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Selection of Officers for U.S. Naval Aviation Training

Henry P. Williams
Amanda O. Albert
David J. Blower
Naval Aerospace Medical Research Laboratory
51 Hovey Road
Naval Air Station Pensacola, Florida 32508-1046
USA

Summary

This paper reviews the process of selecting officers for U.S. naval aviation training and describes one of the principal selection tools, the Aviation Selection Test Battery (ASTB). The 1992 version of the ASTB is a paper-and-pencil test administered to all applicants for naval aviation training. ASTB scores and ground school and flight training performance data were available for 2852 student naval aviators and student naval flight officers, and these data were used to re-assess the validity of the ASTB in predicting student performance. The results indicated that the ASTB remains a valid predictor of ground school and flight training grades, and to a lesser extent, attrition from training. For a small subset of the sample used in these analyses, data from a computer-based performance test (CBPT) were also available. The CBPT required subjects to engage in multi-axis tracking tasks concurrently with other cognitive tasks, such as dichotic listening and working memory tasks. Scores from the ASTB, the CBPT, and grades from ground school were entered into a linear regression upon primary flight training grades. The results showed that the combination of ground school and CBPT scores can be used as a good predictor of performance (R^2 = .33, p <.0001). Although these results will require cross validation, the CBPT shows promise as a new selection tool. The importance of these results is discussed in the context of a recently developed computer-based version of the ASTB.

Introduction

Earning the wings of a U.S. naval aviator is a goal that many seek. Each year, approximately 10,000 individuals demonstrate this interest by taking the U.S. Navy and Marine Corps Aviation Selection Test Battery (ASTB). The ASTB is one of the initial filters in selecting students for training as either pilots or naval flight officers (NFOs, who perform navigation and weapons systems duties in the cockpit). This paper describes the ASTB and reviews the aviator selection process, and then presents analyses that were conducted on data from existing and potentially new methods of selecting U.S. Navy pilots.

The ASTB

The ASTB was originally introduced in 1942, and revisions followed in 1953, 1971, and 1992 (Frank & Baisden, 1993). The current 1992 version was developed and validated by Educational Testing Services of Princeton, New Jersey. It is a paper-and-pencil test that takes approximately 2.5 hours to administer, and consists of six sub-tests. The six sub-tests are the math-verbal test, the mechanical comprehension test, the spatial apperception test (which measures spatial reasoning abilities), the aviation and nautical information test, the biographical inventory (which contains questions on personal history and interests), and the aviation interest test. Weighted combinations of the sub-tests are used to calculate the following three scores used in the pilot selection process:

1. The academic qualification rating (AQR) - validated to predict academic performance in ground school.

2. Pilot Flight Aptitude Rating (PFAR) - validated to predict flight grades in primary flight training.

3. Pilot Biographical Inventory (PBI) - validated to predict attrition through primary flight training.

The Naval Operational Medicine Institute (NOMI) oversees the ASTB testing program, including test distribution, official scoring, and database management.

The Selection Process

The ASTB plays an early role in narrowing down the very large field of those who apply for naval aviation training. Data provided by NOMI show that approximately half of those taking the ASTB fail to meet minimum selection scores. Those who score favorably must then undergo a thorough physical examination to ensure that they meet medical standards. Approximately 25% do not pass the physical screening process. Those who remain eligible are interviewed by two officers who complete an evaluation form on the applicant, and the applications are forwarded to a three-member evaluation board. This board usually consists of two naval aviators and a program manager who is knowledgeable of current and projected demands for naval aviators. Approximately half of the applications are recommended for selection by the board. Upon final approval, the selected applicants are offered the opportunity to enter naval aviation training. Overall, then, only about 15% of those who take the ASTB are selected to begin training.

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Applicants who were selected from the U.S. Naval Academy (USNA) or from Naval Reserve Officer Training Corps (NROTC) programs begin 6 weeks of ground school training at Aviation Pre-flight Indoctrination (API). API is located at Naval Air Station Pensacola, and students must master topics such as aerodynamics, fundamentals of turbine engines, air navigation, flight rules and regulations, aviation physiology, and water survival. Applicants who did not graduate from either the USNA or an NROTC program must first complete 13 weeks of Officer Candidate School before beginning API. After completing API, pilots and NFOs proceed to separate primary flight training programs.

