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ORTHOGONAL AND OBLIQUE SOLUTIONS OF A BATTERY OF APTITUDE, ACHIEVEMENT AND BACKGROUND VARIABLES

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Introduction

MEASURING devices used for classification, selection, and assignment of Air Force personnel can be applied with increased effectiveness when the population of airmen can be defined in terms of how they compare with the general population of young men of military age. Accordingly, from time to time a large representative sample of airmen is given, in addition to the AF psychological tests, test batteries that have established norms for the nation-wide adult population or well-defined segments of it. This study is a factorial analysis of data from the so-called Normative Survey of the March 1948 population of basic airmen.

In order to study the coverage of the *Airman Classification Test Battery*, a series of correlational studies in addition to the one referred to above is planned. Batteries which it is planned to administer in conjunction with the *Airman Classification Test Battery* include the following:

a. the *USES General Aptitude Test Battery;*
b. parts of the *Guilford-Zimmerman Aptitude Survey;*
c. the *AF Aircrew Classification Test Battery;*
d. a battery of individually-administered temperament and intelligence tests; and
e. the *Army Classification Test Battery.*

By these comparative studies it should be possible to determine whether the present battery is assessing important areas now being covered by other batteries. It should also be pos-

[1] This study was done while the writer was a civilian employee of the USAF Air Training Command, Human Resources Research Center. The opinions expressed, however, are those of the writer and are not to be construed as official or those of the USAF.

sible, by multiple-correlation equations, to reproduce the results on any given test from a suitable combination of other tests so that validation and normative data collected for these tests can be related to scores derived from the *Airman Classification Test Battery*.

The Tests

The correlational study reported here is based on the *Airman Classification Test Battery*, the *Army General Classification Test*, the *AG Mechanical Aptitude Test*, the *Differential Aptitude Tests*, the *Gray-Votaw General Achievement Tests*, and several other tests and variables listed in Table 1. The tests are described briefly below.

1. AGCT Part I (Reading and Vocabulary). Fifty-three multiple-choice items based on reading and comprehension of thirteen paragraphs.

2. AGCT Part II (Arithmetic Computation). Fifty-three multiple-choice items of addition, subtraction, multiplication, division, percentages, fractions, decimals and proportions.

3. AGCT Part III (Arithmetic Reasoning). Fifty-three verbally and diagrammatically presented multiple-choice problems.

4. AGCT Part IV (Pattern Analysis). Fifty items based on ten figures. Each figure contains a solid object and an unfolded pattern of it. Corresponding sides of the figure and pattern are to be matched.

5. *AG General Mechanical Aptitude Test*, MA-2. Fifty mechanical and electrical information items, 45 pattern analysis items, and 45 mechanical-comprehension and mechanical-movement items, all multiple choice.

6. Education. Number of years of schooling.

Variables 7 through 20 are tests in the USAF *Airman Classification Test Battery* (ACTB).

7. ACTB Arithmetic Reasoning. Thirty verbally-stated multiple-choice arithmetic problems.

8. ACTB Aviation Information. Forty-five multiple-choice items concerning information on aviation topics which could be learned by reading the newspapers, popular science and popular aviation magazines.

9. ACTB Background for Current Affairs. Forty-five

multiple-choice items of vocabulary, geography, history and economics information which could be acquired by keeping informed on current events.

TABLE 1

Variables Included in the Normative Survey Factor Analysis Battery

Variable	Code*
1. AGCT Reading and Vocabulary (Part I)	AGCT-RV
2. AGCT Arithmetic Computations (Part II)	AGCT-AC
3. AGCT Arithmetic Reasoning (Part III)	AGCT-AR
4. AGCT Pattern Analysis (Part IV)	AGCT-PA
5. AG General Mechanical Aptitude 2	AG-MA-2
6. Education in Years	Ed in Yr
7. ACTB Arithmetic Reasoning, Form A	AR
8. ACTB Aviation Information, Form A	AI
9. ACTB Background for Current Affairs, Form A	BCA
10. ACTB Dial and Table Reading, Form A	DTR
11. ACTB Electrical Information, Form A	EI
12. ACTB General Mechanics, Form A	GM
13. ACTB Mechanical Principles, Form A	MP
14. ACTB Memory for Landmarks, Form A	ML
15. ACTB Numerical Operations II, Form B	NO II
16. ACTB Reading Comprehension, Form A	RC
17. ACTB Speed of Identification, Form A	SI
18. ACTB Tool Functions, Form A	TF
19. ACTB Word Knowledge, Form A	WK-A
20. ACTB Biographical Inventory, Instructor, Form B	BI-Instr
Differential Aptitude Tests:	
21. Abstract Reasoning, Form A	DAT-AR
22. Clerical Speed and Accuracy, Part II, Form A	DAT-CS-II
23. Language Usage, Part I, Form A	DAT-LU-I
24. Language Usage, Part II, Form A	DAT-LU-II
25. Numerical Ability, Form A	DAT-NA
26. Space Relations, Form A	DAT-SR
Gray-Votaw General Achievement Tests:	
27. Test 1. Elementary Science	GV-Sci
28. Test 2. Social Studies	GV-SS
29. Test 3. Knowledge of Literature	GV-Lit
30. Test 4. Choice of Words	GV-CW
31. Test 5. Reading	GV-Read
32. Test 6. Arithmetic	GV-Arith
33. Iowa High School Content, Form L, Composite Score	IHS
34. Otis Quick-Scoring Mental Ability Tests, Gamma, Form AM	Otis -QS
35. Sims Score Card for Socio-Economic Status, Form C	Sims

* This code is used to identify the variables in Tables 2, 4, and 5.

