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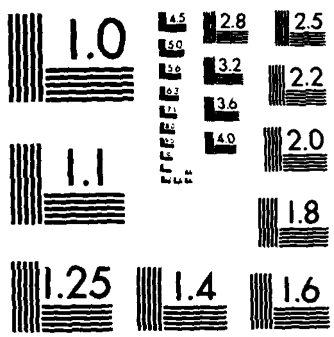

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UTILIZATION OF PSYCHOMOTOR SCREENING FOR USAF PILOT CANDIDATES: INDEPENDENT AND INTEGRATED SELECTION METHODOLOGIES

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An Air Force Human Resources Laboratory (AFHRL) research and development (R&D) program was designed to capitalize on state-of-the-art technologies in computer-aided testing to develop accurate measures of psychomotor ability (hand-eye coordination) and then to investigate different ways to use these psychomotor measures in the selection of pilot training candidates. Psychomotor ability is one of several characteristics which historically have demonstrated relevance to flying performance. This report documents the validation of two tests of psychomotor ability against USAF Undergraduate Pilot Training (UPT) performance, and development of strategies to incorporate this information into the USAF pilot selection system.

The two tests, Two-Hand Coordination and Complex Coordination, differentiated between UPT graduates and eliminees as well as between fighter- and non-fighter-recommended students. This differentiation can be used through the psychomotor screening system as an additional selection gate for UPT candidates. Three Integrated Pilot Candidate Selection Models (IPCSMs) use all available information, including psychomotor measures, to improve attrition and quality in UPT and also reduce the rejection of potential graduates. Also, the IPCSMs can be used to screen minorities and women without bias. (Continued)

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IPCSM I (Officer Training School Model) is the strongest system and is recommended for use as an input to the final selection decision for candidates going through the Flight Screening Program. IPCSM II (Air Force Reserve Officer Training Corps Model) could be used as a pre-selection input for Officer Training School or Air Force Reserve Officer Training Corps field training selection. IPCSM III (Air Force Academy Model) is not sufficiently stronger in prediction than the psychomotor screening system alone to warrant implementation.

The implementation of psychomotor screening, either as a separate gate or within an integrated selection system, will improve the quality of student candidates in USAF Undergraduate Pilot Training. Based on the results of this effort, an integrated selection system including psychomotor screening is recommended. Future research should extend the information being considered and the criteria to be predicted.

SUMMARY

Two tests of psychomotor ability (hand-eye coordination) previously developed by the Air Force Human Resources Laboratory were validated against USAF Undergraduate Pilot Training (UPT) performance. The two tests significantly predicted UPT eliminations and differentiated between the better and weaker graduating students. Various operational implementation strategies for the psychomotor tests were evaluated, including using the tests by themselves as an additional selection gate and combining the scores from the tests with other normally available selection information. The combined approach proved most accurate, and three Integrated Pilot Candidate Selection Models (IPCSMs) were developed using combinations of the psychomotor tests, Air Force Officer Qualifying Test scores, grades from the Flight Screening Program and biographical data. Comparisons among the IPCSMs were made and recommendations for implementation were presented.

PREFACE

Work was accomplished in support of RPR 78-11, Selection for Undergraduate Pilot Training, issued by USAF Air Training Command. This work was performed under Project 7719, Air Force Personnel System Development on Selection, Assignment, Evaluation, Quality Control, Retention, Promotion, and Utilization; Task 771918, Selection and Classification Instruments for Officer Personnel Programs.

The groundwork for this report resulted from the efforts of many AFHRL scientists beside those referenced in the bibliography. Dr. Dave Hunter and Major John Quebe were instrumental in the development of the psychomotor test equipment. Mr. Dick Nicewonger was principal psychomotor test administrator. Mr. Cal Fresne was responsible for building the data files for the analyses. These contributions and the untiring efforts of Mr. Ed Watkins to program the analyses are deeply appreciated by the authors.

In addition, the authors extend thanks to Major E. Simpson (ATC/TTXPT) for his coordination of the operational guidance and support within the Air Training Command. The implementation of psychomotor screening within the USAF is significantly related to his dedicated efforts.

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I. INTRODUCTION

A multi-year research and development (R&D) program was designed at the request of the United States Air Force (USAF) Air Training Command (ATC) to improve procedures for the selection of candidates for USAF Undergraduate Pilot Training (UPT). The overall R&D program is described in Kantor and Bordelon (1985). Two important objectives of this research were to capitalize on state-of-the-art technologies in computer-aided testing for the development of accurate measures of psychomotor ability (hand-eye coordination) and then to investigate different ways to use these psychomotor measures in the selection of UPT candidates.

The principal goal of selection for UPT is to screen out those candidates with extremely low chances of completing training. According to ATC calculations, the average cost of each UPT eliminee is approximately $64,000 (FY84 dollars). Therefore, screening out potential failures can avoid considerable attrition costs. Also, the increased complexity of the weapon systems and missions in which USAF aircrews are employed requires selection of high-quality students. Flying aptitude tests are traditionally used to differentiate among UPT candidates.

The ideal selection system would measure and consider all relevant characteristics of a candidate. These would include physical and mental characteristics as well as the candidate's previous experiences, such as actual flying. This information would be used to predict a candidate's probability of success in an optimally weighted manner. The candidates with the lowest probability of success would be screened out before training.

The UPT selection system currently used by the USAF does not consider all relevant information about candidates. Thus, many candidates fail training because of deficiencies in flying aptitude. Psychomotor ability is one of several characteristics that historically has demonstrated relevance to flying performance. Though not currently used by the USAF, psychomotor screening is used by several other national Air Forces to select their pilot candidates. This report documents the validation of two tests of psychomotor ability against USAF UPT performance and develops strategies to incorporate this information into the USAF pilot selection system.

Background

Between February 1942 and July 1955, measurement of the psychomotor ability of pilot training candidates was an important component of the Air Force (prior to 1947, the Army Air Corps) pilot selection procedure. Screening on psychomotor ability was discontinued in 1955 because the electro-mechanical equipment used to measure it was difficult to calibrate under decentralized testing conditions and was hard to maintain (Passey & McLaurin, 1966). Since 1955, the principal components considered in USAF pilot selection have included physiological fitness, the paper-and-pencil Air Force Officer Qualifying Test (AFOQT), and actual flying experience. Recently, the candidate's age and possession of a technical degree (defined as a college degree in math, science, engineering, or computer science) have been included as factors in the selection decision.

Improvements in computer technology provided the potential to develop reliable and maintainable psychomotor tests and revived interest in psychomotor assessment for pilot candidate screening. In 1969, the Air Force Human Resources Laboratory (AFHRL) contracted to design, develop, and determine the reliability of two computer-based psychomotor tests (Sanders, Valentine, & McGrevy, 1971). The basic task elements of these new tests and the responses required of the subject duplicated earlier electro-mechanical tests developed in 1942 by the Army Air Forces School of Aviation Medicine (now the USAF School of Aerospace Medicine). The newly designed tests differed from the earlier versions in several respects, but the most important difference was that, for the first time, a minicomputer controlled the test procedures, providing reliability and standardization not achievable on electro-mechanical devices.

The first of these tests, called Two-Hand Coordination, is a pursuit tracking task measuring the subject's ability to coordinate the movement of both hands to track a moving target. The second test, called Complex Coordination, requires multi-limb, dual-task compensatory tracking and measures the subject's ability to adjust two independent responses to control a changing stimulus pattern. The effectiveness of the tests was initially demonstrated with a sample of 120 Officer Training School (OTS) cadets. Stable task performance was obtained after 10-minute test sessions and reliabilities were very high. Inter-test correlation was low, suggesting that each test may contain unique information and that both should be further evaluated. The high multiple correlation between the scores on both tests and training outcome at UPT ($R = .46$) suggested that these psychomotor tests could enhance the prediction of pilot training success. These results precipitated a recommendation for large-scale validation of an operational version of the psychomotor tests (McGrevy & Valentine, 1974).

In 1975, AFHRL contracted with Systems Research Laboratory, Inc., Dayton, Ohio, to design and develop five computer-based test devices that could administer the two psychomotor tests. These transportable devices were self-contained and did not require highly trained test administrators. The devices faithfully reproduced the two tests that BioTechnology, Inc. had developed on the minicomputer.

Objectives

In 1978, AFHRL began a multi-year R&D effort to use the new test devices to obtain psychomotor measures from USAF pilot candidates from all three commissioning sources: Air Force Academy (AFA), Air Force Reserve Officer Training Corps (AFROTC), and Officer Training School (OTS). Initially, the actual UPT outcomes of the candidates would be used to validate the usefulness of the psychomotor scores for pilot screening. (Though not part of this report, these test scores will later be validated against measures of successful operational flying.) In addition, this study sought to determine the best manner to integrate the psychomotor test information with available selection information to achieve the greatest improvement in the USAF pilot selection process.

