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FIELD DEPENDENCE-INDEPENDENCE AND ITS RELATIONSHIP TO FLIGHT TRAINING PERFORMANCE

Thomas R. Carretta

MANPOWER AND PERSONNEL DIVISION
Brooks Air Force Base, Texas 78235-5601

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Previous research has suggested that level of field dependence-independence could be used as a measure of social skills and vocational interests. According to this research, field-dependent individuals tend to prefer areas of work that require social skills, whereas field-independent individuals favor positions in the sciences or practical-analytical-oriented occupations. This study examined the usefulness of field dependence-independence measure for predicting performance during flight training. One thousand nine hundred seventy-seven (1,977) United States Air Force pilot candidates were administered the Embedded Figures Test as part of a computer-administered test battery prior to entry into Undergraduate Pilot Training (UPT). Several items on the Embedded Figures Test demonstrated poor reliability. Further, the level of field dependence-independence was not found to be related to performance during flight training. It was recommended that the test be eliminated for consideration as a selection and classification tool. Keywords: job analysis; flight crews

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Thomas R. Carretta

MANPOWER AND PERSONNEL DIVISION
Brooks Air Force Base, Texas 78235-5601

Reviewed and submitted for publication by

William R. Ercoline, Lt Col, USAF
Chief, Cognitive Skills Assessment Branch

This publication is primarily a working paper. It is published solely to document work performed.

SUMMARY

It has been suggested by Witkin, Moore, Goodenough, and Cox (1977) that level of field dependence-independence could be used as an instrument for vocational selection and classification. Witkin and his colleagues contended that field-dependent individuals tend to prefer areas of work that emphasize social skills, whereas field-independent individuals prefer positions in the sciences or practical-analytical-oriented areas. This effort examined the usefulness of a field dependence-independence measure for the selection and classification of United States Air Force pilot candidates. One thousand nine hundred seventy-seven (1,977) United States Air Force pilot candidates were administered the Embedded Figures Test as part of an experimental, computer-administered test battery prior to entry into Undergraduate Pilot Training (UPT). Several items of the test demonstrated poor reliability. Further, the level of field dependence-independence, as measured by this test, was not related to flight training performance. It was recommended that the Embedded Figures Test be eliminated for consideration as a selection and classification device.

PREFACE

This work was completed under Work Unit 77191845 in support of a Request for Personnel Research (RPR 78-11, Selection for Pilot Training) submitted by Air Training Command training program managers.

This paper is intended to serve as an interim report regarding one of the personality/attitudinal tests of the Basic Attributes Tests (BAT) battery.

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I. INTRODUCTION

The cognitive style of field dependence-independence (Witkin, 1949) has been investigated thoroughly over the last 30 years. Originally, the investigations involved tasks designed to determine how individuals orient themselves in space by altering the usual relationship between visual and kinesthetic cues (Body-Adjustment Test, Rod and Frame Test, Rotating Room Test). These studies of the conflict between visual and kinesthetic cues indicated that wide individual differences existed in the way individuals resolve this type of disparity. Some individuals relied heavily on the visual field to judge orientation (field dependent), whereas others relied on impressions from their body to make their judgments (field independent).

A new task (Embedded Figures Test) was designed that did not involve a conflict between bodily and visual cues, but rather, required the disembedding of a simple geometric pattern from an organized visual field (Witkin, 1950; Witkin, Oltman, Raskin, & Karp, 1971). It was found that individuals who were affected most by the visual field in the Body-Adjustment Test and the Rod and Frame Test (i.e., were field dependent) had the greatest difficulty in finding the simple embedded figures in the Embedded Figures Test. Conversely, individuals who were affected more by their body position on the Body-Adjustment Test and the Rod and Frame Test (i.e., were field independent) found the simple figures easily on the Embedded Figures Test.

More recently, studies have linked field dependence-independence to social skills and vocational interests (Arbuthnot & Gruenfeld, 1969; Witkin, Moore, Goodenough, & Cox, 1977). According to these studies, field-dependent individuals tend to favor areas of work that require social skills, whereas field-independent individuals prefer jobs in the sciences or practical-analytical-oriented occupations. Ragan et al. (1979) suggested that the application of field dependence-independence research might be useful for personnel selection and classification in the area of Air Force technical training. They suggested that a field-independent cognitive style might be helpful in learning and performing analytic tasks (e.g., troubleshooting an equipment malfunction), whereas a field-dependent cognitive style might be useful in jobs where interpersonal skills are more important (e.g., personnel management).