10. ACTB Dial and Table Reading. One hundred-and-fifty multiple-choice items based on correct interpretation of dials, charts and tables.

11. ACTB Electrical Information. Forty-five multiple-choice electrical vocabulary items and forty-one multiple-choice electrical symbols and principles items.

12. ACTB General Mechanics. Forty-five multiple-choice mechanical vocabulary and information items.

13. ACTB Mechanical Principles. Forty-five pictorially-presented mechanical comprehension, mechanical movement and mechanical function items. The choices are stated verbally.

14. ACTB Memory for Landmarks. Thirty-five matching items. This is a paired-associates memory test in which each item consists of an outline drawing of a body of water (lakes, rivers or bays) and an assigned name. The examinee is given four minutes to memorize the names associated with a page of outlines (15 items). He then must turn the page and match 12 of the outlines with a list of fifteen names.

15. ACTB Numerical Operations II. Eighty multiple-choice subtraction and division items printed on an IBM answer sheet.

16. ACTB Reading Comprehension. Thirty multiple-choice items based on the comprehension of seven technical paragraphs.

17. ACTB Speed of Identification. Forty-eight items in which front and side views of plane silhouettes are matched.

18. ACTB Tool Functions. Thirty items each giving five verbal choices for uses of tools presented pictorially.

19. ACTB Word Knowledge. Thirty multiple-choice general vocabulary items.

20. ACTB Biographical Inventory, Instructor key. One hundred-and-twenty-five items of preferences for various types of technical training, assignment, school subjects, vocations, avocations, and extent of participation in various activities and other biographical data, scored by an empirically derived key for selecting instructors.

Variables 21 through 26 are tests of the *Differential Aptitude Test* battery (DAT).

21. DAT Abstract Reasoning. Fifty multiple-choice items. A logical series is shown by means of four geometrical designs. The examinee selects from five choices the figure which would best continue the series.

22. DAT Clerical Speed and Accuracy, Part II. One hundred items in which the examinee matches an underlined pair of letters and numbers in the test booklet with the same pair on

the answer sheet. The stimulus pair and response pair must each be selected from four distractors.

23. DAT Language Usage, Part I. One-hundred words which must be recognized as correctly or incorrectly spelled.

24. DAT Language Usage, Part II. Fifty sentences, each divided into five parts. Each sentence part must be examined for mistakes in grammar, punctuation and spelling.

25. DAT Numerical Ability. Forty multiple-choice arithmetic computation items.

26. DAT Space Relations. Forty multiple-choice diagrammatically presented items. Each item consists of a pattern and five objects. Some of the patterns are shaded and the task is to select the object which could be made by folding the pattern.

Variables 27 through 32 are tests from the *Gray-Votaw General Achievement Battery*, an academic achievement battery at the elementary-school level.

27. G-V Elementary Science. Forty-five multiple-choice science comprehension items.

28. G-V Social Studies. Sixty multiple-choice geography, history, government, current events and general information items.

29. G-V Knowledge of Literature. Forty-five multiple-choice items of knowledge concerning literature studied in elementary school.

30. G-V Choice of Words. Sixty two-choice sentence completion items. The examinee must choose between a grammatically correct and incorrect completion to each sentence.

31. G-V Reading. Thirty multiple-choice vocabulary and thirty multiple-choice reading-comprehension items.

32. G-V Arithmetic. Thirty multiple-choice arithmetic computation and reasoning problems.

33. *Iowa High School Content Examination*. Composite score of 100 English and literature, 60 mathematics, 75 science, and 100 history and social studies items, all multiple-choice.

34. *Otis Q-S Mental Ability Test, Gamma*. An eighty item multiple-choice intelligence test.

35. *Sims Score Card for Socio-Economic Status*. Twenty-six items concerning economic and cultural level of home background. Several of the items were modified slightly to make them more suitable for the airman population.

Procedure and Results

The tests were administered to 881 male basic airmen at Lackland Air Force Base, San Antonio, Texas, during the period of 10–24 March 1948. The commercial tests were administered and scored according to the manuals furnished by the publishers. The Airman Classification Test Battery tests were scored by the formula $R - \frac{W}{4}$ with the following exceptions.

Test	*Scoring Formula*
Biographical Inventory (Instructor), BE601B	R − W + 40
Numerical Operations II, CI702B	R − W
Speed of Identification, CP610A	R − W

Numerical Operations and Speed of Identification were administered as speeded tests. All other Airman Classification Test Battery tests were administered with ample time limits to allow almost all examinees to try every item.

The scores on all tests and variables were converted to a normalized single-digit, standard-score scale with a mean of 5.00 and a standard deviation of 2.00, with the exception of Education in which the standard deviation is in terms of years of education.

These normalized variables were intercorrelated by the product-moment method and the resulting matrix is indicated in Table 2.