II. METHOD

Predictive Validation

A testing plan was jointly developed between AFHRL, ATC, AFA, and AFROTC. In the spring of 1978, four of the psychomotor test devices were transported to the Air Force Academy to test the cadets from the three upper classes. In the spring of 1979, the devices were shuttled by van to all of the AFROTC detachments in the continental United States to test AFROTC juniors and seniors. Then, the devices were placed at the AFHRL Lackland Testing Facility, Lackland AFB, Texas, to test OTS pilot candidates entering the Flight Screening Program (FSP) from the fall of 1979 through the fall of 1981. The pilot candidates were then tracked through UPT, and the performance of those who completed UPT between FY79 and FY82 was used to validate the psychomotor test scores. All UPT student records from FY79 to FY83 were obtained to ensure as many matching cases as possible. The test subjects who completed UPT during FY83 were used to cross-validate the developmental results.

Concurrent Validation

As an additional validation of the psychomotor scores, the test devices were sent to Williams AFB, Arizona, in June 1984 to test UPT graduating students. For this sample, the results of the Advanced Training Recommendation Board (ATRB) were obtained as criteria. The ATRB r commends students for follow-on assignments to either fighter-attack-reconnaissance (FAR) or tanker-transport-bomber (TTB) aircraft, and only the better students receive a FAR recommendation.

Table 1 shows the sample sizes of the test groups. Analyses reported here include factor analysis of the psychomotor measures and comparisons among the means for the different training outcome groups from UPT. A psychomotor screening system and three integrated selection systems were developed using multiple linear regression techniques. The utility of the systems was demonstrated using a hit-miss classification algorithm which computed correct and incorrect selection decisions for all of the possible cutoff scores.

Table 1. Subjects Tested by Source

Source	Subjects tested
Air Force Academy	382
Air Force Reserve Officer Training Corps	1,229
Officer Training School	603
Unknown Source of Commission	314
Testing Plan Total	2,528
UPT, Williams AFB	95
Total	2,623

Apparatus

The test devices administered both of the psychomotor tests. The internal computer generated the test images and presented them on a monochrome cathode-ray tube (CRT). A pre-recorded cassette tape played test instructions to the subject through headphones. Two small joysticks (one on the left and the other on the right of the CRT) were used for inputs during the Two-Hand Coordination Test. An aircraft-style, floor-mounted joystick and two foot-operated, rudder-style pedals were used for inputs during the Complex Coordination Test. The subject sat on an ordinary chair in front of the free-standing test device. Located on the rear of the device were three digital displays that presented the final scores of either test that was selected by a switch. Once started by a test administrator, the device would provide the subject with 5 minutes of instructions and practice time for the first test, then a 5-minute test session, and then repeat the same sequence for the second test. Thus the entire procedure required only 20 minutes.

Two-Hand Coordination Procedures

The first of the tests - Two-Hand Coordination - presented a triangular-shaped target and a cross-shaped pipper on the CRT (Figure 1). The computer moved the target in an elliptical path and with varying speeds (faster near the 4 o'clock position and slower near the 11 o'clock position). The subject moved the pipper using the two small joysticks. The left joystick controlled the pipper only in the up-down, or vertical, axis whereas the right joystick controlled the pipper in the left-right, or horizontal, axis. The subjects were instructed to use both joysticks simultaneously in a coordinated manner to move the pipper, keeping it as close as possible to the target on the CRT.

PSYCHOMOTOR TESTS

TEST I

- **LEFT — RIGHT HAND COORDINATION**
- **10 MINUTES**

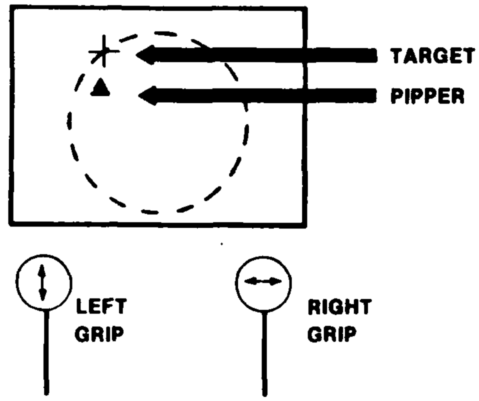

Figure 1. Two-Hand Coordination Test Depiction.

Sixty times each second, the computer measured in inches the absolute distance from the pipper to the target as both moved around the CRT. The horizontal and vertical components of this error measurement were computed and accumulated during the 5-minute test period. The two scores obtained from Two-Hand Coordination were the cumulative horizontal (X_1) and cumulative vertical (Y_1) error scores.

Complex Coordination Procedures

The second test - Complex Coordination - presented a set of cross-hairs centered on the CRT, a dot-shaped pipper, and a thin vertical bar at the bottom of the CRT (Figure 2). The subject controlled the pipper, both horizontally and vertically, using the floor-mounted joystick. The control responses were the reverse of what is traditionally required on aircraft (i.e., left movement of the joystick moved the pipper to the right, back movement of the joystick moved the pipper downward, etc.). This arrangement was intentionally selected to reduce the advantage of a subject with prior flying experience. In the same way, the vertical bar was moved horizontally to the left by pressing the right foot pedal and to the right by pressing the left foot pedal. The subjects were instructed to use the joystick to center the pipper horizontally and vertically on the intersection of the cross-hairs and simultaneously press the appropriate rudder-style pedal to center the "rudder bar" over the lower part of the vertical cross-hair. The computer randomly changed the gain on the input controls, which drove the pipper and rudder bar off their marks, requiring the subject to constantly compensate for the forced displacement.

Sixty times each second the computer measured in inches and accumulated during the 5-minute test period the absolute distance from the pipper to the intersection of the cross-hairs and from the rudder bar to the vertical cross-hair. The three scores obtained from the Complex Coordination test were the cumulative horizontal error component for the pipper (X_2), the cumulative vertical error component for the pipper (Y_2), and the cumulative horizontal error for the rudder bar (Z_2).

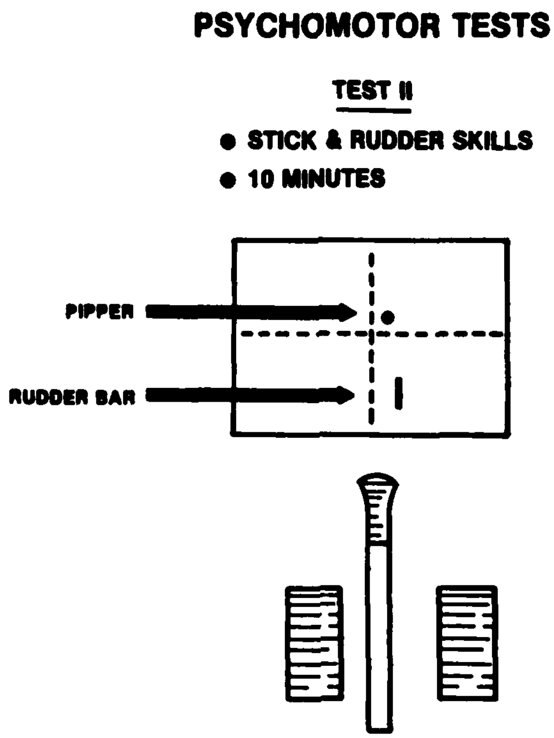

Figure 2. Complex Coordination Test Depiction.

III. RESULTS

Psychomotor Scores

The two psychomotor tests produced a total of five error scores (X_1, Y_1, X_2, Y_2, Z_2) for each subject. Because the scores measure error, low scores are better than high scores. Table 2 lists basic statistics for the scores obtained from the original sample of 2,528 candidates from all commissioning sources. The mean error scores from the Two-Hand Coordination Test were much higher (worse) than those for the Complex Coordination Test, which suggests that the requirements for this pursuit tracking task were more difficult than for the compensatory tracking task.

Table 2. Means, Standard Deviations and Ranges of Psychomotor Scores (N = 2,528)

Test score	Mean	SD	Range
Two-Hand Coordination			
X1 (Horiz)	14,709	5,400	428 - 65,268
Y1 (Vert)	16,748	5,538	5,687 - 57,292
Complex Coordination			
X2 (Horiz)	4,514	6,520	326 - 71,040
Y2 (Vert)	3,860	6,445	486 - 76,320
Z2 (Rudder)	5,580	6,018	167 - 71,040

Outliers

The values at the high end of the ranges of all five scores were much larger than anticipated. Subjects averaged approximately 4 inches of tracking error for the entire 5-minute test session (4 inches x 5 minutes x 60 sec per min x 60Hz = 72,000 inches). These large values might be expected as the error score when the subject made no tracking input on that component of the test. However, none of the subjects had extremely large values on all five scores. If one or more axes were ignored, the test taken by that subject would be different from the presented test and the scores would not be comparable to the results of other subjects. These extremely large scores were from 7.3 to 11.2 standard deviations above the mean of the respective distributions. There were few such outliers, with the vast majority of the scores within six standard deviations of the respective means. A cutoff of six standard deviations above the respective mean was arbitrarily imposed, removing 35 cases from further analyses. The updated descriptive statistics including the cutoff of the new sample of 2,493 subjects are listed in Table 3.