Field dependence-independence might also be related to flight training performance and outcome, especially concerning advanced training recommendations. These recommendations are made by training wing personnel, based on their prediction of where each student's skills and abilities could be best used. Although analytic skills are important for all pilots, they are especially important for those who fly fast jets (Fighter-Attack-Reconnaissance, or FAR, aircraft). Interpersonal skills, on the other hand, might be more important in multiperson aircraft (Tanker-Transport-Bomber or TTB). Thus, it was expected that student pilots who were FAR-recommended would tend to be more field independent than would student pilots who were TTB-recommended. The demonstration of such a relationship would provide the Air Force with a tool that could lead to early identification of advanced training potential, resulting in more efficient and cost-effective training.

Currently, pilot candidates are selected for Undergraduate Pilot Training (UPT), in part based on their performance on the Air Force Officer Qualifying Test (AFOQT) (United States Air Force, 1983). This test provides five composite scores based on several subtests: Verbal, Quantitative, Academic Aptitude (verbal and quantitative combined), Navigator-Technical, and Pilot. Of these, only the Navigator-Technical and Pilot composite scores have been used in the operational selection of candidates for UPT. Only the Pilot composite score was used in the present effort, as it has demonstrated the greatest validity for pilot training performance. The

Pilot composite score is based on subtests such as verbal analogies, mechanical and instrument comprehension, scale and table reading, electrical maze, block counting, and aviation information. The Hidden Figures subtest on the AFOQT is a form of the Embedded Figures Test, but it is not used to calculate the Pilot composite score. A breakdown of the subtests that contribute to each AFOQT composite score is provided in Table 1.

Table 1. Construction of AFOQT Composite Scores

AFOQT subtests	Verbal	Quantitative	Academic aptitude	Navigator-technical	Pilot
Verbal Analogies	X		X		X
Arithmetic Reasoning		X	X	X	
Reading Comprehension	X		X		
Data Interpretation		X	X	X	
Word Knowledge	X		X		
Math Knowledge		X	X	X	
Mechanical Comprehension				X	X
Electrical Maze				X	X
Scale Reading				X	X
Instrument Comprehension					X
Block Counting				X	X
Table Reading				X	X
Aviation Information					X
Rotated Blocks				X	
General Science				X	
Hidden Figures				X	

The present investigation used the predictive utility of the AFOQT-Pilot composite score as a baseline by which to judge the usefulness of scores on the Embedded Figures Test for improving pilot selection and classification for advanced training. In order to be of practical use to the Air Force, performance on the Embedded Figures Test must improve the prediction of flight training performance beyond that already provided by the AFOQT-Pilot composite score.

II. METHOD

Subjects

The subjects in this study were 1,977 Air Force officer candidates targeted for UPT. They were tested on the Embedded Figures Test prior to their entry into UPT. Pilot training performance measures were available for only a portion of these subjects, as many of them had not yet completed UPT.

Procedure

The Embedded Figures Test was included in a computer-administered test battery that consisted of 15 tests designed to assess psychomotor skills and a variety of cognitive/perceptual skills and personality characteristics believed to be related to flight training performance (Basic Attributes Tests, or BAT; see Carretta (1987) for a more complete description of the test battery). After initialization of the testing equipment by a test administrator, the test session was self paced by the subject. The entire session lasted about 3 1/2 hours and included scheduled breaks between tests to avoid problems with mental and physical fatigue.

For the Embedded Figures Test portion of the battery, subjects were presented with sets consisting of a simple geometric figure and two complex geometric figures. Their task was to decide which of the two complex figures had the simple figure embedded within it, and to indicate a choice by pressing the keypad response button corresponding to that figure. There were 30 trials, which required about 15 minutes to complete.

UPT Performance Criteria

UPT final outcome was scored as a dichotomous variable, with pass = 1 and fail = 0. Pilot candidates who passed UPT received a post-UPT assignment recommendation from an Advanced Training Recommendation Board (ATRB) for advanced training in either a TTB aircraft or a FAR aircraft (FAR = 1 and TTB = 0). Final outcome and ATRB recommendation were determined, in part, by a subject's performance on six check flights during UPT. A check flight involved an in-flight performance evaluation by an Instructor Pilot. The first three check flights took place in a T-37, a low-performance jet trainer; the later three took place in a T-38, a high-performance supersonic jet trainer. The T-37 check flights included: midphase contact, a subject's first check flight; contact, in which the subject's ability to perform maneuvers and aerobatics by visual cues outside the plane was evaluated; and instrument, in which the subject was required to perform maneuvers by reference to the display on the cockpit instrument panel. The T-38 check flights, in addition to contact and instrument, included an evaluation of the subject's ability to fly in formation with other aircraft. Each subject received a check flight grade (1-unsatisfactory, 2-fair, 3-good, or 4-excellent) and a percentage score for all flights that were completed during training. The check flight percentage scores are not linear transformations of the 4-point check flight grades. The check flight grade reflects the Instructor Pilot's evaluation of a student compared to all other pilot candidates at the same point in training. In contrast, the percentage grade is a weighted average of the maneuver grades from a check flight. The number of subjects who had scores on the Embedded Figures Test and performance measures is indicated in Table 2.

