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ITEM ANALYSIS AND REVISION OF THE FLIGHT APTITUDE SELECTION TESTS

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INTRODUCTION

The Flight Aptitude Selection Test (FAST), the Army's primary selection instrument for applicants for flight training, became operational in 1966 (Kaplan, 1965). Enlisted applicants use the Warrant Officer Candidate Battery (WOCB) version, commissioned applicants the Officer Battery (OB) version. Although these batteries have proved to be effective selection instruments, the predictive validity of the WOCB was found to have declined somewhat by 1975 (Eastman and McMullen, 1978). Because of this reduction in validity, as well as changes in the initial entry flight training program and the population of trainees, the US Army Aviation Center (USAAVNC) requested research to revise the FAST battery.

The current operational FAST battery is scored by hand more than 90% of the time. Quality checks at MILPERCEN and reports from field testing locations reveal a high error rate among hand-scored tests. This required es ablishing a quality control system in 1975 by which FAST test scores are checked by hand at MILPERCEN. Thus, it was apparent that a desirable test battery would be one which was easier to administer and which could be "checked" by machine.

At the time the FAST was originally developed provisions were made for further analysis to shorten the battery and provide more effective prediction of training performance, (Kaplan, 1965). This research represents an effort to accomplish these objectives and to develop a single FAST battery for all applicants consisting of fewer, shorter, and more easily scored component tests.[1]

METHOD

SAMPLES

The samples used for these item analyses consisted of 4,977 Warrant Officer Candidates (WOC) and 2,030 Commissioned Officers who met standards qualifying them for admission to the Initial Entry Rotary Wing (IERW) course at the USAAVNC during the period 1966 to 1972. Only trainees for whom FAST scores and training performance data were available were included in the item analysis samples.

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[1] The authors are indebted to Mr. Edmund Fuchs for the helpful insights he provided, several of which are incorporated into the text of this research memorandum.

VARIABLES: PASS/FAIL CRITERIA

A dichotomous pass/fail criterion was used. Reasons for elimination were also examined and analysis was conducted using different "failing" groups. The first included all those eliminated regardless of the reason for attrition. The second included only those individuals who were eliminated for reasons clearly related to the training requirements of IERW. The differences between the "failing groups" were found to be small, and the larger group was used for item analysis purposes, because many of the ostensibly irrelevant reasons for elimination were found to be used as "ways out" for incipient flight and academic failures.

FAST COMPONENT TESTS

A total of 12 tests comprised the original FAST. These are listed in Table 1. Of these, 8 were common, two (Mechanical Principles and Flight Orientation) were used only with Officers, and a Biographical Information measure for Officers had a counterpart in a Self-Description measure for WOC. These tests contained a total of 563 items, which were included in the analyses described below.

ANALYSIS PROCEDURE

As indicated earlier, a principal objective in the revision effort was to shorten the battery. To accomplish this the following two-phase approach was applied: First, the number of tests included in the battery was reduced by factor analysis and stepwise multiple correlation. Second, items in each of the more predictive tests were subjected to the item analysis procedures described in Appendix A to retain the more valid items and eliminate the less effective ones.

RESULTS AND DISCUSSION

To determine if fewer tests might adequately measure the aptitudes underlying performance on the FAST battery, the intercorrelations of component tests and pass/fail criterion were computed.

The intercorrelations among tests in Tables 2 and 3 suggest that clusters of variables measure the same factor. To confirm this observation the correlation matrices were factor analyzed. Table 4 shows the factor matrices resulting from this analysis.

The factor loadings in Table 4 represent correlations between test and factor scores. For example, the number in the left-hand corner of the table represents the correlation between a first factor, labeled perceptual skills, and the Visualization of Maneuvers test. This correlation is high because the Visualization of Maneuvers test correlates highly with perceptual skills; Self-Description, by comparison, correlates slightly negatively with the perceptual skill factor.