Table 3. **Means, Standard Deviations, Ranges, and Cutoffs of Psychomotor Scores (N = 2,493)**

Test Score	Mean	SD	Range	Cutoff
Two-Hand Coordination				
X1 (Horiz)	14,624	5,194	428 - 39,358	47,109
Y1 (Vert)	16,683	5,427	5,687 - 45,093	49,976
Complex Coordination				
X2 (Horiz)	4,113	4,349	326 - 42,215	43,634
Y2 (Vert)	3,426	3,600	486 - 37,667	42,530
Z2 (Rudder)	5,502	5,746	167 - 40,888	41,688

Intercorrelations

The five test scores were all measures of psychomotor ability; therefore, each could include some common information about the subjects. The strength of this shared information, expressed as intercorrelations, is shown in the matrix at Table 4. As might be expected, the psychomotor scores *within* the same test had the highest intercorrelations whereas the correlations across tests were small.

Table 4. **Intercorrelations of Psychomotor Scores (N = 2,493)**

	X_1	Y_1	X_2	Y_2
X1 (Horiz)				
Y1 (Vert)	.87			
X2 (Horiz)	.20	.25		
Y2 (Vert)	.19	.23	.86	
Z2 (Rudder)	.20	.24	.77	.71

A principal components factor analysis followed by a varimax rotation further evaluated the relationships among the five scores. The two extracted factors had eigenvalues greater than 1.0

(2.85 and 1.58) and accounted for 88.5% of the original variance. Table 5 lists the rotated factor loadings. The varimax rotation separated the scores clearly into two factors. Each factor was dominated by only the scores from a single test. Therefore, the two psychomotor tests were measuring different abilities with very little in common between the tests. The results of the factor analyses indicate that both of the tests should be considered in further validity analyses.

Table 5. Varimax Rotated Factor Loadings of Psychomotor Scores (N = 2,493)

	X_1	Y_1	X_2	Y_2	Z_2
Factor I	.10	.15	.96	.88	.79
Factor II	.92	.92	.11	.10	.13

Criterion Data

The criterion used to assess the validity of the psychomotor test scores was training outcome in UPT. Except for the Williams AFB sample, it was necessary to track the tested candidates through the 49 weeks of UPT before their outcome was known. Many candidates in the sample failed to start UPT because they did not receive a commission or were eliminated during normal screening. To obtain criterion data on as large a sample as possible, all of the UPT results from FY79 to FY83 were obtained from ATC. Table 6 lists the sizes of the validation samples after matching the UPT criterion and psychomotor data. A sample of 1,725 candidates who had valid psychomotor test information and ended UPT between FY79 and FY82 was identified and analyzed in August 1983. This group was used for the predictive validation analyses and the development of the psychomotor and integrated selection systems. A separately matched and more recently available sample of 166 FY83 UPT students was analyzed in November 1983 to cross-validate these selection systems. Finally, the results of the 95 Williams AFB students tested nearing UPT graduation were analyzed in August 1984 for concurrent validity assessment.

Table 6. Psychomotor Validation Samples

Sample	N
Predictive Validation (FY79 to FY82 UPT, 5 bases)	1,725
Cross-Validation (FY83, 5 UPT bases)	166
Concurrent Validation (FY84 UPT, Williams AFB)	95

Predictive Validation

For the psychomotor scores to be useful, at least some of them must significantly differentiate between candidates who graduate from UPT and those who eliminate. Reasons for elimination from UPT are classified as *flying deficiency*, *academic deficiency*, *medical*, self-initiated, and fatality. If psychomotor ability is related to flying aptitude, then the greatest differences should exist between the psychomotor scores of the graduates and those who eliminate for flying deficiency reasons.

These hypotheses were evaluated by comparing the means of the psychomotor scores among three categories: UPT graduates, all UPT eliminees, and UPT flying deficiency eliminees. Figure 3 presents the differences among these groups. The actual means with their zero-order correlations to UPT outcome and tests of significance are listed in Appendix A. All five scores had significant differences ($p \leq .001$) between graduates and either category of eliminees. In addition, for all three of the Complex Coordination scores, the means for flying deficiency eliminees were significantly worse ($p \leq .01$) than those for individuals eliminated for all other reasons. These results suggest that both tests identify eliminees, but the Complex Coordination Test does a better job of identifying flying deficiency eliminees. These results validate the use of all five psychomotor scores as predictors of success or elimination in USAF UPT.

Concurrent Validity

The psychomotor testing of UPT students nearing graduation at Williams AFB permitted the concurrent validation of the tests against two criteria of UPT flying performance supplied by ATC. The first was the ATRB decision whether or not to recommend the student for follow-on assignment to a fighter-attack-reconnaissance (FAR) aircraft. Graduates who were not FAR-recommended would receive a follow-on assignment to a tanker-transport-bomber (TTB) aircraft. Only the better students received a FAR recommendation. The second criterion was an experimental class ranking accomplished by the flight commanders of the UPT training squadron. Figure 4 presents all five means for both FAR- and non-FAR-recommended students. The FAR students had significantly ($p \leq .01$) better scores than the non-FAR students on two of the five psychomotor measures (a third score was significant at $p \leq .05$). Also, using multiple linear regression, the five psychomotor scores had significant ($p \leq .01$) multiple correlations against both the class ranking ($R = .41$) and the FAR/non-FAR ($R = .43$) criteria. These results show that in addition to identifying candidates with low probabilities of UPT success, psychomotor scores also relate to superior performance in UPT. Taken altogether, these results indicate that the quality of UPT students can be improved with psychomotor screening.

Psychomotor Screening Equation

To obtain the maximum prediction accuracy from the psychomotor scores, a weighted equation or linear model was developed to predict UPT outcome. This equation provides a screening score based on psychomotor ability. Because the criterion was dichotomous and was coded 0 for eliminees and 1 for graduates, the screening score can be roughly interpreted as a probability of success in UPT. To determine the weights for the model, multiple linear regression was used, with all five psychomotor scores as predictors and UPT outcome as the criterion variable.

Although all five psychomotor scores were significant predictors of UPT outcome, the scores of each test were highly interrelated, as shown by the factor analyses. Accordingly, the most useful linear model would contain the fewest psychomotor scores which still accounted for as much of the criterion variance as all five scores together. However, that does not mean that the tests could be changed to present only the most predictive axes, because that would change the nature of the tasks in the tests. After several comparisons using the F-ratio, the final