The matrix of intercorrelations was factored by the centroid method. Eight significant factors were extracted and are listed in Table 3 along with the communalities and the share of the total variance contributed by each factor. A ninth factor was also extracted, but Tucker's phi and Coomb's criterion, as well as its small range, indicated it to be negligible.

The centroid axes were rotated to psychologically-meaningful positions in accordance with the principles of simple structure and positive manifold. Orthogonal structure was maintained. It was obvious however, after the orthogonal rotations had been completed, that an oblique solution would give better simple structure. It seemed desirable, therefore, to complete a set of oblique rotations to see if interpretations would be affected by the type of rotational solution. Two solutions are reported: Table 4 gives the rotated factor loadings for the orthogonal

TABLE 2

Intercorrelations. Population: 881 Airmen (Decimal points are omitted throughout so that all correlations are in thousandths)

Test Variable*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. AGCT-RV		517	625	461	548	481	615	637	673	589	615	512	461	437	505	686	325	318
2. AGCT-AC	517		692	482	498	459	653	474	496	642	468	346	402	435	666	500	348	260
3. AGCT-AR	625	692		583	575	467	776	547	589	676	563	485	519	492	607	634	316	354
4. AGCT-PA	461	482	583		679	344	526	477	477	600	471	423	617	517	339	477	476	414
5. AG-MA-2	548	498	475	679		452	591	611	548	616	669	636	687	445	392	567	493	613
6. Ed in Yr	481	459	467	344	452		482	464	528	536	502	410	331	388	411	462	266	270
7. AR	615	653	776	526	591	482		580	608	657	587	520	531	492	577	638	326	366
8. AI	637	474	547	477	611	464	580		740	552	679	586	527	429	356	644	380	445
9. BCA	673	496	589	477	548	528	608	740		577	638	509	440	445	442	687	360	354
10. DTR	589	642	676	600	616	536	657	552	577		579	450	499	523	596	563	469	375
11. EI	615	468	563	471	669	502	587	679	638	579		669	575	408	415	646	340	549
12. GM	512	346	485	423	636	410	520	486	509	450	669		633	298	261	588	270	670
13. MP	461	402	519	617	687	331	531	527	440	499	575	633		402	244	522	366	618
14. ML	437	435	492	517	445	388	492	429	445	523	408	298	402		377	471	341	232
15. NO II	505	666	607	339	392	411	577	356	442	596	415	261	244	377		478	325	152
16. RC	686	500	634	477	567	462	638	644	687	563	646	588	522	471	478		326	404
17. SI	325	348	316	476	493	266	326	380	360	469	340	270	366	341	325	326		337
18. TF	318	260	354	414	613	270	366	445	354	375	549	670	618	232	152	404	337	
19. WK-A	736	481	580	456	534	524	622	706	780	564	657	538	467	449	436	710	334	311
20. BI-Instr	149	130	164	100	151	255	189	116	108	152	141	124	120	128	148	131	068	061
21. DAT-AR	519	510	594	604	540	419	574	490	532	614	485	400	521	508	400	547	363	326
22. DAT-CS-II	424	429	407	377	424	379	394	323	366	534	365	233	283	397	497	346	526	225
23. DAT-LU-I	590	470	524	326	385	463	531	508	587	492	539	382	312	348	483	557	261	176
24. DAT-LU-II	619	467	546	390	483	450	554	534	558	507	549	438	441	426	427	600	289	258
25. DAT-NA	532	715	707	474	475	483	662	478	546	615	505	374	437	451	613	556	308	272
26. DAT-SR	416	402	509	681	644	304	497	494	464	523	485	438	611	452	270	474	481	452
27. GV-Sci	645	498	548	467	593	506	616	660	670	558	626	561	525	423	407	658	350	374
28. GV-SS	712	540	612	424	550	539	625	709	794	605	641	510	434	439	514	683	364	316
29. GV-Lit	588	399	444	340	443	421	486	561	611	447	477	373	323	352	370	553	307	179
30. GV-CW	569	452	492	371	471	398	507	524	547	457	531	415	440	381	418	583	293	238
31. GV-Read	732	542	620	498	599	495	669	680	717	622	656	559	519	461	507	714	394	360
32. GV-Arith	576	696	728	464	522	467	713	501	543	667	526	430	440	451	677	582	330	296
33. IHS	630	535	562	384	552	580	592	595	669	564	576	402	381	405	540	606	361	209
34. Otis QS	717	599	697	554	644	518	728	662	706	681	649	517	531	534	555	687	402	340
35. Sims	312	206	244	230	270	408	243	355	343	301	305	220	201	249	163	288	196	159

* See Table 1 for interpretation of test variable code.