Table 2. Number of Subjects

	N
Embedded Figures	1,977
UPT (pass/fail)	602
ATRB (TTB/FAR)	418
Check Flight Scores	162

III. RESULTS AND DISCUSSION

Embedded Figures Test

Descriptive Measures

The 30 items in this test were sorted into three groups of 10 items each, based on their expected levels of difficulty. Expected difficulty level was based on archived paper-and-pencil test "discriminability" data (1 = low, 2 = moderate, 3 = high). Average response times for correct responses, percent correct, and item-total score correlations are summarized by trial in Table 3.

It appeared that many subjects did not realize that the test had begun, as only 4.9% of the subjects responded correctly on the first trial. As a result, scores from Trial 1 were not used in later analyses. The average accuracy of response was 64.9% correct over the remaining 29 trials, and was significantly lower for difficulty level 3 (57.4%) than for difficulty levels 1 (68.1%) and 2 (68.3%) combined ($\underline{F}$ [1,1975] = 754.1, $\underline{p} \leq .001$) (see Table 4). This suggested that, in general, the level 3 figures were somewhat more difficult to discriminate than were the level 1 and 2 figures. It should be noted, however, that accurate responses fell below "chance level" (50%) on 10 of the 29 trials. Surprisingly, these "low-accuracy" trials were distributed fairly evenly across the three difficulty levels. Most of these trials exhibited low correlations with the item-total score, suggesting that the stimuli used on these trials were poor discriminators of level of ability and should be omitted from future forms of this test. Despite this problem, response accuracy on the test was shown to be fairly reliable (alpha = .702).

Table 3. Embedded Figures: Response Time, Percent Correct, and Item-Total Score Correlation by Trial

Trial	Expected difficulty	Response time (ms) Mean	SD	% Correct	Item-total correlation
1	3	17,346	13,204	4.9	.052
2	1	13,568	9,646	86.8	.126
3	1	15,355	11,784	42.5	.047
4	1	13,347	10,347	67.2	.168
5	3	11,427	6,839	81.9	.316
6	3	14,094	11,284	51.1	.177
7	3	12,426	9,595	46.0	.316
8	1	10,938	8,246	89.5	.302
9	2	20,728	12,506	38.6	.259
10	2	20,702	13,502	55.0	.107
11	2	12,423	8,448	74.2	.341
12	3	19,599	12,745	66.7	.250
13	3	11,851	9,481	69.8	.326
14	2	21,147	13,644	45.2	.176
15	2	16,392	11,555	49.3	.309
16	3	10,262	7,759	62.7	.389
17	2	17,978	12,012	83.9	.221
18	2	8,799	7,342	87.4	.283
19	3	12,913	9,641	40.6	.192
20	3	8,831	6,880	45.1	.032
21	2	7,182	4,452	67.0	.379
22	2	7,321	5,413	92.7	.228
23	2	11,408	9,103	89.5	.163
24	1	13,788	9,687	82.8	.233
25	1	8,309	6,430	77.7	.345
26	1	11,538	7,876	38.5	.063
27	1	7,255	5,475	90.3	.219
28	1	18,577	12,770	41.9	.117
29	3	14,004	9,578	52.9	.380
30	1	11,438	11,364	63.7	.337

Note: N = 1,977.

Average response time, measured in milliseconds (ms), was fairly consistent across difficulty level (level 1 = 12,245 ms., level 2 = 12,308 ms., level 3 = 12,665 ms.) and was very reliable over the 29 trials (alpha = .915).

Results from the accuracy and response time measures suggested that there was an accuracy by response time interaction due primarily to the difficulty level 3 trials. Although average response time did not change much as difficulty level increased, accuracy of response decreased significantly on the level 3 trials.

Table 4. Embedded Figures: Analyses of Variance

Source of variation	Sum of squares	df	Mean square	F
Average Response Time				
Between subjects	154,870,000,000	1,976	78,377,774	
Within subjects	45,939,000,000	3,954	11,618,243	
Difficulty level	181,368,067	2	90,684,033	7.83*
Residual	45,757,000,000	3,952	11,578,230	
Percent Correct				
Between subjects	1,252,664	1,976	634	
Within subjects	957,813	3,954	242	
Difficulty level	152,630	2	76,315	374.56*
Residual	805,183	3,952	204	

*$p \leq .001$.