Table 1

FLIGHT APTITUDE SELECTION TESTS (FAST)

Measure	Battery For WOC	Officers
Stick and Rudder Orientation	X	X
Instrument Comprehension	X	X
Complex Movements	X	X
Helicopter Knowledge	X	X
Mechanical Functions	X	X
Self-Description Blank	X	
Biographical Inventory		X
Mechanical Information	X	X
Visualization of Maneuvers	X	X
Aviation Information	X	X
Mechanical Principles		X
Flight Orientation		X

(WOC = Warrant Officer Candidates)

Table 2

CORRELATION MATRICES OF FAST BATTERY COMPONENT TESTS WARRANT OFFICER BATTERY

	Self-Des	Inst Comp	Mech Info	Complex Mvmts	Vis of Maneuvers	Hel Knowl	Stick & Rudder	Avn Info	Mech Func
Self-Description	-	-.36	-.02	-.06	-.11	.03	-.05	.01	-.08
Inst Comp	-.36	-	.13	.28	.41	.25	.35	.27	.29
Mech Information	-.02	.13	-	.05	.11	.40	.12	.31	.36
Complex Mvmts	-.06	.28	.05	-	.31	.09	.21	.07	.18
Vis of Maneuvers	-.11	.41	.11	.31	-	.19	.37	.17	.39
Hel Knowledge	.03	.25	.40	.09	.19	-	.27	.54	.36
Stk & Rudder Orien	-.05	.35	.12	.21	.37	.27	-	.33	.31
Avn Information	.01	.27	.31	.07	.17	.54	.33	-	.31
Mech Functions	-.08	.29	.36	.18	.39	.36	.31	.31	-

Table 3

CORRELATION MATRICES OF FAST BATTERY COMPONENT TESTS OFFICER BATTERY

	Inst Comp	Mech Info	Complex Mvmts	Vis of Maneuvers	Hel Knowl	Stick & Rudder Orien	Avn Info	Mech Func	Bio-Info	Mech Prin	Flt Orien
Inst Comp	-	.21	.33	.49	.30	.42	.29	.38	.06	.37	.39
Mech Information	.21	-	.13	.22	.46	.21	.34	.42	.33	.56	.19
Complex Mvmts	.33	.13	-	.35	.18	.21	.10	.20	.01	.28	.35
Vis of Maneuvers	.49	.22	.35	-	.26	.44	.24	.42	.08	.42	.42
Hel Knowledge	.30	.46	.18	.26	-	.30	.55	.40	.22	.44	.23
Stk & Rudder Orien	.42	.21	.21	.44	.30	-	.33	.38	.12	.32	.41
Avn Information	.29	.34	.10	.24	.55	.33	-	.35	.21	.36	.25
Mech Functions	.38	.42	.20	.42	.40	.38	.35	-	.17	.59	.34
Biographical Info	.06	.33	.01	.08	.22	.12	.21	.17	-	.23	.06
Mech Principles	.37	.56	.28	.42	.44	.32	.26	.59	.23	-	.41
Flight Orien	.39	.19	.35	.42	.23	.41	.25	.34	.06	.41	-

TABLE 4

FACTOR ANALYSIS OF FAST BATTERIES

Warrant Officer Battery

Test	Factor 1 Perceptual Skills	Factor 2 Knowledge	Factor 3 Personal Attributes
Visualization of Maneuvers	.76	.13	-.05
Complex Movements	.71	-.14	.00
Stick and Rudder Orientation	.61	.27	-.04
Instrument Comprehension	.61	.26	.11
Helicopter Knowledge	.15	.76	.07
Aviation Information	.14	.75	.09
Mechanical Information	.00	.74	.01
Mechanical Functions	.47	.52	-.14
Self-Description	-.07	-.04	.98

Officer Battery

	Factor 1	Factor 2
Visualization of Maneuvers	.76	.15
Flight Orientation	.72	.13
Instrument Comprehension	.70	.16
Complex Movements	.66	-.05
Stick and Rudder Orientation	.62	.24
Mechanical Information	.12	.77
Helicopter Knowledge	.23	.70
Aviation Information	.22	.63
Mechanical Principles	.46	.62
Biographical Information	-.05	.61
Mechanical Functions	.47	.53