Given the important role that the ASTB plays in the selection process, it is important to assess its validity continually. Frank and Baisden (1993) and Hiatt, Mayberry, and Sims (1997) have examined the predictive validities of ASTB scores, and their findings are summarized in Table 1. The *r* values represent correlations uncorrected for restriction of range. Note the negative association between PBI scores and attrition status, indicating that those with higher PBI scores are less likely to fail out of primary flight training.

Table 1
Previously reported correlations between ASTB scores and criterion variables

	Frank & Baisden (1993)	Hiatt, et al. (1997)
AQR : academic performance in API	$r = .40$ p not reported	$r = .42$ $p < .05$
PFAR : primary flight training grades	$r = .27$ p not reported	$r = .40$ $p < .05$
PBI : attrition from primary flight training	$r = -.25$ p not reported	$r = -.12$ $p < .05$

Damos (1996) reviewed correlations between flight training performance and a wide variety of other aviation selection tests and found results comparable to those for the ASTB. Although the correlations are statistically significant, the best that can be said for most of them, including those for the ASTB, is that they are only moderately strong. Selecting pilot candidates and predicting their flight training performance is unquestionably a very difficult and complex endeavor, yet it seems that we should be able to do better.

For several decades, scientists at the Naval Aerospace Medical Research Laboratory (NAMRL) have been developing aviator selection tests that could be used in conjunction with the ASTB. These efforts have been reviewed by Blower and Dolgin (1991). Many of these tests are computer-based and measure a participant's cognitive and psychomotor skills in both single- and dual-task/divided attention contexts. The fact that these tests include psychomotor tasks that must be performed in a divided attention setting brings them a step closer to representing what is demanded of the pilot in the cockpit, as compared to the paper-and-pencil ASTB. With this in mind, we set out to reexamine the validity of the aging ASTB and to identify any incremental validity that computer-based tests could add to the current methods used to select applicants into aviation training.

Method

As part of an ongoing project, NAMRL has obtained a large set of ASTB and flight training scores. ASTB scores were provided by NOMI, API scores by Naval Aviation Schools Command (NASC), and flight training grades by Training Wing Five and the Chief of Naval Air Training (CNATRA).

The first goal of analyzing the data was to determine the degree of association between ASTB AQR scores and API grades. AQR scores and API grades were available for 2852 individuals. This group included students in both the pilot and NFO programs. Since the ground school curriculum at API is identical for pilots and NFOs, we decided to include both groups in the analysis. The group consisted of 2687 males and 165 females, and they were enrolled in API between November 1993 and October 1998. The Pearson correlation coefficient between AQR and API scores was calculated for this group.

The second goal was to find the strength of association between the PFAR and primary flight training grades for the student pilots in the sample described above. There were 1660 individuals for whom both PFAR and primary flight grades were available. Of this group, 1573 were male and 87 were female. These students were enrolled in primary flight training between November 1993 and July 1998. The Pearson correlation coefficient between PFAR and primary flight training grades was calculated for this group.

The third goal was to determine the strength of association between PBI scores and attrition status for students in the sample. The PBI was originally validated to predict attrition due to flight failure, drop on request (voluntarily withdrawing oneself from training), or academic failures. Therefore, cases of attrition due to medical, family hardship, or unidentified reasons were removed from the sample. For the remaining cases, an attrition variable was created and coded as 0 for those who successfully completed primary training or 1 for those who failed to complete due to attrition from either API or primary flight training. In a total of 1849 cases available for this analysis, 1744 were male and 105 were female, and they were enrolled in API between September 1993 and October 1998. Again, the correlation coefficient between PBI scores and attrition status was calculated for this group.

In addition to the selection and training data described above, NAMRL researchers collected psychomotor task data on 210 student pilots who were waiting to begin API.