Factor Structure

The most conceptually important measures from this test were average response time and percent correct for the three levels of difficulty, as they provided information regarding individual differences in the speed and accuracy of decisions. Standard deviation of response time was included also, as consistency of response time was also considered of interest.

The inter-item correlation matrix, presented in Table 5, indicated that the average response time measures were related strongly to each other ($.649 \leq r \leq .674$) and to their standard deviations ($.698 \leq r \leq .831$), but were not related to percent correct ($.018 \leq r \leq .198$). The standard deviations also were interrelated strongly ($.468 \leq r \leq .572$) but were related weakly to percent correct ($.210 \leq r \leq .371$). Finally, the percent-correct measures were only weakly related to each other ($.363 \leq r \leq .499$).

The factor analysis yielded two factors that accounted for 66.2% of the total item variance. The principal factor included all three average response times and standard deviations. It was interpreted as a general "response latency" factor. The second factor was interpreted as an "accuracy index," as all three percent-correct measures loaded on this factor. These two factors accounted for 100% of the explained variance (66.2% of total item variance). A summary of the factor analysis is provided in Table 6.

Results of the factor analysis suggested that overall speed and accuracy of response measures were necessary to describe performance on the Embedded Figures Test adequately. As a result, average response time and percent correct across difficulty levels, and a response time by percent correct interaction term, were calculated and retained for the regression analyses to predict flight training performance.

Inferential Measures

A regression equation that used only the AFOQT-Pilot composite score (an operational selection instrument) demonstrated a significant, but relatively low relationship to UPT pass/fail outcome ($r = .109$, $p \leq .01$) and ATRB recommendation-TTB/FAR ($r = .138$, $p \leq .01$). However, the AFOQT-Pilot composite score was not related significantly to any of the check flight performance scores. A summary of these regressions is provided in Table 7.

Table 5. Embedded Figures: Inter-Item Correlation Matrix

Variable	Average RT 1	Average RT 2	Average RT 3	SD RT 1	SD RT 2	SD RT 3	Percent Correct 1	Percent Correct 2	Percent Correct 3
Average RT 1	1.000								
Average RT 2	.674	1.000							
Average RT 3	.659	.649	1.000						
SD RT 1	.749	.554	.501	1.000					
SD RT 2	.565	.831	.576	.572	1.000				
SD RT 3	.457	.502	.698	.468	.536	1.000			
Percent Correct 1	.018	.045	.039	.210	.161	.181	1.000		
Percent Correct 2	.042	.198	.118	.182	.326	.273	.389	1.000	
Percent Correct 3	.014	.058	.092	.124	.196	.371	.363	.499	1.000

Note. These variable labels refer to, respectively, average response time, standard deviation of response time, and percent correct for each of the three levels of difficulty.

Table 6. Embedded Figures: Summary of Factor Analysis

Variable	Communality	Factor 1	Factor 2
Average RT 1	.718	.843	-.080
Average RT 2	.722	.848	.063
Average RT 3	.623	.787	.064
SD RT 1	.528	.714	.137
SD RT 2	.667	.776	.253
SD RT 3	.520	.630	.352
Percent Correct 1	.270	.053	.517
Percent Correct 2	.497	.132	.692
Percent Correct 3	.526	.058	.723

Factor	Eigenvalue	% of Explained variance	Cumulative %
1	3.80	74.9	74.9
2	1.27	25.1	100.0

Note. N = 1,977.

Table 7. AFOQT-Pilot Composite Score: Summary of UPT Regression Analyses

Outcome measure	N	Outcome measure Mean	Outcome measure SD	AFOQT-Pilot Mean	AFOQT-Pilot SD	r
UPT pass/fail	601	0.80	0.40	71.5	18.0	.109**
ATRB TTB/FAR	418	0.60	0.49	73.3	17.4	.138**
T-37 midphase grade	162	2.48	1.19	70.0	19.2	.095
T-37 contact grade	160	2.92	0.92	70.1	19.1	.066
T-37 instrument grade	155	2.91	1.05	70.2	19.1	.156
T-38 contact grade	145	2.51	1.18	70.4	19.4	.047
T-38 instrument grade	143	2.80	1.11	70.4	19.4	.041
T-38 formation grade	141	2.87	1.00	70.5	19.5	.137
T-37 midphase percentage	162	84.82	9.20	70.0	19.2	.040
T-37 contact percentage	160	90.95	5.26	70.1	19.1	.104
T-37 instrument percentage	155	91.72	7.30	70.2	19.1	.065
T-38 contact percentage	145	91.31	5.73	70.4	19.4	.059
T-38 instrument percentage	143	92.16	9.98	70.4	19.4	-.027
T-38 formation percentage	141	92.72	8.14	70.5	19.5	.109

*$p \leq .05$.
**$p \leq .01$.