Stepwise multiple correlation was next used to determine which of the test loading on the three factors correlate highest with the training performance criterion. This statistical procedure adds tests to the multiple regression equation in a stepwise fashion, i.e., the test that best predicted training success is included first; the test which combined with the best predictor increases the multiple r the greatest amount is added second, and so on, until all the predictor variables are included in the regression equation. These results show agreement of the first five measures for Officers with five of the first six measures for WOCs (counting Biographical Information and Self-Description as overlap). Because these are correlations in the samples of students selected for training, they represent significant restriction in range because of selection on the battery. Hence, the true validities in the applicant population are almost certain to be significantly higher.

In each sample the multiple r tended to stabilize, and an increase of less than .01 was provided by tests not included in the revised battery. These "back" validities showed multiple r's of .31 in the Officer sample and .39 in the WOC sample. Table 5 shows that those tests identified by the factor analysis as measures of perceptual factors contribute most to the multiple regression equation. Next in importance were the tests involving aviation and mechanical knowledge. Finally, those tests assessing personal factors contributed least to the prediction. Based on the results of both the factor analysis and the stepwise multiple regression analysis, the tests indicated in Table 6 and their associated factors were selected for retention in the battery. After tests were chosen for retention in the battery, specific items were selected for inclusion using the item analysis statistics described in Appendix B. The basic procedure consisted of eliminating items with very high or low difficulty levels; then for each item in each test, a phi coefficient was computed between the relation of right or wrong response on the item to passing or failing the course. The phi coefficient used was corrected for the restriction in range resulting from screening the aviator training candidates on the FAST battery (Gillman & Goode, 1946; Walker and Lev, 1969). It has proven feasible to reduce each test to about half the original number of items with the suggested increase rather than reduction in overall validity of the battery (see Appendix A, Table A-1).

The number of items retained in each subset was based on several considerations: (1) validity, (2) desirability of shortening the test, and (3) keeping standard deviations of the component tests close enough to permit unit weighting of component tests. The standard deviations of the original component tests in Appendix B show a narrow range for the retained tests except for Helicopter Knowledge. Because the Helicopter Knowledge test showed a smaller standard deviation than the other tests, its number of items was not reduced. Instead, new items were substituted for those with low phi values. Because the items which were eliminated from the retained test tended to have low phi values, any reductions have probably been in non-valid variance, thus tending to improve the validity of the shorter measures and the new battery. Table 7 shows the number of items in the original tests and the number retained after item analysis.

Table 5

STEPWISE MULTIPLE REGRESSION OF FAST COMPONENT TEST ON THE PASS/FAIL CRITERION

Test in Order of Inclusion	Multiple R	Dominant Factor
Warrant Officer Battery		
Stick & Rudder Orientation	.27	Perceptual
Helicopter Knowledge	.32	Aviation Information
Complex Movements	.35	Perceptual
Instrument Comprehension	.37	Perceptual
Mechanical Functions	.38	Mechanical Knowledge
Self-Description	.39	Background
Officer Battery		
Instrument Comprehension	.24	Perceptual
Stick & Rudder Orientation	.27	Perceptual
Biographical Information	.29	Personality/Background
Complex Movements	.30	Perceptual
Helicopter Knowledge	.31	Information/Knowledge

Table 6

TESTS RETAINED AFTER ANALYSIS AND THEIR DOMINANT FACTORS

Test	Dominant Factors
Self-Description	Personality/Background
Biographical Information	Personality/Background Knowledge
Instrument Comprehension	Perceptual
Complex Movements	Perceptual
Helicopter Knowledge	Knowledge
Stick and Rudder Orientation	Perceptual
Mechanical Functions	Knowledge

With evidence that the test selection technique has identified a subset of measures which cover the valid variance of the FAST, and that the item analysis technique has identified, for each retained test, a subset of the more valid items, the shorter test in the shorter battery will probably correlate as well with the criterion as do the longer tests in the longer battery