TABLE 2 (continued)

Test Variable*	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1. AGCT-RV	736	149	519	424	590	619	532	416	645	712	588	569	732	576	630	717	312
2. AGCT-AC	481	130	510	429	470	467	715	402	498	540	399	452	542	696	535	599	206
3. AGCT-AR	580	164	594	407	524	546	707	509	548	612	444	492	620	728	562	697	244
4. AGCT-PA	456	100	604	377	326	390	474	681	467	424	340	371	498	464	384	554	230
5. AG-MA-2	534	161	540	424	385	483	475	644	593	550	443	471	599	522	552	644	270
6. Ed in Yr	524	255	419	379	463	450	483	304	506	539	421	398	495	467	580	518	408
7. AR	622	189	574	394	531	554	662	497	616	625	486	507	669	713	592	728	243
8. AI	706	116	490	323	508	534	478	494	660	709	561	524	680	501	593	662	355
9. BCA	780	108	532	366	587	558	546	464	670	794	611	547	717	543	669	706	343
10. DTR	564	152	614	534	492	507	615	523	558	605	447	457	622	667	564	681	301
11. EI	657	141	485	365	539	549	504	485	626	641	477	531	656	526	576	649	305
12. GM	538	124	400	233	382	438	374	438	561	510	373	415	559	430	402	517	220
13. MP	467	120	521	283	312	441	437	611	525	434	323	440	519	440	381	531	201
14. ML	449	128	508	397	348	426	451	453	423	439	352	381	461	451	405	534	249
15. NO II	436	148	400	497	483	427	613	270	407	514	370	418	507	677	540	555	163
16. RC	710	131	547	346	557	600	556	474	658	683	553	583	714	582	607	687	288
17. SI	334	068	363	526	261	289	308	481	350	364	307	293	394	330	361	402	196
18. TF	311	061	326	225	176	258	272	452	374	316	179	238	360	296	209	340	159
19. WK-A		127	526	340	682	639	530	436	710	761	671	612	794	556	661	750	354
20. BI-Instr	127		096	201	087	149	132	055	140	107	116	124	126	145	219	166	312
21. DAT-AR	526	096		378	386	452	539	378	517	520	436	422	556	541	461	624	270
22. DAT-CS-II	340	201	378		322	335	358	310	336	392	299	288	429	413	444	447	276
23. DAT-LU-I	682	087	386	322		620	500	273	551	624	522	546	662	521	596	627	200
24. DAT-LU-II	639	149	452	335	620		516	364	582	587	481	623	654	534	588	652	258
25. DAT-NA	530	132	539	358	500	516		423	514	580	437	490	547	722	570	625	229
26. DAT-SR	436	055	578	310	273	364	423		469	414	339	394	467	422	342	533	215
27. GV-Sci	710	140	517	336	551	582	514	469		718	605	562	702	549	623	674	301
28. GV-SS	761	107	520	392	624	587	580	414	718		690	595	742	602	716	729	353
29. GV-Lit	671	116	436	299	522	481	437	339	605	690		517	655	463	617	627	274
30. GV-CW	612	124	422	288	546	623	490	394	562	595	517		616	478	541	612	240
31. GC-Read	794	126	556	429	662	654	547	467	702	742	655	616		609	658	776	303
32. GV-Arith	556	145	541	413	521	534	722	422	549	602	463	478	609		607	661	204
33. IHS	661	219	461	444	596	588	570	342	623	716	617	541	658	607		694	325
34. Otis QS	750	166	624	447	627	652	625	533	674	729	627	612	776	661	694		316
35. Sims	354	312	270	276	200	258	229	215	301	353	274	240	303	204	325	316	

* See Table 1 for interpretation of test variable code.

TABLE 3

Centroid Loadings (Decimal points are omitted throughout so that table entries are all in thousandths)

Test Variable	I	II	III	IV	V	VI	VII	VIII	h^2
1. AGCT Reading and Vocabulary (Part I)	793	159	113	−027	−060	050	080	−120	694
2. AGCT Arithmetic Computations (Part II)	707	133	−370	044	172	−030	−094	056	699
3. AGCT Arithmetic Reasoning (Part III)	795	073	−273	171	118	−123	070	−107	786
4. AGCT Pattern Analysis (Part IV)	668	−376	−216	091	−209	−089	030	073	700
5. AG Mechanical Aptitude 2	768	−369	049	115	050	100	−108	109	778
6. Education in Years	637	030	078	−219	230	−100	075	100	539
7. Arithmetic Reasoning, BI201A	805	090	−182	153	109	−095	041	−096	744
8. Aviation Information, BI101A	774	−033	248	−029	−076	−073	−168	−087	710
9. Background for Current Affairs, BI102A	803	132	180	−114	−128	−113	−151	−137	779
10. Dial and Table Reading, BP622A-621A	788	−086	−257	−082	052	055	020	−078	713
11. Electrical Information, BI901A	775	−107	240	103	124	089	−046	−088	714
12. General Mechanics, BI902A	654	−237	330	290	196	040	−053	−155	744
13. Mechanical Principles, BI903A	662	−395	077	326	−021	−021	021	062	712
14. Memory for Landmarks, BI510A	599	−105	−191	−068	−140	−085	145	−033	460
15. Numerical Operations, II, CI702B	629	240	−365	−084	222	189	−030	−043	681
16. Reading Comprehension, BI601A	796	088	131	093	−054	−009	009	−125	686
17. Speed of Identification, CP610A	504	−305	−157	−218	−140	256	−143	112	538
18. Tool Functions, BI904A	493	−481	204	267	193	098	−166	−126	678
19. Word Knowledge Form A, BI602A	818	210	254	−030	−174	−031	041	−071	817
20. Biographical Inventory, Instructor, BE601B	209	−065	051	−213	273	−125	246	137	266
21. DAT-Abstract Reasoning, Form A	696	−127	−190	045	−162	−155	067	−044	595
22. DAT-Clerical, Part II, Form A	538	−142	−220	−373	070	292	078	−032	594
23. DAT-Language Usage, Part I, Form A	674	345	093	017	−048	157	099	040	621
24. DAT-Language Usage, Part II, Form A	711	191	109	102	−065	131	222	134	653
25. DAT-Numerical Ability, Form A	728	180	−301	112	142	−126	−076	089	715
26. DAT-Space Relations, Form A	632	−394	−131	149	−252	−085	−073	077	676
27. Gray-Votaw, Science (1)	782	076	200	027	−068	−057	−072	042	673
28. Gray-Votaw, Social Studies (2)	823	232	169	−127	−075	−043	−195	−061	825
29. Gray-Votaw, Literature (3)	665	234	173	−125	−175	−022	−103	052	588
30. Gray-Votaw, Choice of Words (4)	676	176	128	095	−120	075	068	180	570
31. Gray-Votaw, Reading (5)	843	153	138	022	−133	110	053	−070	791
32. Gray-Votaw, Arithmetic (6)	758	184	−300	102	182	007	−070	−021	747
33. Iowa High School Content, Form L	764	241	079	−183	077	036	−061	154	716
34. Otis Quick-Scoring, Gamma, Form AM	867	112	−019	009	−089	030	065	−028	779
35. Sims Score Card, Form C	393	−106	164	−357	116	−247	180	053	430
Mean of factor loadings squared	.497	.048	.041	.027	.021	.014	.012	.009	

