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ABSTRACT

Many multiple aptitude test batteries, including the Air Force Officer Qualifying Test (AFOQT), used for assigning or classifying individuals to jobs or for occupational counseling have subtests covering a broad range of content such as science, mathematics, reading, vocabulary, perceptual, mechanical, or technical knowledge. This content reflects a belief that performance in different jobs is best predicted by subtests whose content appears to be closely related to jobs. It has been demonstrated that the subtests of a multiple aptitude test battery all measure, in large part, an examinee's general learning ability, often called psychometric g, in addition to the specific abilities implied by the differing contents of the subtests. This study investigated methods for estimating psychometric g from the Air Force Officer Qualifying Test Form O. The methods used and compared were unrotated principal components, unrotated principal factors and variants of hierarchical factor analysis. Subjects were 2,984 applicants to Air Force commissioning programs. Results indicated that the methods produced estimates of g which were equal except for scale with a range of correlations from .980 to .999. This relationship was all predictable from a theorem presented by S. S. Wilks. (Contains 16 references and 12 tables.) (Author)

AL-TP-1991-0039

ARMSTRONG LABORATORY

AIR FORCE OFFICER QUALIFYING TEST (AFOQT): ESTIMATING THE GENERAL ABILITY COMPONENT

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The Public Affairs Office has reviewed this paper, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This paper has been reviewed and is approved for publication.

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This study investigated methods for estimating psychometric g from the Air Force Officer Qualifying Test Form O. The methods used and compared were unrotated principal components, unrotated principal factors and variants of hierarchical factor analysis. Subjects were 2,984 applicants to Air Force commissioning programs.

Results indicated that the methods produced estimates of g which were equal except for scale with a range of correlations from .980 to .999. This relationship was all predictable from a theorem presented by S.S. Wilks.

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PREFACE

This research and development effort was conducted under Task 77191867 to clarify the constructs underlying the aptitude test used to select U.S. Air Force officer personnel. The nature of the Air Force Officer Qualifying Test is important for its use in selecting and classifying those applying for a commission. Proper assignment, classification, training, and retention are difficult without a full understanding of the constructs measured.

Many people in the Air Force Human Resources Laboratory (now the Human Resources Directorate of the Armstrong Laboratory) contributed to this effort. Special thanks are offered to Lonnie D. Valentine, Jr., Jacobina Skinner, and William E. Alley who gave their time freely. Their critical reviews were very helpful. Sgt David Tucker and William Glasscock of AFHRL/SC are thanked for their expertise and perseverance in the computer analyses.

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"*There's more than one way to skin a cat.*"
Folk saying

AIR FORCE OFFICER QUALIFYING TEST (AFOQT):
ESTIMATING THE GENERAL ABILITY COMPONENT

INTRODUCTION

Much of early psychological testing began with the assessment of **g** or general ability (Spearman, 1904; 1927). The topic has become of interest to researchers again. One issue is how to estimate **g** from a set of cognitive variables such as the subtests of a test battery.

Ree and Earles (1991) have shown that the commonly accepted methods of estimating **g** are almost identical and almost linear transformations of one another for the Armed Services Vocational Aptitude Battery (ASVAB), one of the most widely administered tests in the world. However, the high positive manifold of the ASVAB (average subtest correlation is .59) may make it less than an ideal instrument for examination of **g** estimation procedures. The Air Force Officer Qualifying Test (AFOQT), on the other hand, has six more subtests than the ASVAB, a more varied topology, and measures more content areas including a special emphasis on space perception which is not measured by ASVAB. Positive manifold in the AFOQT with an average subtest correlation of .43 is less than in the ASVAB. For these reasons the AFOQT may be a better instrument for examining the stability of **g** estimates across commonly applied estimation procedures.

In practice there are three generally accepted methods of estimating **g** from the data (Jensen, 1987). These are:

1. the unrotated first principal component,
2. the unrotated first principal factor and,
3. the first factor from a hierarchical factor analysis.

The three methods all make use of a correlation matrix and each treats the data with a slightly different model of the relationship between **g** and the observed data. The three models are discussed in order of increasing mathematical complexity. This order also turns out to be the increasing order of the number of decisions to be made in applying the model and the decreasing order of expected uniformity of results from different investigators.