All subjects participated on a voluntary basis. The 200 males and 10 females were enrolled in API between October 1995 and February 1999. Data were collected using the Computer Based Performance Test (CBPT) battery (Blower & Dolgin, 1991), which includes a series of tracking and information processing tasks presented in single- and dual-task contexts. The CBPT battery runs on personal-computer-type processors, and for this study IBM-compatible 486 processor-based machines were used. Each of the CBPT test stations includes two commercially available joysticks, a set of rudder pedals, a set of stereo headphones, and a numeric keypad that the subject uses for keyboard inputs. The tracking tasks are presented on a standard VGA monitor.

The first task in the CBPT is a two-dimensional (2-D) compensatory tracking task in which the subject uses a joystick to keep a cursor centered over a set of crosshairs that intersect in the middle the computer screen. The cursor is continuously driven by horizontal and vertical disturbance functions that work to displace the cursor from the center. The computer records combined horizontal and vertical error as cursor pixel distance from the center of the crosshairs. The difficulty of this task is increased by the fact that the cursor is reverse-controlled in the horizontal axis. That is, moving the joystick to the left moves the cursor to the right, and vice versa. In the vertical axis, control is more stereotypical. Moving the joystick forward moves the cursor downward; moving the joystick aft moves the cursor upward. Subjects are instructed to use their right hand to control the joystick. The 2-min 2-D tracking task is preceded by a 2-min practice session.

The second part of the CBPT is a dichotic listening task (DLT) that requires the subject to selectively attend to information presented to either the left or right ear. Two different streams of letters and single digit numbers are simultaneously presented to each ear over the headphones. The subject must pick out each number presented to the target ear and enter the number via the numeric keypad. The computer assigns the target ear before each trial. There are 12 trials, each presenting 9 numbers and 13 letters to each ear. Subjects receive four practice trials before beginning the DLT, which takes 5 min to administer. The number of correct responses is recorded automatically.

The third part of the CBPT requires the subject to simultaneously perform both the 2-D tracking task and the DLT. The computer presents 5 min of the 2-D tracking task, during which the subject engages in the DLT.

The fourth task in the CBPT adds an additional cursor that moves only in the horizontal axis at the bottom of the computer screen. The subject must keep this cursor centered using the rudder pedals, while still keeping the original 2-D tracking task cursor centered with the joystick. Rudder cursor input control is conventional: left rudder input moves the cursor left, while right rudder input moves the cursor right. This fourth task is 2 min in duration and is preceded by a 2-min practice session.

The fifth CBPT task adds the DLT to the fourth task. Subjects engage in the 2-D tracking task, the rudder tracking task, and the DLT simultaneously for a 2-min practice session and then begin the 2-min test session.

The sixth CBPT task adds yet another cursor that moves only in the vertical axis along the left side of the computer screen. The subject must keep this cursor centered in the vertical axis with a second joystick mounted on the left side of the test station. Subjects are instructed to use their left hand to manipulate this second joystick. Cursor control is again conventional: forward stick input moves the cursor downwards while aft stick input moves the cursor upwards. In this sixth task, the subject must also keep the original 2-D cursor and the rudder cursor centered with the right hand joystick. There is no DLT associated with this three-cursor task, and 2 min of practice precede 2 min of testing.

The seventh CBPT task is also a tracking task, but it is not associated with or added to any of the tasks described above. It is a one-dimensional (horizontal) tracking task that requires the subject to keep a cursor centered on a target within a horizontal rectangle. Control mapping of the cursor is standard in that left joystick movement moves the cursor to the left, and right input moves it right. Similar to all of the other previous tracking tasks, the cursor is continuously driven by a disturbance function that works to displace the cursor off center. The subject engages in six 2-min trials, with a 30-s rest period between trials.

The eighth CBPT task is a working memory task in which the subject must calculate the absolute difference between single digit numbers that are sequentially presented on the computer monitor. In all cases, the correct answer ranges from 1 to 4, and the subject is instructed of this fact. The subjects input their responses via the numeric keypad using their left hand, and the computer automatically records the number of correct responses. The task is self-paced in that each response causes the next number to appear on the screen. The absolute difference (AD) task is presented as a single 2-min test.