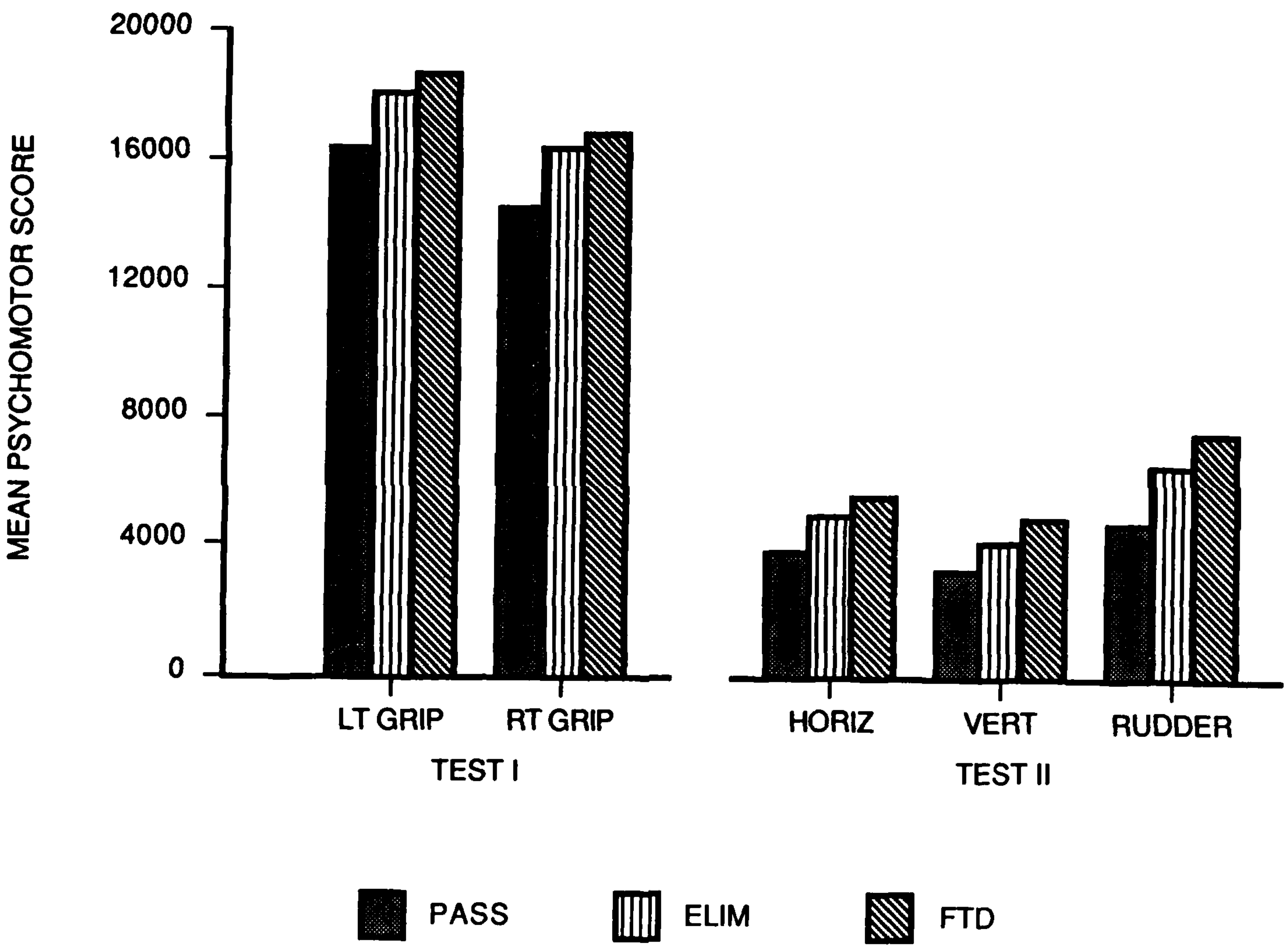

Figure 3. Mean Psychomotor Scores by UPT Outcome.
(N = 1,725)

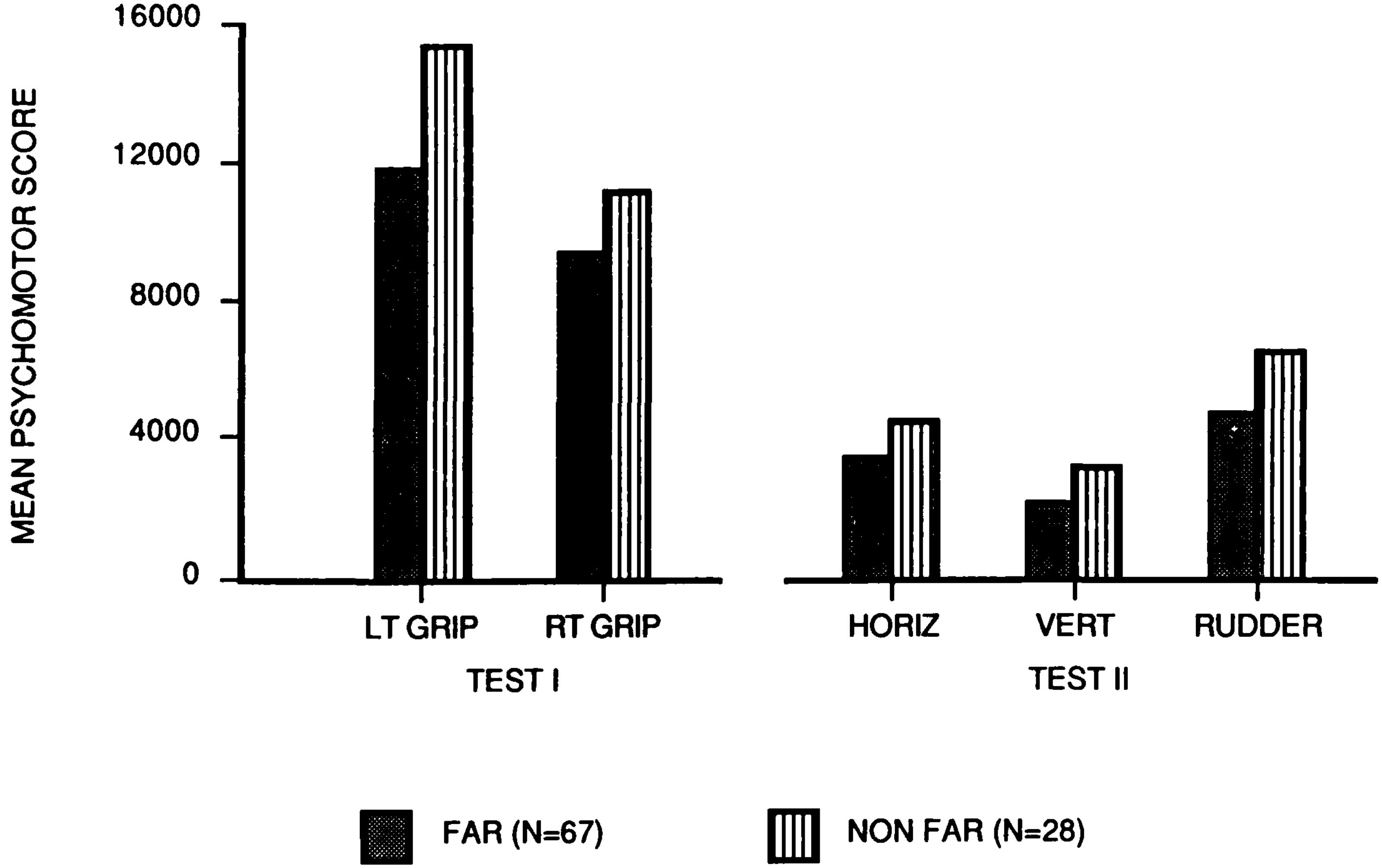

Figure 4. Mean Psychomotor Scores by FAR/Non-FAR (TTB).
(N = 95)

screening equation ($R = .196$) contained only the X_1 and Y_2 scores. (Appendix B summarizes this analysis.) Therefore, the most useful screening score based on psychomotor ability can be computed from the following equation:

$$Y_i = a + (b_1 \times X1_i) + (b_2 \times Y2_i)$$

where Y_i = psychomotor screening score of ith subject
a = constant (0.95648)
b_1 = weight of psychomotor X_1 score (-0.0000075748)
b_2 = weight of psychomotor Y_2 score (-0.000020375)
$X1_i$ = psychomotor X_1 score of ith subject
$Y2_i$ = psychomotor Y_2 score of ith subject

This psychomotor screening score was computed for the 1,725 cases in the developmental sample. The mean screening scores for the UPT graduates (79.0) and UPT eliminees (75.1) are depicted in Figure 5. Though the difference in the means was small, it was statistically significant ($p \leq .001$).

Psychomotor Screening System

The next step in the analyses was to determine the practical value of these scores differences. To use this information in a selection system, the psychomotor screening scores could be computed from the psychomotor test results for all available candidates. The candidates could then be rank-ordered, based on the computed screening scores; and the best candidates could be selected to fill the required training quotas. Figure 6 depicts such a ranking of the 1,725 subjects of the development sample. The sample was segmented into decile groups (10% each) for ease of comparison. The lowest-ranked decile is on the far left and the highest-ranked is on the far right. Each decile bar was further divided by the percentage of that decile that actually eliminated from UPT. As shown by the trend across the deciles, the lower-ranked deciles had greater percentages of eliminees than did the deciles ranked higher by the psychomotor screening system.

Utilization of Psychomotor Screening System

If all available candidates could be compared simultaneously, then the selection procedure could simply choose the number of candidates required from those with the highest screening scores. In operational use, this procedure would be complicated by the problems of multiple commissioning sources and the long-term planning required in the UPT selection process. An alternate approach would select only those candidates who obtain a screening score above a predetermined cutoff. The cutoff score would be determined and updated by comparing the recruiting environment and UPT attrition information. This approach would permit psychomotor screening to function as a "gate" at any step in the selection process in the same way that the AFOQT and FSP results are currently used (i.e., candidates with scores above the minimum cutoff proceed to the next phase of selection while those below the cutoff are rejected).