Each method can produce an estimate of **g**; each has advantages and disadvantages; and each is based on a set of assumptions. Jensen (1987) has found that all produce similar results for the data sets he has investigated. These include an individual intelligence test and what he called "real tests."

Humphreys (1989) implied that the three analytic methods may not give the same results when the variables do not have positive manifold, but this is not an issue for the AFOQT nor for any multiple aptitude battery with which the authors are familiar.

Wilks (1938) demonstrated by mathematical proof that weighting a positive manifold of variables is a matter of indifference when the weights are positive, when there are "enough" variables, and when the average correlation is "sufficiently" high. The Wilks theorem predicts that the methods of **g** estimation should yield almost identical results because all the methods apply positive weights to each of the 16 subtests.

This study extends the previous (Ree & Earles, 1991) evaluation of methods of estimating **g** to the more factorially rich AFOQT. A further refinement is the presentation of residualized lower order factors in the hierarchical factor analyses.

Principal Components

Hotelling (1933a, 1933b) developed the principal components method as a way of reorienting the reference axes of a set of data. It analyzes a correlation matrix (1.0 in the diagonal) and forms a set of linearly independent variables from which the original variables can be reproduced. If there are **n** variables in the original matrix, then **n** components can be computed. Principal components require no decisions and provide a completely determined result. Component scores may be computed directly, and the first of these is the estimate of **g**. The solution is not rotated because that would distribute a portion of the first component variance among the remaining components.

Principal Factors

The principal or common factors method is a variant of the principal components method. It analyzes a reduced correlation matrix with some measure of communality in the diagonal (Mulaik, 1972) and reproduces only the common variance in the matrix. At least one decision, the estimation of communality, is required. This decision may be made in several ways including: squared multiple correlations, iterated squared multiple correlations, highest correlation of the variable in the matrix, or the reliability of the variable. Occasionally the estimate of communality may be greater than one for the iterated squared multiple correlations creating what have become known as the Heywood cases (Harman, 1967, p. 117-118). This is not an insurmountable problem in practice since iterated squared multiple correlations have been used successfully. Again the solution is not rotated to retain **g** in the first principal factor.

Hierarchical Factor Analysis

For a hierarchical factor analysis, the factorial model can be principal components or principal factors (or any other factor extraction method), but an oblique rotation and factoring of the correlations of the factors is performed. This process can be continued until the number of higher-order factors is fewer than three, at which stage a further factoring is impossible. The first or only higher order factor serves as the estimate of **g**. Although the lower factors can be residualized by the method of Schmid and Leiman (1957), it will have no effect on the factor which estimates **g**. Several decisions are required: the method of factoring at each stage, communality estimation, number of factors at each stage, and angle of oblique rotation. These decisions could lead to different estimates of **g** in hierarchical analyses. For example, the number of factors extracted could be based on the results of previous factorings, confirmatory factor analyses, *a priori* beliefs about factor structure, mechanical rules (eigenvalue greater than 1.0, scree rules), comparison of multiple solutions, Humphreys' parallel analysis, likelihood ratio tests, or a search for simple structure.

Since these different methods may yield different **g** estimates, the goal of this study was to apply each to a data set factorially richer than the ASVAB and examine the relations among the **g** estimates.

METHOD

Subjects

The subjects were a random sample of 2,984 applicants to the Air Force Reserve Officer Training Corps (ROTC) and the Officer Training School (OTS) commissioning programs (Skinner & Ree, 1987). This sample was collected from 1980 through 1984. Their descriptive characteristics are shown in Table 1. The subjects' average age was 22.19 years and average education was 14.41 years.

TABLE 1. PERCENTAGE OF SAMPLE BY DEMOGRAPHIC CATEGORY

Sex	%	Race	%	Degree	%	Program[a]	%
Male	84	Black	12	High School	54	OTS	45
Female	16	White	80	Associate's	7	ROTC	43
		Other	8	Bachelor's	37	ANG	4
				Master's	2	Reserves	1
						Other	7

[a]OTS is the Officers Training School, ROTC is the Reserve Officer Training Corps, ANG is the Air National Guard.