solution, Table 5 the rotated factor loadings for the oblique solution, and Table 6 the cosines of the angular separations between the oblique axes.

TABLE 4

Orthogonal Rotated Loadings (Decimal points are omitted throughout so that all table entries are in thousandths)

Test Variable*	I	II	III	IV	V	VI	VII	VIII	h^2
1. AGCT-RV	615	273	193	217	243	236	055	194	694
2. AGCT-AC	193	683	072	197	226	250	116	151	698
3. AGCT-AR	335	633	182	054	361	196	−003	258	784
4. AGCT-PA	078	243	198	189	692	166	126	196	701
5. AG-MA-2	165	254	524	307	451	198	237	134	777
6. Ed in Yr	280	258	190	237	038	274	201	429	538
7. AR	383	577	217	075	324	225	026	233	743
8. AI	452	131	360	200	285	462	075	134	709
9. BCA	547	185	201	208	254	523	019	147	778
10. DTR	265	480	167	370	380	189	008	259	713
11. EI	435	233	536	215	226	224	097	160	713
12. GM	335	168	716	046	222	152	033	121	743
13. MP	166	196	536	044	544	090	190	133	713
14. ML	235	253	020	191	452	142	024	283	461
15. NO II	279	666	005	360	055	107	022	115	679
16. RC	559	283	293	128	301	276	049	146	685
17. SI	028	124	125	564	384	138	143	026	538
18. TF	035	113	740	141	290	099	−005	039	679
19. WK-A	708	158	179	150	263	354	122	169	818
20. BI-Instr	025	069	073	089	−081	006	160	463	265
21. DAT-AR	250	315	101	120	544	231	030	243	597
22. DAT-CS II	152	258	045	633	185	015	022	257	593
23. DAT-LU-I	640	312	066	179	102	132	204	071	618
24. DAT-LU-II	601	275	146	130	240	035	305	157	652
25. DAT-NA	249	662	080	075	241	298	164	165	713
26. DAT-SR	068	174	259	152	691	219	138	088	677
27. GV-Sci	501	208	279	143	268	382	207	142	672
28. GV-SS	577	257	175	253	164	531	101	103	823
29. GV-Lit	531	136	052	202	171	414	188	071	585
30. GV-CW	528	229	137	115	248	167	334	068	569
31. GV-Read	663	263	216	240	307	234	119	117	790
32. GV-Arith	310	695	136	172	208	231	073	131	746
33. IHS	479	336	108	311	058	366	291	205	715
34. Otis-QS	553	376	162	234	365	249	128	195	778
35. Sims	149	−049	084	167	049	246	104	546	431
Mean of factor loadings squared	.166	.123	.080	.057	.106	.069	.022	.045	

* See Table 1 for interpretation of test variable code.

While oblique axes fit the present data better, orthogonal axes are a more useful reference frame for classification since they assume independent psychological functions. Thus the mechanical-experience and visualization factors are correlated, indicating that for the present population and with our present

TABLE 5

Oblique Rotated Loadings (V-Matrix) (Decimal points are omitted throughout so that all table entries are in thousandths)