The Embedded Figures Test model (average response time, percent correct, and response time-percent correct interaction) demonstrated poor predictive utility against all of the UPT performance criteria. The model was not related to either UPT pass/fail outcome (multiple R = .046, n.s.) or ATRB-TTB/FAR rating (multiple R = .091, n.s.). Although the zero-order correlations were generally in the expected direction for the check flight scores, the Embedded Figures model was related significantly only to T-38 formation check flight grade (multiple R = .244, $p \leq .05$). Subjects who made quick and accurate responses on the Embedded Figures Test performed better on this flight. Results of these regression analyses are presented in Table 8.

Table 8. Embedded Figures: Summary of UPT Regression Analyses

Outcome measure	N	Average RT	% Correct	Average RT by % correct	Multiple R: Embedded Figures	Multiple R: AFOQT Pilot	Multiple R: Combined model
UPT pass/fail	601	.007	-.020	.039	.046	.109**	.126*
ATRB TTB/FAR	418	-.018	.018	.088	.091	.138**	.166*
T-37 midphase grade	162	-.121	.085	.041	.161	.095	.169
T-37 contact grade	160	-.071	.104	-.033	.143	.066	.144
T-37 instrument grade	155	-.035	.117	.052	.135	.156	.180
T-38 contact grade	145	-.037	-.020	.107	.111	.047	.121
T-38 instrument grade	143	-.165	-.115	-.021	.194	.041	.201
T-38 formation grade	141	-.185*	.044	.162	.244*	.137	.261*
T-37 midphase percentage	162	-.120	.094	.012	.164	.040	.165
T-37 contact percentage	160	-.018	.098	-.109	.154	.104	.169
T-37 instrument percentage	155	-.058	.045	.000	.079	.065	.089
T-38 contact percentage	145	-.015	.029	.067	.075	.059	.090
T-38 instrument percentage	143	.044	-.063	-.012	.082	.027	.082
T-38 formation percentage	141	-.163	.045	.111	.200	.109	.210

*$p \leq .05$.
**$p \leq .01$.

A Combined Model

A series of regression analyses was performed to determine whether scores from the Embedded Figures model improved the prediction of UPT performance beyond that provided by the AFOQT-Pilo composite score alone. The Combined model included the AFOQT-Pilot composite score and the average response time, percent correct, and response time-percent correct interaction term from the Embedded Figures Test model.

Although the combined model was related significantly to both UPT final outcome (multiple R = .126, $p \leq .05$) and ATRB rating (multiple R = .166, $p \leq .05$), it did not improve prediction beyond that provided by the AFOQT-Pilot composite score alone, (UPT pass/fail- F [3,596] = 0.81, n.s.; ATRB TTB/FAR - F [3,413] = 1.21, n.s.).

The combined model also was related significantly to the T-38 formation check flight grade (multiple R = .261, $p \leq .05$) but did not statistically improve prediction over AFOQT-Pilot composite score (F [3,136] = 2.40, n.s.). See Table 8 for a summary of these regression analyses.

IV. CONCLUSIONS

Although several individual items in the Embedded Figures Test did not discriminate well among good and poor performers, the test exhibited acceptable reliability overall.

Performance on the Embedded Figures Test, however, was not found to be related to flight training performance. This may have occurred for a variety of reasons. One possibility is that the level of field dependence-independence simply may not be related to flight training performance. Another possibility is that the BAT Embedded Figures Test is not a good measure of field dependence-independence. As noted previously, several of the stimuli on the BAT version did not discriminate well between good and poor performers on the test. Most versions of the

Embedded Figures Test present the subject with one complex figure and five simple geometric figures, one of which is contained in the complex figure. The BAT version uses two complex figures and one simple geometric figure. The task dynamics for these two paradigms are quite different. The reliability of the BAT version probably is limited compared with the more widely used version of the test.

Finally, it should be noted that the AFOQT currently includes the widely accepted version of the Embedded Figures Test (i.e., Hidden Figures subtest of the Navigator-Technical composite). As a result, the Air Force officer candidates who entered UPT had already been screened partially based on their field dependence-independence scores.

Based on the facts that pilot candidates are already being tested for field dependence-independence via the Hidden Figures subtest of the AFOQT and that performance on the BAT version is not related to UPT performance, it is recommended that this test be eliminated from the current BAT battery.

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