated by 15-second rest periods, are automatically presented and timed. Index: cumulated time on target for eight trials.

Santa Ana Finger Dexterity Test (CM116A). This test is designed to measure the speed and precision of movement involved in turning pegs. The examinee is presented with a board containing 48 pegs having a square and a round end. His task is to remove each peg in turn, rotate it clockwise through 180 degrees, and reinsert it in its hole. Five 35-second trials, separated by short rests, are presented. Index: number of pegs correctly turned in five trials.

SAM Rudder Control Test (CM120C). This test is designed to measure the ability of an examinee to make compensatory motor adjustments to visually perceived displacements. Since the examinee is also displaced, the test performance involves static and tactile factors as well as proprioceptive and visual factors. The examinee is required to maintain the alignment of a sighting bar, mounted on a mock fuselage, with a target which shifts discretely among three positions in a preestablished sequence. The alignment is maintained by manipulation of the rudder pedals. Three 30-second trials, separated by 15-second rests, are presented first under a single-target (central target) condition, followed by three 112.5-second trials separated by 27.5-second rest periods under the triple-target condition. Index: total time on target for the combined conditions.

SAM Rudder Reaction Test (CM507A2). This test was designed to measure a more delicate type of foot coordination than that required in CM120C. In this test the position of a steel ball rolling freely along a horizontal runway may be controlled by pedals in such a way that the ball is made to stay atop a "hump" located in the center of the runway. Eight 1-minute trials are given. Indexes: (a) cumulative time during which the ball is on the "hump" over the eight-minute testing time, and (b) whenever the ball is permitted to contact the stops at either end of the runway, a count is produced and accumulated over the eight-minute testing time.

SAM Compensatory Balancing Test (CM510A). This is a test of visual motor coordination in which, as in earlier timing reaction types of tests, the examinee must control the attitude of a platform in such a way that a gravity-activated steel ball is made to negotiate a prescribed pathway. Factors involved in this performance are judgments of motion, precision of timing, and avoidance of overcontrol movements. In this test a manually operated platform supports a tortuous alley maze containing 10 choice points. The examinee must roll the ball through the correct pathway, avoiding the cul-de-sac at each choice point. The pathway is negotiated repeatedly, under self-paced conditions, throughout an 8-minute test period. Indexes: (a) cumulative total choice points successfully passed in the 8-minute period (on a given maze sequence a point only scores once), (b) a ratchet and pawl device actuated by cables attached to the platform stores and sums half the movement of the platform in the pitch and roll axes over the 8-minute period. No movement can occur in yaw.

SAM Complex Coordination Test (CM701E). This test has been described elsewhere as a serial reaction task. It is a discrimination reaction time task in which the examinee is required to make complex motor adjustments to successive patterns of visual stimuli. It differs somewhat from conventional tests of this variety in that (a) the response requires the use of both hands and feet, and (b) successive approximations are required to produce the correct amount and direction of movement. A 2-minute practice period precedes the test period. Index: number of patterns achieved in 8 minutes.

SAM Pursuit Confusion Test (CM702B). This is an adaptation of the conventional mirror-tracing task. It is a visual-motor direct pursuit task in which the examinee is required to cause a stylus to follow a variable-speed target through a diamond-shaped pathway. The perceptual component of the task is complicated by the fact that the target is visible only by mirror-vision. This results in the perceptual transposition of the proximal-distal components of the pursuit movement without altering the perceived characteristics of the transverse components. Six 1-minute trials are given with a 15-second rest period between trials. Indexes: (a) cumulative time on target over the six-minute test time, and (b) cumulative time during which the stylus is in contact with the sides of the pathway is scored independently of time on target, and both may accumulate simultaneously.