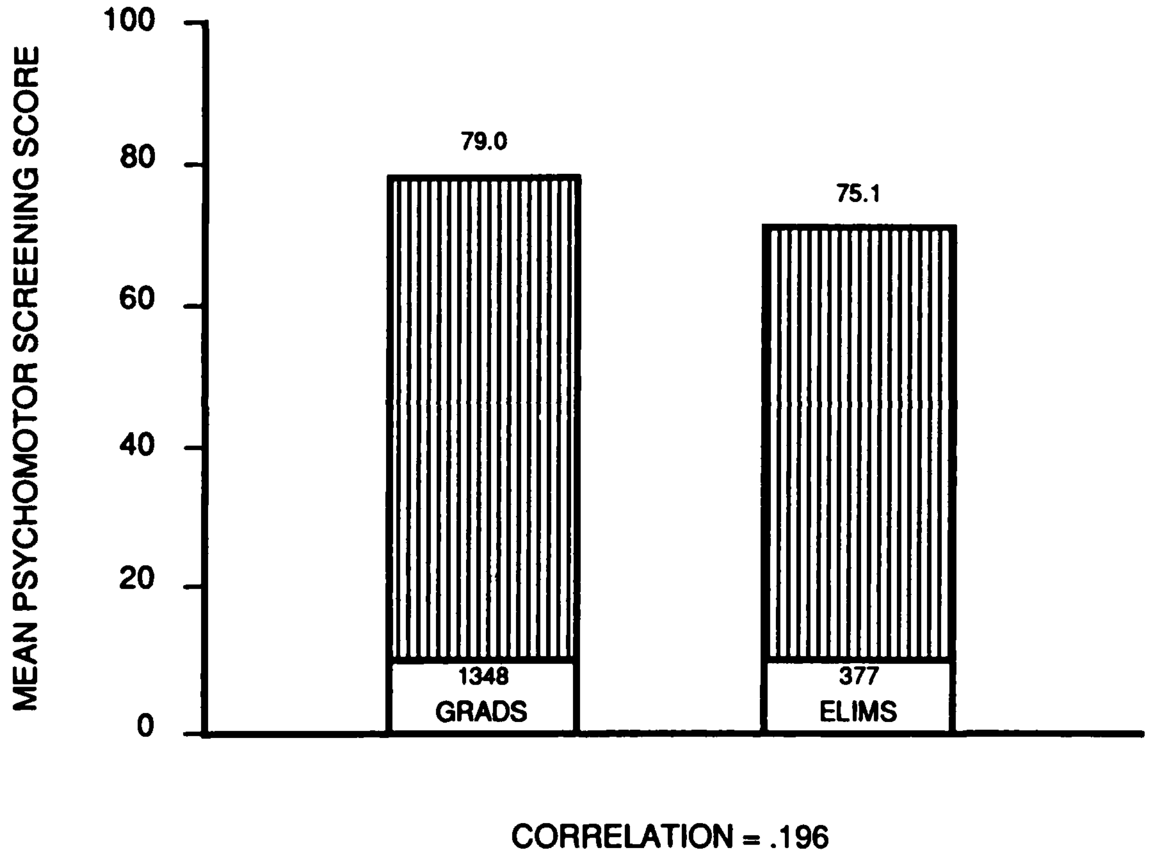

Figure 5. Mean Psychomotor Screening Score by UPT Outcome.
(N = 1,725)

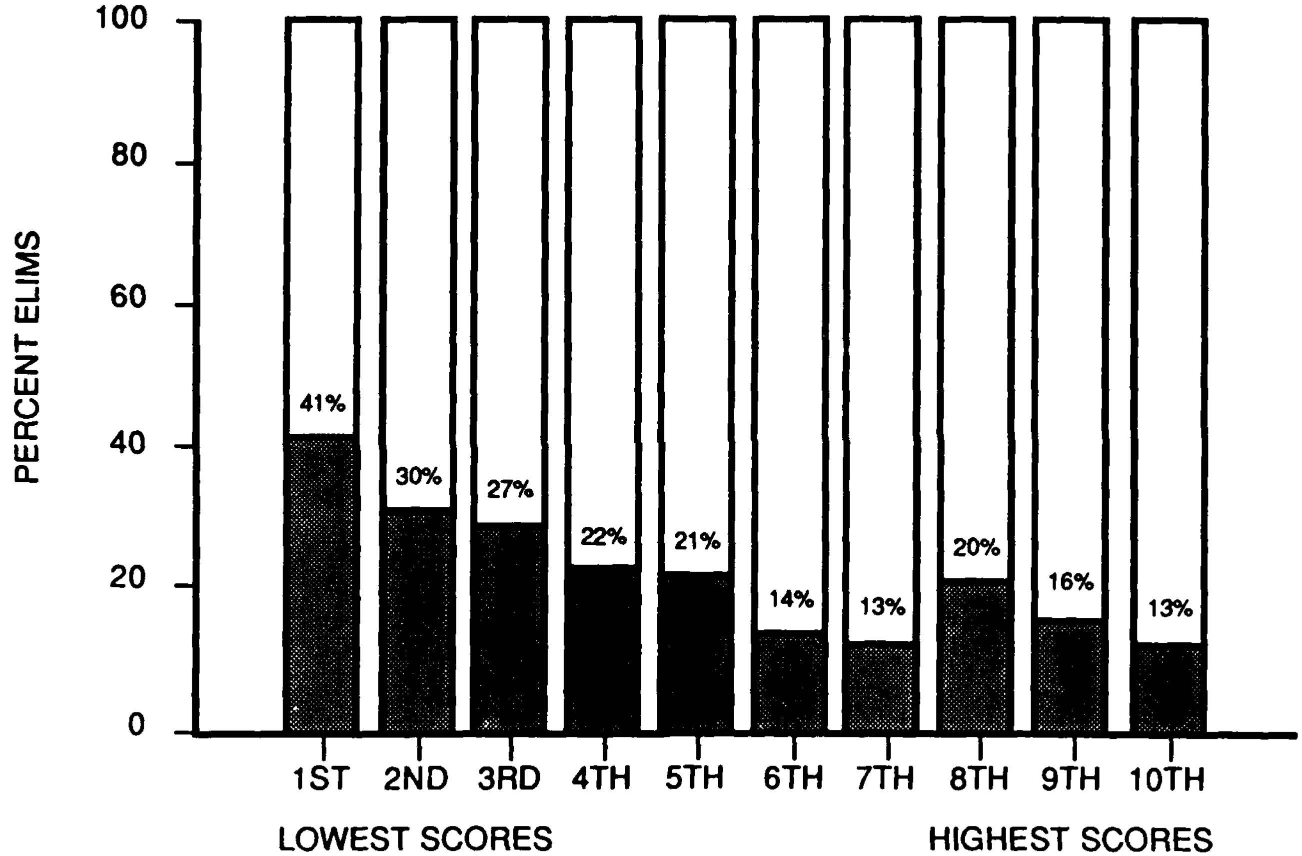

Figure 6. **Decile Groups Ranked by Psychomotor Screening Score.**
(N = 1,725)

The higher the psychomotor screening cutoff score is set, the greater the impact on attrition in UPT. However, some rejection of candidates who could pass training will also occur. This "false rejection" is a problem with all screening systems, including flying screening, and must be evaluated in terms of the percentages screened and the quality of the graduating students. Since the psychomotor scores were related to measures of UPT quality (class ranking and FAR recommendation), it is likely that the potential graduates in the lower deciles who would be "false rejections" would be poorer-performing graduates who would require more instruction and flying time.

Table 7 shows some examples of cutoff scores with the corresponding results that would have occurred had the cutoff applied to the 1,725 cases of the development sample. For each cutoff score, the hit-miss classification provided the percentile of the entire sample which would be screened, the percentage of actual UPT attritees in the sample who would be correctly screened and the percentage of UPT graduates in the sample who would be falsely rejected.

Table 7. Examples of Psychomotor Screening

Cutoff score percentile	% of attritees correctly rejected	% of graduates incorrectly rejected
5th	11.1	3.5
10th	19.6	8.0
20th	31.8	15.7
30th	45.9	26.7

Cross-Validation

Results were cross-validated using 166 candidates who completed UPT in FY83. These were the latest data from UPT available at the time of the analyses. The screening scores, computed for the FY83 sample using the psychomotor screening equation above, correlated significantly ($p \leq .005$) with UPT outcome ($R = .23$). The correlation was slightly larger than those found in the development samples, but this sample was considerably smaller. These results validate the psychomotor screening system on a more recent sample that was independent of its development. This suggests that psychomotor measures are sufficiently robust to be collected several years prior to UPT and still permit the psychomotor screening system to be effectively applied at UPT entry.

IV. INTEGRATED SELECTION SYSTEM

A potentially more effective approach to pilot candidate selection would consider all valid screening information simultaneously, including psychomotor. The advantage of an integrated approach is that, through analytical techniques, the best mix of the information from the multiple sources can be obtained, with components selectively weighted to increase screening effectiveness. Such an integrated system would contain a selection profile with the ranges of all the screening measures known for UPT graduates. A candidate's scores on all of the screening measures would be simultaneously compared to the successful graduate profile to produce an overall predicted probability of UPT success.

Current operational USAF pilot selection considers information from the five composite scores of the AFOQT, age at the start of UPT, possession of a college technical degree, and possession of a private pilot's license (PPL) or completion of a USAF light aircraft flying program like the

FSP. Upon investigation, USAF historical records were found to be very limited regarding the possession of a PPL and the flying results of the AFA Pilot Indoctrination Program (PIP) and the AFROTC Flight Instruction Program (FIP). Therefore, these data were not included in the developmental analyses. The only flying information included was the standardized results of the FSP conducted at Hondo AFB, Texas. The technical degree information and FSP final outcome information were used as dichotomous variables and coded 1 or 0 as appropriate. Two continuous variables based on FSP results were also included. These were the grade of the final evaluation flight and the sum of the grades from all of the other flights. In addition, gender and race of the candidates were included in the analysis. Appendix C lists the zero-order correlations of these measures with the criterion (UPT graduation/elimination for all reasons), each derived for all available subjects from the historical (FY79 to FY83) records.