The Air Force Officer Qualifying Test

The AFOQT Form O is a multiple aptitude test battery. AFOQT Form O contains 380 items organized into 16 separately timed subtests and requires about 4.5 hours to administer. Table 2 lists the subtests, shows the number of items in each, and gives their administration times. Skinner and Ree (1987) state that the battery was designed to assess verbal (VA,RC,WK,GS), quantitative (AR,DI,MK,SR), spatial-perceptual (MC,EM,BC,RB,HF), and specialized pilot knowledge (IC,AI,TR) areas. Three of the subtests are power (MC,RB,GS) and the others are speeded to some degree.

TABLE 2. DESCRIPTION OF AFOQT FORM O SUBTESTS

Subtests	Number of Items	Testing Time in Minutes
Verbal Analogies (VA)	25	8
Arithmetic Reasoning (AR)	25	29
Reading Comprehension (RC)	25	18
Data Interpretation (DI)	25	24
Word Knowledge (WK)	25	5
Math Knowledge (MK)	25	22
Mechanical Comprehension (MC)	20	22
Electrical Maze (EM)	20	10
Scale Reading (SR)	40	15
Instrument Comprehension (IC)	20	6
Block Counting (BC)	20	3
Table Reading (TR)	40	7
Aviation Information (AI)	20	8
Rotated Blocks (RB)	15	13
General Science (GS)	20	10
Hidden Figures (HF)	15	8

Procedure

The correlations of AFOQT subtests were computed using the applicant sample, and **g** was estimated by the three methods. The principal components were computed. Principal factors were computed with communalities estimated by iterated squared multiple correlations which Howard and Cartwright (1962) have shown to be the most accurate estimate of communality. Hierarchical factor analyses were conducted using both principal components and principal factors for the initial factoring. In each case three different first-order factor solutions based on 5, 6, or 7 lower-order factors were computed. It is posited that this range of factors encompasses the reasonable solutions regardless of the method used to select the "appropriate" number of factors.

The Oblimin (Carroll, 1960) oblique factor rotation method was used in the first-order factor analyses. All higher-order factor analyses were principal components. Investigators using principal components for the first-order analysis would not be likely to reduce dimensionality by using principal factors in the hierarchical analyses. Investigators using principal factors analysis in the first-order factor analyses have already reduced the matrix to its common elements. Therefore they would not be expected to reduce it further with a hierarchical analysis based on principal factors. A total of 6 hierarchical factor analyses were run. The lower order factors were residualized (Schmid & Leiman, 1957) to remove the effects of the higher order factor or factors.

Scores for each of the eight estimates of **g** were computed for each subject in the sample. The standard scores of the AFOQT subtests were weighted by the score coefficients of the first principal component and first principal factor. For the hierarchical estimates, the first-order factor scores were computed and weighted in standardized form by the higher-order factor-score coefficients. The eight estimates of **g** were then correlated. Another measure of association of factors commonly computed from factor loadings when individual scores on the variables are not available is the coefficient of congruence (Burt, 1948; Tucker, 1951). It was computed in this study to determine its relationship to correlations based on factor scores.

RESULTS AND DISCUSSION

Table 3 shows the matrix of correlations of AFOQT subtest scores computed in the applicant sample. All correlations were positive and ranged from .173 to .765 with an average of .434. The highest was between Word Knowledge and Reading Comprehension, two verbal measures. The lowest was between Word Knowledge and Electrical Maze, a space-perceptual test. Arithmetic Reasoning had the highest average correlation (.505) with the other subtests while Aviation Information had the lowest (.340).

Principal Components

Table 4 shows the unrotated loadings of the subtests on the principal components. The first component is the **g** estimate.

Principal Factors

Table 5 shows the unrotated loadings of the subtests on the principal factors. The first factor is the estimate of **g**.

TABLE 3. INTERCORRELATIONS OF AFOQT SUBTESTS

	VA	AR	RC	DI	WK	MK	MC	EM	SR	IC	BC	TR
VA												
AR	576											
RC	734	580										
DI	527	668	552									
WK	680	456	765	456								
MK	552	706	513	598	397							
MC	478	508	460	460	397	476						
EM	267	375	229	380	173	396	444					
SR	478	661	451	622	366	601	483	446				
IC	344	412	332	435	278	394	495	442	488			
BC	448	525	400	512	323	493	500	471	611	491		
TR	340	443	351	465	267	441	303	312	557	336	508	
AI	302	306	335	339	318	249	495	284	332	557	305	212
RB	432	474	353	421	288	485	535	415	493	455	546	342
GS	507	487	547	439	511	524	568	339	406	408	369	253
HF	397	399	354	393	311	400	393	340	467	364	454	362

	AI	RB	GS	HF
AI				
RB	339			
GS	462	404		
HF	267	419	338	

Note. Decimal points and diagonal omitted.