The ninth task is a dual-task combination of the horizontal tracking task and the absolute difference task. Subjects engage in three 2-min trials of this dual-task test.

The tenth and final test of the CBPT is a mental rotation task called the Manikin Test. In the CBPT version of the Manikin Test, simplified drawings of a sailor appear on the computer monitor. The sailor is holding a red square in one hand and a green circle in the other. The object in each hand alternates randomly and sailor appears randomly in one of four orientations: upright and facing the subject, upright with his back towards the subject, upside down and facing the subject, or upside down with his back towards the subject. The subject's task is to quickly determine which of the sailor's hands (right or left) is holding the red square. Subjects indicate their response by pressing one of two keys on the numeric keypad. The Manikin Test is self-paced, with each response triggering the next stimulus. The computer automatically records the number of correct responses. This test is composed of four 2-min trials.

For all of tracking tasks listed above, subjects were instructed to maximize tracking accuracy. For the DLT, AD, and Manikin tasks, subjects were instructed to respond as quickly and accurately as possible. On dual-task tests, subjects were instructed to perform as well as possible on each task, and to give each equal priority.

The CBPT provides a source of at least 10 variables that might be of use in predicting primary flight training performance. API grades and the 3 ASTB scores increase this number to a pool of 14. Our fourth goal was to reduce this to a more practical number and then conduct an exploratory analysis to identify promising predictors. To narrow down the large number of potential predictors, variables were selected according to three decision strategies:

1. If there were a priori reasons to believe that a variable would make a good predictor, it was selected for analysis. This criterion pointed to the PFAR score, which has been shown to predict primary flight grade, and API grades because the API curriculum is designed to cull out students who are likely to have trouble in primary flight training.

2. Variables that were measures of dual- or multi-task performance were favored because, at a basic level, such performance is what is required of the pilot in the cockpit. However, more complicated psychomotor test batteries are often burdened with reliability, calibration, and quality control problems that have led to a poor history of wide-scale implementation (Griffin & Koonce, 1996; North & Griffin, 1977). With this in mind, the CBPT variables that required the rudder pedals or more than one joystick were eliminated and the following variables were chosen:
   a) 2-D tracking task scores and DLT scores, where these tasks were performed in combination with each other.
   b) Horizontal tracking task scores and AD task scores, again where these tasks were performed in combination with each other. Because there were three trials in this set, scores were averaged across the trials.

3. We also decided to include the Manikin Test variable, because this task is unique in that it requires the subject to engage in mental rotation, rather than in a tracking task.

These procedures reduced the pool of potential predictors to the following seven: PFAR score, API score, 2-D tracking error, DLT score, horizontal tracking error, AD score, and Manikin Test score. The variables were examined for extreme outliers, as defined by values more than three standard deviations above or below the mean. This procedure eliminated 2-D tracking data for four subjects, horizontal tracking and Manikin data for three subjects, and DLT data for two subjects. Also, PFAR scores were not available for nine subjects.

The remaining data were then analyzed in a stepwise linear regression upon primary flight grade. The *p*-value to enter was set at $p < 0.05$, and the value to remove was set at $p > 0.10$.

Results

Correlation Analyses

Summary statistics for all variables analyzed in the correlation analysis of ASTB scores, API grades, and primary flight grades are presented in Table 2 below.

Table 2
Summary Statistics of ASTB Scores, API Grades, and Primary Flight Grades

Variable	Mean	*SD*	*N*
AQR	188.0	23.4	2852
API Grade	49.1	6.9	2852
PFAR	207.5	23.6	1660
Primary Flight Grade	47.6	10.4	1660
PBI	58.8	8.6	1849

The analysis of association between AQR scores and API grades showed a significant correlation between the two variables ($r = .47$, $p < .0001$, two-tailed), indicating that API grades increase with increasing AQR scores. The analysis of PFAR scores and primary flight grades also yielded significant results ($r = .36$, $p < .0001$, two-tailed), indicating that primary flight grades increase with increasing PFAR scores. The final correlation analysis was between PBI scores and attrition status. Individuals who failed out of the program were coded with a value of 1 for this variable, while those who successfully completed were coded with a 0. This analysis also revealed a significant correlation between the two variables ($r = -.10$, $p < .0001$, two-tailed). Those with higher PBI grades were less likely to fail out of the program.