Identification of the specified tests as most appropriate for a revised FAST, which will be used for helicopter pilot selection, gains strong support from the sub-batteries of the original FAST. At the time the FAST was developed, the Army Aviation Center provided training to both fixed wing and rotary wing pilots. Fixed wing training was generally restricted to officers, but to be prepared for any shift in pilot requirements, the regulations on application for flight training called for applicants to take the entire appropriate (WOC or Officer) test battery (see Table 8). Sub-batteries of these tests are scored separately as the Rotary Wing Score and Fixed Wing Score. To be considered for any flight training the candidate had to pass a composite of the Rotary and Fixed Wing scores, thus involving all the tests in the battery. The separate sub-batteries represented research on the separate training programs. Interestingly, the set of tests identified by the test selection process reported above consititute the counterpart Rotary Wing Score sub-battery with the single substitution of the Instrument Comprehension test for the Visualization of Maneuver test. In effect, based on large samples collected over varied conditions, the appropriateness of the battery identified here is supported by the research which first provided the FAST battery.

Table 7

NUMBER OF ORIGINAL FAST QUESTIONS RETAINED AFTER ITEM ANALYSIS

Test	Original Number of Items	Number of Items Retained
Self-Description (WOCB)	190	73
Biographical Information (OB)	74	27
Instrument Comprehension	30	15
Complex Movements	60	30
Helicopter Knowledge	20	12*
Stick and Rudder Orientation Test	30	15
Mechanical Functions	34	20
TOTALS	438	200

* Eight new items added for a total of 20.

Because of administrative problems in operational use of the FAST, the current research has stressed the abbreviation of the selected tests, the simplification of scoring procedures, and the use of a single test battery for all applicants. Specifically, provisions have been made for hand-calculated composite scores to be coded on the revised FAST answer sheet for validation when the answer sheets are machine scored. Table 9 shows the restructuring of the FAST battery results from test and item analyses. The revised FAST will be a shorter test which is easier to administer and score than the original battery. It is anticipated that it will be a more valid selection instrument because it is more helicopter-oriented and consists of items selected for high criterion-related validity.

Table 8

CONSTITUTION OF FLIGHT APTITUDE SELECTION TESTS

Test	Officer		Warrant Officer	
	Rotary	Fixed	Rotary	Fixed
Biographical Information	X	X		
Mechanical Principles		X		
Flight Orientation		X		
Aviation Information				
Fixed-Wing		X		X
Rotary-Wing	X		X	
Mechanical Information		X		X
Mechanical Functions	X		X	
Visualization of Maneuvers	X	X	X	X
Instrument Comprehension		X		X
Complex Movements	X		X	
Stick and Rudder Orientation	X		X	
Self-Description			X	X

Table 9

RESTRUCTURING OF THE FAST BATTERY

	Original Batteries	Revised Test
Number of Tests	12	6
Total Nr. Items OB	458	
WOCB	384	200
Administration Time	4	2 hours

SUMMARY AND CONCLUSIONS

This Research Memorandum describes the analysis procedures used to select component tests and items in tests for retention in a single revised FAST battery to be used by both officers and WOC. Twelve tests comprising a total of 561 items were analyzed using passing and failing subgroups of samples of 4,977 Warrant Officer candidates and 2,030 commissioned officers enrolled in IFRW flight training. The tests which were most predictive of success in IFRW were subjected to item analysis and the most effective items in each test were included in the revised battery. Several new items were added to round out the number of items and to make the magnitude of the standard deviations of component tests approximately equal. In summary:

1. Three factors were found to be accountable for examinee composite FAST scores: (a) perceptual, (b) information knowledge, and (c) personality background factors, in that order.

2. Several tests were selected for retention in the revised battery based on the magnitude and purity of their loadings on the three factors and the results of a stepwise multiple-regression analysis of all component tests on training performance outcome. Those tests were (a) three tests of perceptual ability (Instrument Comprehension, Complex Movements, and Stick and Rudder Orientation), (b) two tests assessing knowledge and information (Helicopter Knowledge and Mechanical Functions), and (c) a test combining personality background information (Self-Description Background Information Form).