Test Variable*	I	II	III	IV	V	VI	VII	VIII
1. AGCT-RV	376	106	108	072	058	113	012	050
2. AGCT-AC	−009	555	−050	081	116	066	047	−033
3. AGCT-AR	132	502	067	−050	232	−017	−059	066
4. AGCT-PA	−038	068	006	111	559	−022	067	070
5. AG-MA-2	−040	066	339	215	201	050	175	026
6. Ed in Yr	006	197	089	099	−042	182	128	321
7. AR	156	443	099	−042	175	031	−033	049
8. AI	130	−003	167	008	093	353	−018	011
9. BCA	207	054	013	−015	098	408	−080	005
10. DTR	095	296	034	258	235	013	−046	100
11. EI	178	081	413	100	−024	111	048	051
12. GM	112	059	600	−023	−035	050	−005	046
13. MP	015	045	374	000	320	−069	149	037
14. ML	118	116	−089	104	378	−009	−017	159
15. NO II	149	513	−024	274	−066	−030	−004	−042
16. RC	305	127	173	−016	099	139	−003	000
17. SI	−041	−080	−007	486	231	054	106	−040
18. TF	−100	005	602	113	051	010	−040	001
19. WK-A	404	−001	059	−035	076	243	062	024
20. BI-Instr	−083	097	071	062	−050	−019	136	442
21. DAT-AR	086	170	−058	009	443	048	−032	094
22. DAT-CS II	097	072	010	570	073	−064	−002	179
23. DAT-LU-I	444	148	044	065	−080	039	191	−062
24. DAT-LU-II	426	100	117	049	041	−081	301	029
25. DAT-NA	008	555	−057	−055	137	106	086	−027
26. DAT-SR	−061	003	045	067	536	046	073	−025
27. GV-Sci	192	071	116	−031	079	262	129	004
28. GV-SS	220	121	001	023	−009	421	003	−056
29. GV-Lit	246	008	−081	012	032	333	115	−055
30. GV-CW	318	070	056	003	060	059	304	−057
31. GV-Read	422	060	119	092	081	105	082	−031
32. GV-Arith	097	554	032	056	062	046	015	−058
33. IHS	165	203	000	127	−096	266	216	059
34. Otis-QS	312	184	044	087	174	086	077	025
35. Sims	−067	−041	−005	046	078	204	035	500

* See Table 1 for interpretation of test variable code.

TABLE 6

Cosines of Angular Separations of Oblique Reference Vectors ($\lambda'\lambda$)

	I	II	III	IV	V	VI	VII	VIII
I	1.000							
II	−.246	1.000						
III	.095	−.040	.999					
IV	.092	−.234	.106	1.000				
V	−.094	−.138	−.433	−.143	1.000			
VI	−.425	−.066	−.299	−.258	−.104	1.000		
VII	.006	−.085	.009	.051	−.120	−.196	1.000	
VIII	−.160	−.043	.063	.009	.098	−.101	−.036	1.000

tests they tend to go together. Since the goal of optimal prediction, however, implies independent measures, it is useful to

work with orthogonal axes to represent the hypothetically independent factors we are trying to achieve, particularly since interpretations and conclusions do not seem to be affected by the type of solution imposed.

Interpretation

Rotated factor loadings are presented for both the orthogonal and oblique solutions. There are some reversals in the rank order of the variables on a factor but the interpretations of the factors are the same for the two types of solutions.

Rotated Factor I is defined by the following tests:

Test	*Loading*	
	Orthogonal	*Oblique*
ACTB Word Knowledge	.708	.404
Gray-Votaw, Reading	.663	.422
DAT-Language Usage, Part I	.640	.444
AGCT-Reading and Vocabulary	.615	.376
DAT-Language Usage, Part II	.601	.426
Gray-Votaw, Social Studies	.577	.220
ACTB Reading Comprehension	.559	.305
Otis Mental Ability Test	.553	.312
ACTB Background for Current Affairs	.547	.207
Gray-Votaw, Literature	.531	.246
Gray-Votaw, Choice of Words	.528	.318
Gray-Votaw, Science	.501	.192
Iowa High School Content—Composite Score	.479	.165
ACTB Aviation Information	.452	.130
ACTB Electrical Information	.435	.178

Fifteen tests have loadings larger than .4 in the orthogonal solution. This is the well-known verbal-comprehension factor (V) which represents the ability to understand verbal material.

Rotated Factor II is defined by the following tests:

Test	*Loading*	
	Orthogonal	*Oblique*
Gray-Votaw, Arithmetic	.695	.554
AGCT-Arithmetic Computations	.683	.555
ACTB Numerical Operations II	.666	.513
DAT-Numerical Abilities	.662	.555
AGCT Arithmetic Reasoning	.633	.502
ACTB Arithmetic Reasoning	.577	.443
ACTB Dial and Table Reading	.480	.296

Seven tests have projections of greater than .4 on the orthogonal reference vector. This is the numerical-facility factor (N). It represents the ability to do arithmetical computations speedily and accurately.

Rotated Factor III is defined by the following tests:

Test	Loading	
	Orthogonal	*Oblique*
ACTB Tool Functions	.740	.602
ACTB General Mechanics	.716	.600
ACTB Electrical Information	.536	.413
ACTB Mechanical Principles	.536	.374
AG Mechanical Aptitude	.524	.339

This is the mechanical-experience factor (ME). It represents knowledge concerning and experience with mechanical activities. Although it is primarily a measure of achievement, it also indirectly measures interest and aptitude for mechanical work. It has consistently high validity for most AF mechanical technical-training criteria.

Rotated Factor IV is defined by the following tests:

Test	Loading	
	Orthogonal	*Oblique*
DAT-Clerical Speed and Accuracy, Part II	.633	.570
ACTB Speed of Identification	.564	.486
ACTB Dial and Table Reading	.370	.258
ACTB Numerical Operations II	.360	.274

This is the perceptual-speed factor (P). It represents the ability to pick out rapidly visual details imbedded in irrelevant material. The high loading of DAT-Clerical Speed and Accuracy on this factor indicates that a better measure of the factor should be put into the ACTB. The Speed of Identification test was carried over from the *Aircrew Classification Battery* and may not be appropriate for the airman population. A new test, Speed of Perception, being developed to replace Speed of Identification, may prove more suitable.