Regression Analysis

The stepwise multiple regression analysis yielded a two-variable model for predicting primary flight grade. The results are summarized in Table 3. The variables included in the model were API grade and 2-D tracking error, and they accounted for 33% of the variance seen in primary flight grades (adjusted $R^2 = .33$, $p < .0001$).

Table 3
Summary of Regression for Variables Predicting Primary Flight Grade

Step	1	2
Variable	API Grade	2-D Tracking Score
R^2	.251	.339
Adj. R^2	.247	.332
ΔR^2	.251	.088
B	.689	-.0002
SE B	.092	.0001
β	.443	-.303
$p <$	.0001	.0001

Note. ΔR^2 for step 2, $p < .0001$

Although API grades were included in the model above, they are not available until after the student completes the 6-week API curriculum. However, AQR scores are available early in the application process, fairly soon after the applicant takes the ASTB. Because AQR scores were shown to be good predictors of API grades, we decided to run a second regression analysis similar to the first, but replacing API grades with AQR scores. This analysis also yielded a two-variable model that included 2-D tracking error and PFAR score, rather than AQR score. This model accounted for 17% of the variance in primary flight grade (adjusted R^2 = .173, p < .0001), and is summarized in Table 4. Table 5 presents summary statistics for all variables used in the regression analyses.

Table 4
Summary of Second Regression for Variables Predicting Primary Flight Grade, Replacing API Grade With AQR Score

Step	1	2
Variable	2-D Tracking Score	PFAR Score
R^2	.150	.181
Adj. R^2	.146	.173
ΔR^2	.150	.031
B	-.0003	.0961
SE B	.0001	.0352
β	-.376	.1773
$p <$	.0001	.0001

Note. ΔR^2 for step 2, p = .007

Table 5
Summary Statistics of Variables Used in the Regression Analyses

Variable	Mean	*SD*	*N*
AQR	192.4	19.7	201
PFAR	213.1	18.7	201
2-D Tracking Error	28033.9	13127.4	206
DLT	98.6	8.9	208
Horizontal Tracking Error	29414.7	13646.4	207
AD	59.3	13.7	210
Manikin	83.1	19.5	207
API Grade	52.1	6.9	210
Primary Flight Grade	51.0	10.1	210

Discussion

The purpose of the efforts described in this paper was to reexamine the predictive validities of the ASTB and to explore possibilities for new tests that could improve the U.S. naval aviator selection process. Although the current version of the ASTB was introduced 7 years ago, the *r* values found here generally indicate that it is still performing well. The AQR was designed to predict API grades, and the correlation analysis of these two variables shows that as AQR scores increase so do API grades. By squaring the correlation coefficient of r = .47, we see that AQR scores can account for some 22% of the variance in API grades. This correlation coefficient of r = .47 is somewhat stronger than, yet still consistent with, results reported elsewhere (Frank & Baisden, 1993; Hiatt et al., 1997). It also compares favorably with other types of aviation selection tests (see Damos, 1996).

It should be emphasized that the relationship between AQR scores and API grades was observed within a sample of rigorously selected candidates. Therefore, the range of values for both the predictor and outcome variables is certainly restricted as compared to what would be seen if all applicants were permitted to enter training. This condition limits the potential strength of association. The same range restriction is operating on all of the analyses reported here.

The relationship between PFAR scores and primary flight grades also remains fairly strong, with an observed r = .36. This value falls in between those reported by Frank and Baisden (1993) and Hiatt et al. (1997), but it is generally consistent with them (see Table 1). The fact that a simple, inexpensive, paper-and-pencil test can predict cockpit performance as well as this one does is impressive, and we can conclude that the PFAR continues to serve its purpose well.