3. Items within tests selected for the revised battery were analyzed for validity, and the more predictive items were retained.

4. A single shorter test battery was constructed which can be used for all applicants and is more easily administered and scored. It also includes provisions for the quality assurance of hand-scored answer sheets.

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APPENDIX A

ITEM SELECTION PROCEDURES

Items for inclusion in the tests were selected using the following item analysis statistics:

N - number of frequency of examinees responding to an item.

p value - the proportion of examinees who pass the item.

difficulty - the average proportion of all samples passing the item.

discrimination - the difference in the proportion of correct responses between the passing and failing groups.

phi coefficients - a measure of the correlation of each item with success or failure in flight training.

Questions within a test with a difficulty level greater than .80 and less than .20 were eliminated first. The remaining items were then arranged in descending order according to the magnitude of the phi validity coefficient computed between each item and the pass/fail criteria. A value of phi was then picked that would reduce the set to approximately half the number of questions in the original set (see Table 5).

Questions from 1 and 2 were combined as a new test under the title "Self-Description/Background Information Form." For tests 1 and 2, when a test item was comprised of several questions, if the majority of the questions were eliminated by the above criteria, the whole item was eliminated. If the majority of the questions were accepted, the whole item was accepted. One new item was added to round out the number of items to 100.

In Complex Movements, two items that had been eliminated were added back in to round out the subtest to 30 items. They were from the end of the original test and as a result had a low frequency of attempted answers. Both were below the lower cut score on difficulty.

Helicopter Knowledge had one item with low phi added back (.03) in addition to 8 new items.

Stick & Rudder had one low phi item (.07) added back in to round to 15 items.

Mechanical Information had two (2) items with low phi and two (2) items with high difficulty but high phi added back in to bring the number to 20 in the subtest and 200 in the overall test.

Table A-1 shows the old and new FAST batteries' relative lengths and the median phi values for retained and rejected items with some interpretation between the values for Officers and WOCs.

TABLE A-1

COMPARISON OF THE NUMBER OF ITEMS AND MEDIAN PHI'S
OF ORIGINAL AND REVISED FAST BATTERIES

	Number of Items		Median Phi's	
MEASURE	Original FAST	Revised FAST	Retained	Rejected
Stick and Rudder Orientation	30	15	.11	.07
Instrument Comprehension	30	15	.13	.08
Complex Movements	60	30	.08	.04
Helicopter Knowledge	20	20*	.09	.05
Mechanical Functions	34	20	.07	.02
Self-Description/ Biographical	264	100	.04	.01

*Actually, 12 retained and 8 new items

APPENDIX B

MEANS AND STANDARD DEVIATIONS OF WOCB AND OB COMPONENT TESTS

WARRANT OFFICER CANDIDATE BATTERY (N = 4977)

Test	Mean	Standard Deviation
1. Self-Description	79.69	7.61
2. Instrument Comprehension	16.87	8.22
3. Mechanical Information	14.11	6.41
4. Complex Movements	23.81	9.96
5. Visualization of Maneuvers	17.57	6.25
6. Helicopter Knowledge	9.75	4.18
7. Stick and Rudder Orientation	23.77	8.26
8. Aviation Information	8.55	5.79
9. Mechanical Functions	14.01	7.04
OFFICER BATTERY (N = 2030)		
1. Instrument Comprehension	18.08	7.94
2. Mechanical Information	13.33	6.51
3. Complex Movements	24.28	10.03
4. Visualization of Maneuvers	16.90	6.44
5. Helicopter Knowledge	10.12	4.22
6. Stick and Rudder Orientation	23.30	8.36
7. Aviation Information	7.64	5.21
8. Mechanical Functions	13.49	7.17
9. Biographical Information	34.79	5.82
10. Mechanical Principles	11.95	6.29
11. Flight Orientation	26.86	14.14