Rotated Factor V is defined by the following tests:

Test	Loading	
	Orthogonal	*Oblique*
AGCT Pattern Analysis	.692	.559
DAT-Space Relations	.691	.536
DAT-Abstract Reasoning	.544	.443
ACTB Mechanical Principles	.544	.320
ACTB Memory for Landmarks	.452	.378
AG Mechanical Aptitude	.452	.201
ACTB Speed of Identification	.384	.231
ACTB Dial and Table Reading	.380	.235

This is the visualization factor (Vz). It represents the ability to manipulate visual images mentally. A new test similar to the Pattern Analysis test, Pattern Comprehension, has been added to the ACTB since this analysis was completed. This, together

with the Mechanical Principles test, should give adequate coverage of this function.

Rotated Factor VI is defined by the following tests:

Test	Loading	
	Orthogonal	*Oblique*
Gray-Votaw, Social Studies	.531	.421
ACTB Background for Current Affairs	.523	.408
ACTB Aviation Information	.462	.353
Gray-Votaw Literature	.414	.333
Gray-Votaw Science	.382	.262
Iowa High School Content, Composite Score	.366	.266

This is interpreted as an academic information factor (AI). It has several possible precedents but is more broadly defined here. A pilot-interest factor was isolated in several aircrew-battery analyses.[2] It was heavily loaded in the General Information Test (Pilot Score) which consisted largely of aviation information items. The present factor may be a composite of the pilot-interest and a social-science-background factor likewise found in an aircrew battery and defined by a geography and history test.

Rotated Factor VII is defined by the following tests:

Test	Loading	
	Orthogonal	*Oblique*
Gray-Votaw, Choice of Words	.334	.304
DAT-Language Usage, Part II	.305	.301

This factor is a "doublet" and cannot be identified with confidence. Both tests require the examinee to make judgments of correct grammatical usage and the factor probably represents knowledge of correct usage of the English language and rules of grammar. It has tentatively been identified as a correct-English-usage factor (CU). It seems to be a specific achievement factor of doubtful usefulness for predicting Air Force specialty criteria, but merits further investigation to determine its scope and validity.

Rotated Factor VIII is defined by the following variables:

Variable	Loading	
	Orthogonal	*Oblique*
Sims Socio-Economic Status Card	.546	.500
ACTB Biographical Inventory (Instructor)	.463	.442
Education in Years	.429	.321

This is interpreted as a socio-economic background factor (SE). The three non-test variables with significant loadings are

[2] Guilford, J. P., (Ed.). *Printed Classification Tests.* Washington, D.C.: U. S. Government Printing Office, 1947, pp. 817–819.

related to educational and socio-economic background. Biographical Inventory (Instructor key) seems to be a good measure of it. It may be that some of the Biographical Inventory empirical keys being developed will have even higher loadings on this factor.

Discussion

In general, the *Airman Classification Test Battery* seems to have adequate coverage of the factors isolated in this analysis with the exception of Factor VII, which was a "doublet" and could not be identified with confidence. Several factors which it had been anticipated would be contained in the *Airman Classification Test Battery*[3] did not appear in this analysis although the expected content may be represented in the specific variances of the tests. These were the reasoning, spatial-relations and memory factors. The Memory for Landmarks test undoubtedly has rote-memory content but since no other memory test was included in the analysis, the memory factor did not appear. A reasoning factor was expected since several reasoning tests (viz. two arithmetic reasoning and an abstract reasoning test) were included. It may be that these traditional reasoning tests are not suitable for this population and further exploratory work needs to be done to develop a suitable reasoning test.

Table 7 presents the estimated reliabilities and specific variances of the tests in the *Airman Classification Test Battery*. Several of the tests have sizeable specific variances. In previous analyses of the Memory for Landmarks test, based on another population,[4] a portion of its variance appeared on a paired-associates memory factor. A memory factor was not isolated in this analysis, probably because but a single test of the memory function was included.

The relatively high specific variance of the Numerical Operations II test was unexpected since analyses of this test based on aircrew samples[5] indicated it to be a pure measure of the

[3] Dailey, J. T., *Development of an Airman Classification Test Battery*, Research Bulletin 48–4, Hq. Training Command, Barksdale AFB, 25 Oct 48, p. 6.

[4] Guilford, J. P. (Ed.). *Printed Classification Tests*. Washington, D.C.: U.S. Government Printing Office, 1947, p. 249.

[5] Ibid, p. 894–5.

numerical factor with little specific variance. Also this test seems to have perceptual-speed variance for the airman population whereas no such variance was apparent for the aircrew samples.