The PBI was originally validated to predict attrition up through the primary flight training portion of flight instruction. The correlation coefficient between PBI scores and attrition status in our analysis was r = -.10. Although this value was statistically significant and indicates that those with higher PBI scores are less likely to fail in training, this association is not very strong. It was comparable to that reported by Hiatt et al. (1997) but weaker than that reported by Frank and Baisden (1993). Given that the predictive power of the AQR and PFAR have held up over the years, this result is somewhat puzzling, but we offer a possible explanation.

The ASTB was validated by Educational Testing Services on a sample of individuals who had taken the test once, and the *r* values reported by Frank and Baisden (1993) reflect this validation. The current ASTB testing policy states that an individual may take the test for a second time 30 days after the first testing. After the second testing, retesting is allowed at 180-day intervals, and there is no limit to the number of retests. In all cases, the most recent scores replace any previous scores. Individuals who take the ASTB for the first time and receive a low score on the PBI may be inclined to change their PBI answers upon retesting, in order to improve the score. The nature of the PBI lends itself to this sort of behavior. By contrast, a person must increase his/her knowledge of the subject matter covered on the portions of the test used to compute the AQR and PFAR scores (i.e., the math-verbal, mechanical comprehension, spatial apperception, and aviation and nautical information tests). This is a much more difficult proposition, and may account for the consistent validities of these scores. By comparing the predictive validities of one-test-only PBI scores to re-test PBI scores, the accuracy of this explanation could be determined. It may well be the case that one-test-only PBI scores have retained their original validity, and this seems to be an appropriate issue for future analysis.

The regressions conducted in the exploratory analysis of the CBPT scores were performed to identify the best variables for predicting primary flight training performance, and stepwise procedures were chosen for this purpose. We are aware that stepwise regression is sometimes criticized for its increased exposure to the possibility of capitalizing upon chance. However, as Hayes (1988) has pointed out, in exploratory analyses such procedures are appropriate provided that selected variables are subject to subsequent independent validation. Accordingly, we would indeed cross-validate any new selection test before recommending it for implementation.

The results of the regression analyses were straightforward and promising at least from a research standpoint. In the first regression, the model included API scores and 2-D tracking scores, accounting for 33% of the variance in the primary flight grades. Prior to conducting this analysis, the best predictor of primary flight grade was the PFAR score, explaining 13% of the variance in the correlation analysis sample. Thus a model that can include API grades and 2-D tracking scores represents a substantial improvement.

From a practical selection standpoint, however, the utility of this first model is limited. In order to obtain API grades, an applicant would first have to complete 6 weeks of ground school. Nevertheless, there are other useful applications for such a model. One example would be to use it for aviation progress review boards. These boards evaluate students who are having difficulty in flight training, and board members must make a recommendation on whether the student should be retained or separated from training. Any tool that can provide an objective assessment of the student would be extremely useful to the board. If this model can be validated, it would certainly fill this role.

The second regression was performed to analyze variables that could be made available before an individual entered training. AQR and PFAR scores meet this requirement. If a version of the CBPT could be implemented, these types of scores would be available as well. The second regression showed that a model incorporating 2-D tracking and PFAR scores accounted for 17% of the primary flight grade variance in our sample. While not as strong as a model that can include API grades, it is an improvement over the current practice of using PFAR scores alone.

The final issue to be addressed is that the results of these analyses come at an opportune time. NAMRL has recently introduced the Automated Pilot Examination (APEX) system, which is a computer-based and networked version of the ASTB. APEX has been successfully operating at several recruiting sites for the past year, and it has performed well. Because APEX is computer-based, it should be possible to include portions of the CBPT into APEX. The analyses reported here indicate that the 2-D tracking task/DLT combination is a good candidate for inclusion. This would greatly facilitate validation efforts, because any applicant who was tested on the APEX system would also be providing 2-D tracking task data (even though those data would not be used for selection purposes during this validation phase). Some of these applicants would eventually enter aviation training, and when they did their CBPT data would already be available for analysis and validation. In this manner, NAMRL could continue to make significant contributions in improving the process of selecting U.S. naval aviators.

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