Model Development

Because pilot candidates are chosen differently, depending on their source of commission, the available sets of historical information were different for each commissioning source. Therefore, three Integrated Pilot Candidate Selection Models (IPCSMs) were developed. Specifically, the FSP results were available only for OTS candidates. In addition, because AFA candidates were not required to take the AFOQT, these scores were available only for OTS and AFROTC candidates. Each IPCSM was developed from the psychomotor scores and the specific information currently used to select candidates from each major commissioning source. The samples used to develop each IPCSM are presented in Table 8. As was done for the psychomotor screening system, the three IPCSMs were reduced to the smallest set of measures possible without losing significant prediction, using F-ratios to compare the results of the various multiple linear regression analyses.

Table 8. Sample Sizes for Integrated Pilot Candidate Selection Models

IPCSMs	Sample Size
IPCSM I (OTS Model)	268
IPCSM II (AFROTC Model)	753
IPCSM III (AFA Model)	310

IPCSM I (OTS Model). The 268 subjects for IPCSM I (OTS Model) had 17 measures available (five psychomotor scores, age, five AFOQT composite scores, three FSP results, technical degree, gender, and race). This full model was reduced in a logical stepwise fashion down to a final seven-variable model. The F-ratio between the full model and the seven-variable final model (containing psychomotor X_1 and Y_2 scores, age, AFOQT pilot and navigator composite scores, and FSP sum of lesson grades and final grade) revealed no significant difference in prediction. Appendix D contains a summary of the analyses. In the presence of these measures, gender, race, and possession of a technical degree did not add to the prediction of UPT outcome.

The final prediction measures of IPCSM I were regressed against UPT outcome to produce a profile of a UPT graduate in the form of a weighted equation. IPCSM I (OTS Model) will produce a score corresponding to the probability of UPT success using the following equation:

$$\begin{aligned} Y_i = \; & a + (b_1 \times X1_i) + (b_2 \times Y2_i) + (b_3 \times \text{age}_i) \\ & + (b_4 \times AFOQTP_i) + (b_5 \times AFOQTN_i) \\ & + (b_6 \times FSP1_i) + (b_7 \times FSP2_i) \end{aligned}$$

where Y_i = IPCSM I Score for ith subject
a = constant (0.10192)
b_1 = weight for psychomotor X1 score (-.000015211)
b_2 = weight for psychomotor Y2 score (-.000010618)
b_3 = weight for age of subject (-.0012)
b_4 = weight for AFOQTP/AFOQT pilot score (0.00112)
b_5 = weight for AFOQTN/AFOQT navigator score (0.00029067)
b_6 = weight for FSP1/FSP final grade (0.08249)
b_7 = weight for FSP2/FSP sum of grades (0.01923)
$X1_i$ = psychomotor X1 score of ith subject
$Y2_i$ = psychomotor Y2 score of ith subject
age_i = age at start of UPT of ith subject
$AFOQTP_i$ = AFOQT pilot composite score of ith subject
$AFOQTN_i$ = AFOQT navigator composite score of ith subject
$FSP1_i$ = FSP final grade of ith subject
$FSP2_i$ = FSP sum of grades of ith subject

IPCSM II (AFROTC Model). Similar analyses were performed for IPCSM II (AFROTC Model) using 753 subjects who had 14 measures available (five psychomotor scores, age, five AFOQT composite scores, technical degree, gender, and race). The F-ratio between the full model and a final five-variable model (psychomotor X_1 and Y_2 scores, age, and AFOQT pilot and navigator composite scores) revealed no significant difference in prediction. Appendix D provides a summary of the analyses. Again, technical degree, gender, and race were found to be redundant in the presence of psychomotor, age, and AFOQT information.

The final prediction measures of IPCSM II were regressed against UPT outcome to produce a weighted profile equation. IPCSM II will produce a score corresponding to the probability of UPT success score using the following equation:

$$Y_i = a + (b_1 \times X1_i) + (b_2 \times Y2_i) + (b_3 \times age_i) + (b_4 \times AFOQTP_i) + (b_5 \times AFOQTN_i)$$

where Y_i = IPCSM II Score for ith subject
a = constant (1.72485)
b_1 = weight for psychomotor X1 score (-.0000030409)
b_2 = weight for psychomotor Y2 score (-.000022526)
b_3 = weight for age of subject (-.04517)
b_4 = weight for AFOQTP/AFOQT pilot score (0.00124)
b_5 = weight for AFOQTN/AFOQT navigator score (0.00225)

The common variables are as defined in the IPCSM I equation.

IPCSM III (AFA Model). Finally, the 310 subjects for IPCSM III (AFA Model) had eight measures available (five psychomotor, age, technical degree, and race). Gender was not included because all AFA candidates in this sample were males. The F-ratio between the full model and a final four-variable restricted model (psychomotor X_1 and Y_2 scores, age, and technical degree) revealed no significant difference in prediction. Appendix D shows a summary of these analyses. Without AFOQT data available, technical degree was found to be a significant predictor in IPCSM III (AFA Model).

The final prediction measures of IPCSM III were regressed against UPT outcome to produce a weighted profile equation. IPCSM III will produce a score corresponding to the probability of UPT success score using the following equation:

$$Y_i = a + (b_1 \times X1_i) + (b_2 \times Y2_i) + (b_3 \times age_i) + (b_4 \times tech_i)$$

where Y_i = IPCSM III Score of ith subject
a = constant (1.43056)
b_1 = weight for psychomotor X1 score (-.0000050818)
b_2 = weight for psychomotor Y2 score (-.0000072309)
b_3 = weight for age of subject (-.02111)
b_4 = weight for possession of technical degree (.08756)
$tech_i$ = 1 if ith subject has a technical degree, 0 otherwise

Common variables are as defined in the IPCSM I equation.

Predictive Validation

The weighted equations of the three IPCSMs were used to generate integrated selection scores for the pilot candidates of the three development samples within each IPCSM classification. These selection scores correspond to a candidate's probability of UPT success as predicted by the measures in IPCSM. The differences of the mean predicted scores between UPT graduates and eliminees for all three IPCSMs, and the correlations between these scores and UPT outcome, were significant ($p \leq .01$) and are shown by Figure 7. These results validate the use of all three IPCSMs as predictors of success or elimination in USAF UPT.

Utilization of the IPCSM Systems

As was done for the psychomotor screening system, the practical value of the significant differences in scores between graduates and eliminees was demonstrated for the three samples by separately ranking them on their IPCSM scores. For example, the 268 subjects in the IPCSM I (OTS Model) sample were rank-ordered and divided into deciles as depicted in Figure 8. Again, the lowest-ranked decile is on the far left, the highest-ranked is on the far right, and the bottom part of each decile bar is further divided by the percentage of that decile that actually eliminated from UPT.

The trend toward increasing percentages of eliminees within each higher-ranked decile is steeper in IPCSM I than for the psychomotor-only screening model (Figure 6) because of the increased accuracy obtained by integrating the selection information. Though not presented, the corresponding plots for IPCSMs II and III were similar.

Any of the three IPCSMs could be used to select UPT candidates in the same manner suggested for the psychomotor screening system. A predetermined cutoff score would form the screening point. Tables 9, 10, and 11 list examples of cutoff scores for the three IPCSMs with the results that would have occurred had the cutoff applied to the corresponding cases of the development samples. For each cutoff score, the hit-miss classification provided the percentile of the total sample which would have been screened, and the percentage of actual UPT attritees and percentage of UPT graduates at or below the cutoff. Each IPCSM would have correctly screened the attritees and incorrectly rejected the potential graduates by the indicated percentages.

Both the percentages of eliminees correctly screened and potential graduates who would be incorrectly screened showed improvement over the psychomotor screening system at every selection score cutoff point in these examples. Each IPCSM system, because of the integration of all of the available information, appears to identify more eliminees and screen fewer potential graduates than use of the same information in a series of gates.