The Biographical Inventory (Instructor key) has sizeable specific variance despite its low estimated reliability. A considerable portion of the items are statements of preference and apparently these preferences are unstable during the eight-week period between the first and second administrations. This is the period during which the airmen are assigned to their military

TABLE 7

Estimated Reliabilities and Specific Variances of the Tests in the Airman Classification Test Battery

Test	Corrected Odd-Even Reliability	Estimated Specific Variance
Arithmetic Reasoning	.85	.11
Aviation Information	.84	.12
Background for Current Affairs	.90	.12
Dial and Table Reading	.79*	.08
Electrical Information	.91	.20
General Mechanics	.81	.07
Mechanical Principles	.80	.09
Memory for Landmarks	.79	.33
Numerical Operations II	.88*	.20
Reading Comprehension	.82	.14
Speed of Identification	.64*	.10
Tool Functions	.75	.07
Word Knowledge	.88	.07
Biographical Inventory (Instructor)	.42*	.15

* Estimates for the speeded tests and the biographical inventory are test-retest reliabilities. The interval between first and second administrations is eight weeks.

occupations and receive much occupational information both formally and informally. Under these circumstances a test-retest reliability coefficient probably gives an underestimation. Since the Biographical Inventory has considerable valid specific variance it would be of interest to identify its content.

Several of the other tests have moderate specific variances which it would be of interest to identify. In general, however, with the above exceptions, the major reliable variances of the tests of the *Airman Classification Test Battery* seem well accounted for by the factors identified in this analysis.

Even though some of the factors are appreciably correlated for this population (e.g. verbal and academic information, me-

chanical-experience and visualization) the two rotational solutions lead to the same interpretations and there are but minor reversals in the rank order of the variables on the factors. The simpler mathematics of the orthogonal solution makes it more convenient and useful unless there is interest in the obliquities *per se*.

In addition to identifying the factorial content of the ACTB, the results of this analysis are interesting because of the information they furnish of the factorial content of the other tests included in the study. Inspection of Table 4 gives the loadings for these tests.

The following comments seem pertinent:

1. The Army Classification tests (variables 1 through 5) have no significant variance on the perceptual-speed, academic information, and socio-economic background factors.

2. The *Differential Aptitude Test* battery has no significant loadings on the academic-information and socio-economic factors. It undoubtedly would have had a loading on the mechanical-experience factor if the DAT Mechanical Reasoning test had been included in the analysis.

3. The *Gray-Votaw General Achievement Tests* have significant loading on the verbal, numerical, academic-information, and correct-usage factors only.

4. The *Iowa High School Content Examination* has loadings on the verbal, numerical, and academic-information factors only.

5. The *Otis Mental Ability Test* has a verbal loading and moderate loadings on the numerical and visualization factors.

6. The *Sims Score Card for Socio-Economic Status* has its variance on and defines the socio-economic background factor.

There are a number of potentially useful factors, isolated in analyses based on other populations, which did not appear in this analysis. Some may be contained in the specific variances of the tests and others need to be represented in this population by new tests. Some of the factors which should be added to the battery are spatial relations, general reasoning, judgment, verbal fluency, and visual memory.

Steps have been taken to construct and try out promising tests in these areas, suitable to the airman population. In addition, work is proceeding on the isolation of factors in the

areas of temperament, social judgment, and interests to extend the coverage of the ACTB to the measurement of relevant personality variables.

Summary

In order to obtain a better understanding of the psychological functions being assessed by the *Airman Classification Test Battery*, which is used to help classify enlisted men in the Air Forces into training assignments, it was submitted to factorial analysis along with the *Army General Classification Test* Battery, the *Gray-Votaw General Achievement Test* and a number of other tests and background variables.

Knowledge of the factorial content of the airman battery has a number of advantages for improving the efficiency of selection and classification:

(1) It delimits the scope of the present battery and indicates in which respects it is satisfactory and in which it is weak.

(2) It analyzes the validity of the tests in terms of psychological functions held in common by tests and criteria.

(3) It establishes a basis for job classification in terms of the factorial content of job-success criteria.

(4) It makes estimation of test validity possible prior to empirical validation.

(5) It gives ideas for the revision of present tests and points up areas for the development of new tests.

The airman battery and other variables were administered to a sample of 881 basic airmen. The distributions of scores were normalized and intercorrelated. Eight centroid factors were extracted from the matrix of intercorrelations and rotated to psychologically meaningful positions. Two solutions were obtained, one based on orthogonal (independent) factors and the other based on oblique (dependent) factors. The 8 factors were identified as follows:

1. Verbal—ability to understand verbal material.

2. Numerical facility—ability to do arithmetic computations speedily and accurately.

3. Mechanical experience—achievement in mechanical knowledge and experience.

4. Perceptual speed—ability to pick out rapidly visual details imbedded in irrelevant material.

5. Visualization—ability to manipulate visual images rapidly.

6. Academic information—knowledge of current events, social science, aviation information, etc., acquired in school or through reading.

7. Correct English usage—knowledge of the rules of grammar and correct use of English.

8. Socio-economic background—level of educational and social background.

Of the eight factors reported, seven are relatively well defined and are expected to reappear in subsequent analyses. The eighth, "correct English usage," is poorly defined by the tests appearing on the factor and may include little more than chance variance.

Several of the factors which had been postulated in the battery were not isolated in this analysis. These are spatial-relations, reasoning, and memory. They are probably represented in the battery but they did not appear in this analysis as separated factors because of insufficient tests to define them.

The results of this study are also of interest because of the information they yield concerning the Army classification tests, the *Gray-Votaw General Achievement Tests*, the *Differential Aptitude Tests* and the other tests and variables included in the study.