SAM Single-Dimension Pursuitmeter (CM801B6). This test is designed to measure the examinee's ability to make compensatory motor adjustments to the visually perceived linear displacement of a pointer, thus keeping the pointer in a null position. The null position is actually a band 5/32 of an inch in width. In order to simulate the latency of response characteristic of aircraft control surfaces, a pneumatic damping device is attached to the actuator through which the examinee controls the movement of the pointer. This valve is set at .02 minute. There are eight 1-minute trials, with 15-second rest periods between them. Indexes: (a)cumulated time spent in the null band for eight trials, (b) cumulated instances in which the pointer moves from a non-scoring to a null band during eight trials.

The SAM Multidimensional Pursuit Test (CM813E). This is a variation of the compensatory visual-motor reaction type of test. This test consists of an instrument panel, mounting four meters (bank, turn, airspeed, and r.p.m.), and simulated aircraft controls (stick, rudder, and throttle). During a test trial the pointers of the various meters drift about slowly, irregularly, continuously, and apparently independently of one another. The examinee's task is to manipulate the controls so that the meter pointers are kept within specified areas on their respective scale. Time is recorded when all pointers are within the specified areas simultaneously. Eight 1-minute trials, separated from one another by 15-second rest periods, are automatically presented and timed. Index: cumulated time for eight trials.

SAM Plane Control Test (CM817B). This is a variation of the compensatory visual-motor reaction type of test in which the attitude of a model airplane is varied irregularly in the roll, pitch, and yaw axes by a motor-driven cam system. The examinee's task is to maintain the aircraft in a straight-and-level attitude by manipulating airplane-like controls. Time is recorded automatically when a straight-and-level attitude is maintained in the three dimensions simultaneously. The width of the scoring area in each dimension is 14/16 inch. Eight 1-minute trials, separated by 15-second rest periods, are automatically presented and timed. Index: cumulated time for eight trials.

SAM Rate Control Test (CM825A). This is a variation of the visual-motor rate pursuit type of test. In this test the examinee's task is to control the angular rate of movement of a pointer so as to keep it constantly in coincidence with a target-line moving irregularly back and forth across a curved scale. The examinee effects changes in the rate and direction of pointer motion by turning a small knob. The directional relation of knob motion to pointer motion may be varied. Time was recorded when pointer and target-line were in alignment. Eight 1-minute trials, separated by 15-second rest periods, are automatically presented and timed. Index: cumulated time for eight trials.

1. In the Air Force Navy Pilot Candidate Research Project the pointer moved in the same direction as the control knob.

SAM Rotary Pursuit Test with Divided Attention (CP410B). This test is designed to measure the ability of examinees to make coordinated rhythmical muscular movements while their attention is divided between the pursuit of a rotating target and a visual-spatial discrimination reaction problem. The examinee's task is to maintain contact between the point of a stylus and a round metal target, inserted in a rotating Bakelite disc, while using his other hand to make differential manual responses to a pair of signal lamps. Time is recorded when both requirements are fulfilled simultaneously. Fifteen 20-second trials, separated by 10-second rest periods (except for 30-second rests between trials 5 and 6 and 10 and 11) are automatically presented and timed. Index: cumulated time for 15 trials.

SAM Discrimination Reaction Time Test (CP611D2). This test is designed to measure the speed with which individuals make differential manual responses to visual stimulus patterns differing from one another with respect to the spatial arrangement of their component parts. The test requires that the examinee react by pushing one of four toggle switches in response to the illumination of red and green signal lamps. The position of the red lamp in respect to the green lamp determines the switch to be activated. Forty-second rest periods separated the sets from one another. Index: cumulative time for 80 responses.

SAM Self Pacing Discrimination Reaction Time Test (CP611E2). The test was designed to measure the speed with which individuals make differential manual responses to visual stimulus patterns differing from one another with respect to spatial arrangements of their component parts. The test requires that the examinee react by deflecting one of four toggle switches in response to the lighting of a red and a green signal lamp. The position of the red lamp with respect to the green determines which one of the four switches is correct; e.g., if red is to the right of green, the switch which is responsive to a right movement must be deflected and this principle applies to other deflections. This is the same task as CP611D2. In this task the examinee self paces through four 2-minute periods. Indexes: (a) cumulative correct responses over four trials and (b) cumulative wrong responses over four trials.