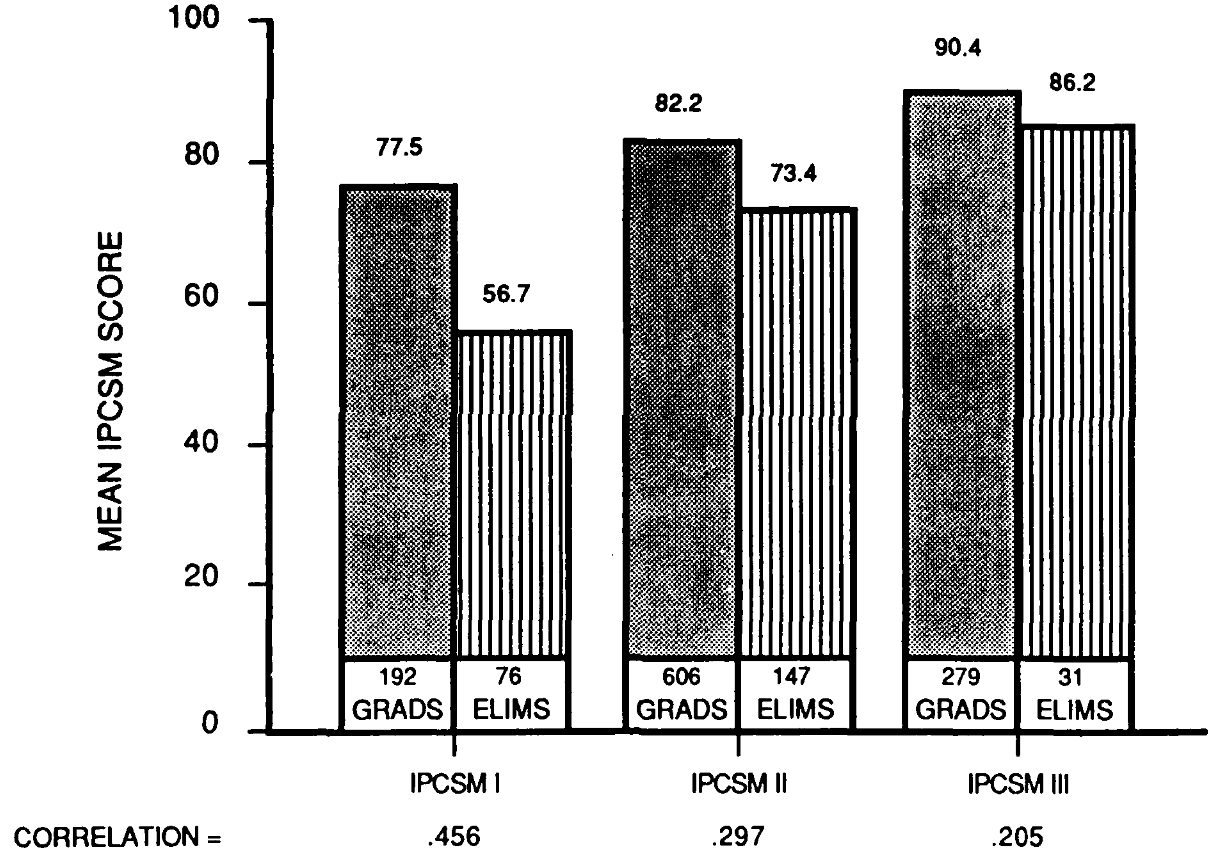

Figure 7. Mean IPCSM Scores by UPT Outcome.

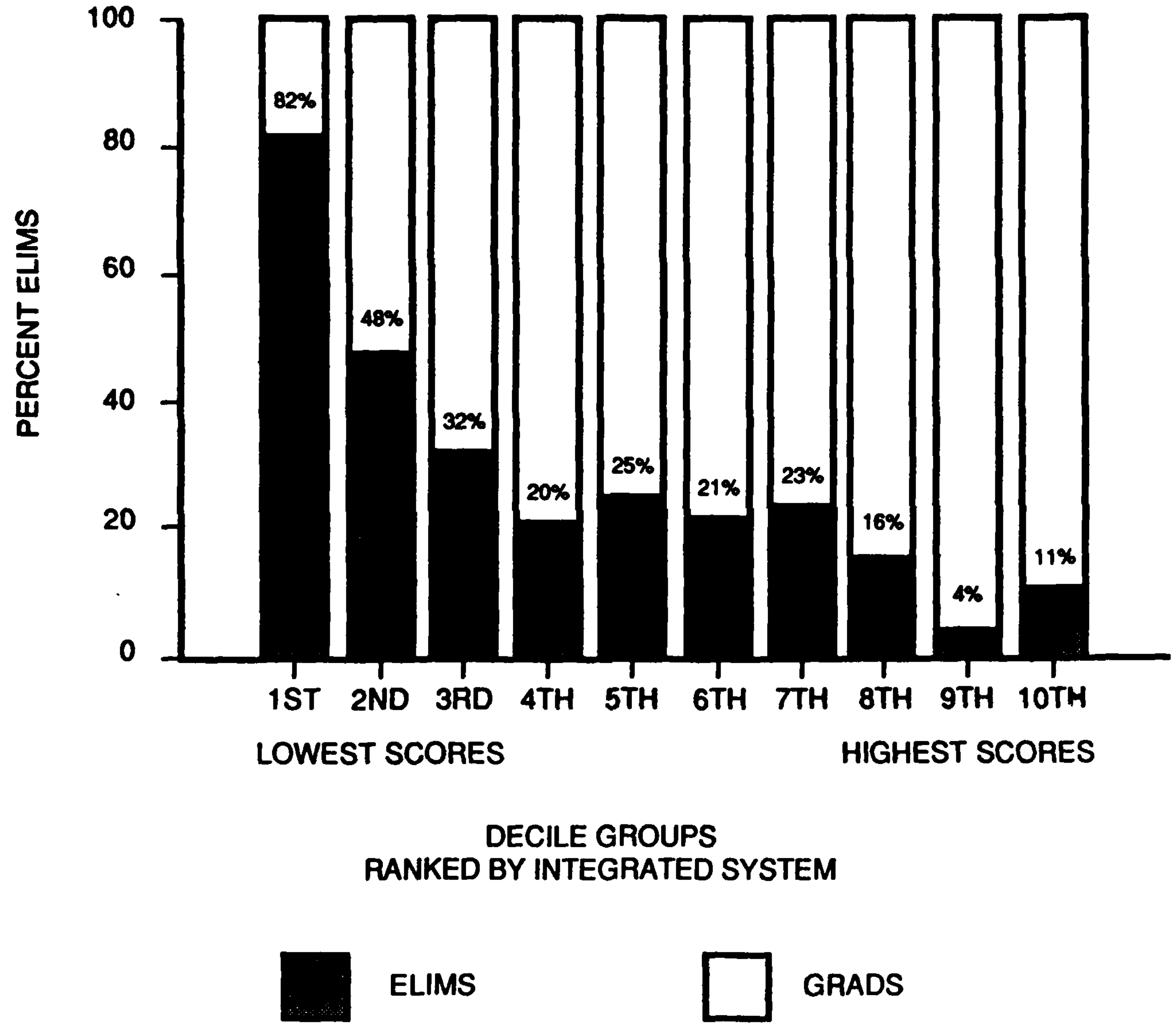

Figure 8. Decile Groups Ranked by IPCSM I (OTS Model).
(N = 268)

Table 9. Examples of IPCSM I (OTS Model) Screening

Cutoff score percentile	% of attritees correctly rejected	% of graduates incorrectly rejected
5th	18.4	0.0
10th	27.6	2.6
20th	47.4	10.4
30th	57.9	19.3

Table 10. Examples of IPCSM II (AFROTC Model) Screening

Cutoff score percentile	% of attritees correctly rejected	% of graduates incorrectly rejected
5th	15.0	2.5
10th	27.2	6.6
20th	38.8	15.7
30th	54.4	26.2

Table 11. Examples of IPCSM III (AFA Model) Screening

Cutoff score percentile	% of attritees correctly rejected	% of graduates incorrectly rejected
5th	16.1	4.3
10th	32.3	8.6
20th	48.4	15.8
30th	51.6	26.2

Cross-Validation

The FY83 UPT sample was again used to cross-validate the three IPCSMs. IPCSM I integrated scores were computed for the 82 subjects with all seven measures available and then correlated ($R = .33$) with UPT outcome. Though some shrinkage in correlation occurred for IPCSM I, the relationships were still significant ($p \geq .001$). For IPCSM II, 64 subjects had five measures available which significantly correlated ($R = .33$, $p \geq .005$) with UPT outcome. Thus, IPCSMs I and II cross-validated as predictors of UPT outcome on a more recent sample which was independent of their development. Finally, 165 subjects had the four measures of IPCSM III which correlated ($R = .11$) with UPT outcome. This correlation was not significant ($p \leq .07$), though the correlation in the development sample was; and questions about the generalizability of IPCSM III remain unanswered.

V. CONCLUSIONS/RECOMMENDATIONS

The results of the analyses in this report demonstrate that the two psychomotor tests generated by the computer-based test devices, Two-Hand Coordination and Complex Coordination, produce scores that are valid predictors of UPT outcome. Candidates who are likely to graduate from UPT can be differentiated by their scores from those who are likely to eliminate. Also, superior UPT students (FAR-recommended) can be differentiated from weaker students (non-FAR).

The differentiation of pilot candidates could be obtained through the implementation of the psychomotor-only screening system in the fashion of other screening gates currently being used (e.g., AFOQT, FSP). Since the cross-validation results demonstrated the robustness of the psychomotor measures over time, psychomotor testing could be administered very early in the selection process and still significantly predict the individual's probability of success without the need to retest the candidate at UPT entry. The strength of prediction and costs of psychomotor testing would be expected to be greater than those associated with the administration of the AFOQT but less than for flying screening. This could determine the logical sequence for these three screening gates. To maximize the impact on attrition and the quality of the students selected for UPT, the highest possible psychomotor screening scores should be selected as the cutoffs. This policy would screen the largest percentage of the candidates who would attrite. However, many potential graduates would also be rejected.