Complex Multiple Reaction Test (CP612AX1).* Imported from Germany following World War II, this is a complex variation of the visual discrimination reaction type of test. Visual and auditory stimuli alternate with one another in a pre-established random order to serve as cues for manual and pedal responses. The visual cues vary chromatically and configurationally, while the auditory cues vary in frequency. The particular chromatic and configurational characteristics of a visual cue determine which of three levers will be manipulated. The relative pitch of an auditory cue determines which of two pedals will be depressed. One at a time, the stimuli occur in rapid sequence under the control of a pacing mechanism. Timing of the test as used in the United States was not indicated in the reference available to the authors. In the German version of the test two sequences of 330 stimuli were presented and each sequence required approximately 8 minutes.

*Aviation Psychology Abstract Series Headquarters U. S. Army Air Forces Abstract No. 188.

SAM Controls Orientation Test (CP638A). This is a variation of the visual discrimination reaction type of test. It differs from other variations in that the discrimination and reaction requirements are considerably more complex. For each problem unit, the examinee is required to select and push a toggle switch that is the same number of switch-units distant from a variable reference point on the switch panel that a key lamp is from a stationary reference point on the lamp panel. The key lamp is never lighted so that its position must be estimated or counted with reference to the two lighted lamps. The distance of the key lamp from the stationary reference point must be similarly ascertained and serves as the basis for selection of the appropriate response. The timing of this test was not provided in references seen by the authors. Indexes: (a) number of correct responses, (b) number of incorrect responses, (c) number of failures to respond, (d) total number of responses made, and (e) the number of patterns attempted. The number of failures to respond was obtained by subtraction of the number of patterns attempted from the total number of patterns presented.

SAM Direction Control Test (CP650A). This is a variation of the visual discrimination reaction type of test. It is designed to measure the examinee's ability to execute rapidly several sequences of responses to patterns of visual cues employing both hands. The bilaterality of manual response is asymmetrical in the sense that the response sequence to be executed by one hand differs from those to be executed by the other at any given point in time. However, the action requirements imposed upon the two hands bear an orderly relationship to one another, and both must be met correctly if success in the task is to be achieved. A correct response is registered when the examinee performs the appropriate manipulations with the two hands concurrently. Indexes: (a) cumulated number of items accomplished correctly in an 8-minute period, (b) cumulated number of inappropriate manipulations with either hand, i.e., responses not called for by visual cue.

SAM Drift Correction Test (Paced) (Uncoded). Both paced and unpaced models of this test present the same display to the candidate. Two concentric rings of eight signal lamps are used, with the inner circle representing plane headings and the outer circle representing wind direction. The candidate is required to throw a snap switch either to the right or left, according to whether the drift produced by wind should be corrected by a course alteration either to the right or to the left. Four paced trials consisting of 39 stimulus presentations each are given. Stimulus presentations are given at 3 second intervals. Indexes: cumulative correct responses over four trials, and (b) cumulative wrong responses over four trials.

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13. ABSTRACT

This report reviews the literature reflecting the employment of perceptual-psychomotor tests for selection of aircrew members since World War II and provides behavioral concepts for consideration as possible future test development areas. The review considers the use of flight experience as well as perceptual-psychomotor screening devices and comments on the results of the programs in which such experience is intentionally used. The fundamental importance of criterion definition to development and validation of selection devices is discussed. Recent research is reviewed leading to the derivation of behavioral concepts recommended for consideration as principles on which new perceptual-psychomotor tests may be based. The merits of simple tests as opposed to complex tests in which numerous facets of performance are concurrently assessed are considered and the latter approach is recommended. References are included in support of the review and critical items are annotated.

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