Psychomotor scores are not the only important information which should be used in the selection of pilots; rather, all significant predictors should be utilized. The IPCSMs capitalize on the utility of all available information, including psychomotor measures, to predict success or failure in UPT as well as quality of performance as measured by FAR recommendations. The "Whole Person Concept" (an appraisal of the important strengths of a candidate) is imbedded in this multi-dimensional IPCSM approach to pilot selection. The IPCSMs will not only impact attrition and quality in UPT, but will also reduce the rejection of potential graduates. Also, IPCSMs I and II can be used to screen minorities and women without consideration of race or gender.

Although the samples used in the development of the IPCSMs were aligned with a particular source of commission, that restriction was data dependent. The cross-validation of IPCSMs I and II were not restricted by source of commission. Therefore, the choice of the appropriate selection model to use should depend on the information available. IPCSM I is the strongest system (highest correlation with UPT outcome) and is recommended for use as the final selection system for candidates going through FSP (traditionally OTS cadets and recently, AFROTC cadets attending Summer Field Training at Lackland AFB, Texas). IPCSM II could be used as a preselection input either for OTS or for AFROTC Field Training.

Unfortunately, IPCSM III does not appear sufficiently stronger in prediction than the psychomotor screening system alone and therefore does not warrant implementation in its current form. However, if objective measures similar to the FSP and AFOQT information were available for AFA candidates in addition to the currently available data and psychomotor scores, then results similar to those from IPCSM I could be expected. A follow-on R&D effort to obtain these measures for Academy cadets and validate an IPCSM system for them is recommended.

Though the systems presented in this report will improve the selection of candidates for UPT, further refinements are possible. One improvement would develop the weights of the selection equations, not using the dichotomous UPT pass/fail criterion but instead, using a continuous measure of the individual's flying performance both in training and on operational missions. The candidates thus selected for training would have good chances of becoming successful operational pilots. The data to produce a Pilot Performance Index to provide this enhancement are being collected by AFHRL, and these analyses are planned for the near future. Another improvement to these systems would include information on candidates who possess a PPL. Research which compares the psychomotor test performance of FSP graduates and candidates with PPLs is recommended to extend the generalizability of these selection systems.

The addition of psychomotor screening to the selection procedure does not preclude the search for other valid measures of flying aptitude. Every valid measure added to an integrated selection procedure would help reduce the attrition and false rejections in training. A promising research area is the measurement of mental aptitudes such as information processing and decisiveness. The advent of extremely powerful microcomputers makes possible the measurement of reaction time and accuracy on very complex mental tests. Including such validated measures in the IPCSM systems would improve the current results. AFHRL has developed a battery of mental and personality tests, called the Basic Attributes Tests (BAT), for this expressed purpose. These 13 tests (Imhoff & Levine, 1981) are administered by a highly portable and flexible test device, called the Porta-BAT. Results of this ongoing effort will be reported in the future.

In conclusion, the implementation of psychomotor screening, either as a separate gate or within an integrated selection system, will improve the quality of student candidates in USAF UPT. Based on the results of this current effort, an integrated selection system including psychomotor screening is recommended. Future research should extend both the selection information being considered and the criteria to be predicted.

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LIST OF ABBREVIATIONS

AFA	Air Force Academy
AFB	Air Force Base
AFHRL	Air Force Human Resources Laboratory (AFSC)
AFOQT	Air Force Officer Qualifying Test
AFROTC	Air Force Reserve Officer Training Corps
AFSC	Air Force Systems Command
ATC	Air Training Command
ATRB	Advanced Training Recommendation Board (ATC)
BAT	Basic Attributes Tests
CRT	Cathode-Ray Tube
FAR	Fighter-attack-reconnaissance (training track)
FIP	Flight Instruction Program (AFROTC)
FSP	Flight Screening Program (OTS)
IPCSM	Integrated Pilot Candidate Selection Model
OTS	Officer Training School
PIP	Pilot Indoctrination Program (AFA)
PPL	Private Pilot's License
RPR	Request for Personnel Research
R&D	Research and Development
TTB	Tanker-transport-bomber (training track)
UPT	Undergraduate Pilot Training
USAF	United States Air Force

APPENDIX A: COMPARISON OF PSYCHOMOTOR SCORES BY UPT OUTCOME

	Psychomotor Scores				
	X_1	Y_1	X_2	Y_2	Z_2
Correlation with UPT outcome(N = 1,725)	-.12	-.10	-.14	-.17	-.15
Means by UPT Outcome[a]					
Graduate Means(N = 1,348)	14,315	16,341	3,559	2,858	4,725
All Elim Means(N = 377)	15,829	17,621	4,936	4,173	6,678
Flying Deficiency (FD) Elim Means (N = 199)	16,302	18,007	5,593	4,702	7,580
Probabilities of Psychomotor Score Differences Occurring by Chance Alone					
Grads vs. All Elims	.001	.001	.001	.001	.001
Grads vs. FD Elims	.001	.001	.001	.001	.001
FD vs. Other Elims	.103	.182	.006	.010	.005

[a]Psychomotor scores reflect errors; therefore, lower scores mean better test performance.

APPENDIX B: PSYCHOMOTOR SCREENING MODEL REDUCTION

	F-RATIO TEST (N = 1,725)			
	Psychomotor variables	Independent predictors	R^2	p value[a]
Full Model	X1,Y1,X2,Y2,Z2	6	.04225	.0000
Restricted Model	X1, Y2	3	.03842	.0000

$$F = \frac{(R_1^2 - R_2^2) / (IP_1 - IP_2)}{(1 - R^2{}_1) / (N - IP_1)}$$

$$F = \frac{(.04225 - .03827) / (6 - 3)}{(1 - .04225) / (1725 - 6)}$$

$$F = 2.38$$

Note. No significant difference in prediction strength of these two models since computed F-ratio value does not exceed the critical F value (F_c = 3.78).

[a]Probability of R^2 Occurring by Chance Alone.

APPENDIX C: ZERO-ORDER CORRELATIONS OF IPCSM PREDICTORS WITH UPT OUTCOME

Predictors	Correlation with UPT pass/fail	N[a]
FSP Pass/Fail	.137	1534
FSP Final Grade	.271	1534
FSP Sum of Grades 2-11	.303	1534
AFOQT Pilot score	.158	4460
AFOQT Navigator Technical score	.148	4460
AFOQT Academic score	.080	4577
AFOQT Verbal score	.007	4576
AFOQT Quantitative score	.138	4577
Psychomotor X1 score	-.118	1918
Psychomotor Y1 score	-.099	1919
Psychomotor X2 score	-.153	1906
Psychomotor Y2 score	-.181	1910
Psychomotor Z2 score	-.146	1916
Age	-.120	8438
Gender	.033	8438
Race	.110	8292
Possession of Tech Degree	.111	8183

[a]The sample sizes (N) were determined for all cases with valid data available for the prediction variable and the UPT criterion from the FY79 to FY83 UPT historical records.

APPENDIX D: IPCSMs REDUCTION USING F-RATIO TESTS

Full model	Restricted Model	$F = \frac{(R^2{}_1 - R^2{}_2) / (IP1 - IP2)}{(1 - R^2{}_1) / (N - IP1)}$
IPCSM I Variables		**F-ratio test calculations**
Psychomotor(5)	Psychomotor(2)	$F = \frac{(.23254 - .21501) / (18 - 8)}{(1 - .23254) / (265 - 18)}$
FSP(3)	FSP(2)	
AFOQT(5)	AFOQT(2)	
Age	Age	
Tech Degree		F = 0.56[a]
Race		
Gender		F(critical) = 2.41
Analyses results		
R^2 = .23254	R^2 = .21501	
df = 17	df = 7	
N = 265	N = 265	
$p \leq .0000$	$p \leq .0000$	
IPCSM II variables		**F-ratio test calculations**
Psychomotor(5)	Psychomotor(2)	$F = \frac{(.09673 - .08437) / (15 - 6)}{(1 - .09673) / (741 - 15)}$
AFOQT(5)	AFOQ1(2)	
Age	Age	
Tech Degree		F = 1.10[a]
Race		
Gender		F(critical) = 2.41
Analyses results		
R^2 = .09673	R^2 = .08437	
df = 15	df = 6	
N = 741	N = 741	
$p \leq .0000$	$p \leq .0000$	
IPCSM III variables		**F-ratio test calculations**
Psychomotor(5)	Psychomotor(2)	$F = \frac{(.05581 - .04294) / (9 - 5)}{(1 - .05581) / (305 - 9)}$
Tech Degree	Tech Degree	
Age	Age	
Race		
		F = 1.01[a]
Analyses results		
R^2 = .09673	R^2 = .08437	F(critical) = 3.32
df = 15	df = 6	
N = 741	N = 741	
$p \leq .0000$	$p \leq .0000$	

[a]No significant difference in models.

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