TABLE 4. UNROTATED PRINCIPAL COMPONENTS LOADINGS

	Component															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
VA	743	-430	-049	-066	133	070	-122	-108	066	012	-159	073	145	-345	-146	084
AR	795	-069	-237	-079	-265	-163	074	-116	-065	-002	-083	118	023	258	-279	112
RC	732	-533	-006	064	061	130	-047	-040	008	023	-021	-018	001	122	-037	-362
DI	762	-038	-205	121	-234	-035	123	-212	-211	140	252	-313	046	-116	035	015
WK	639	-602	078	091	156	207	-062	-038	012	024	049	013	-139	164	193	230
MK	761	-025	-244	-215	-259	-179	125	052	236	-024	-112	047	196	008	290	-024
MC	727	090	328	-197	-014	-059	-093	182	-373	-069	-303	-168	-036	004	063	002
EM	563	440	075	-282	-064	580	175	-023	022	159	-001	061	022	014	-022	-002
SR	777	203	-256	121	-089	-059	041	-063	-094	-056	-019	261	-375	-155	075	-061
IC	648	325	352	255	-052	017	-021	-271	312	-188	-143	-207	-090	023	-034	009
BC	725	298	-152	022	149	102	-270	-019	-121	-379	214	087	196	044	028	-001
TR	587	210	-406	439	044	093	-100	426	087	141	-092	-093	032	016	-050	032
AI	538	098	636	360	-078	-118	051	006	-084	186	064	249	179	-002	038	-004
RB	672	257	066	-304	172	-224	-415	-036	135	291	129	-027	-089	036	-010	-013
GS	688	-210	329	-178	-128	-058	173	382	146	-162	251	-044	-108	-075	-118	012
HF	598	158	-084	-032	623	-182	426	-036	-015	011	-006	-026	028	033	-010	-001

Note. Decimal points omitted.

TABLE 5. UNROTATED PRINCIPAL FACTORS LOADINGS

	Component															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
VA	736	-384	-041	058	137	-125	053	067	033	021	-058	-103	037	-015	006	011
AR	790	-033	-246	-206	-148	-126	-124	-004	-022	-061	006	037	043	039	006	012
RC	735	-519	002	112	-013	-007	000	-057	-067	048	-029	108	024	-032	003	-009
DI	744	-007	-173	-010	-198	-041	-071	-086	007	091	102	-056	-020	-026	-010	001
WK	634	-554	086	167	025	032	013	-048	047	-057	032	-011	-071	046	-001	-003
MK	756	006	-254	-333	-031	019	186	056	-039	022	-018	-009	-025	012	-001	-021
MC	710	098	282	-133	155	032	-179	-012	-018	059	-079	-009	-014	018	-019	-004
EM	532	321	050	-034	109	035	047	-219	063	043	-020	-003	003	01[illegible]	023	002
SR	767	213	-231	078	-122	041	-073	032	137	-080	-066	008	-030	-038	000	-008
IC	633	300	311	112	-151	-143	170	-054	-008	-028	-028	025	-002	001	-018	011
BC	710	279	-117	197	176	006	-025	-046	-142	-088	033	-043	027	-004	-002	-015
TR	562	175	-271	227	-098	188	025	081	-074	061	-035	003	-011	022	002	019
AI	524	101	538	053	-237	002	-038	113	-020	016	016	-025	010	006	019	-014
RB	647	219	052	-037	258	-110	-012	116	-013	012	057	053	-065	-018	009	011
GS	672	-160	272	-237	026	218	036	-011	-001	-069	040	-006	024	-028	-003	016
HF	562	114	-037	106	127	041	038	079	141	038	065	038	071	023	-010	-008

Note. Decimal points omitted.

Hierarchical Factor Analysis

Tables 6 through 8 show the Schmid-Leiman residualized factor pattern matrices of the AFOQT subtest for the 5 factor through 7 factor solutions using principal components factor extraction. The primary factor correlations are also shown.

TABLE 6. FACTOR LOADINGS OF THE SCHMID-LEIMAN RESIDUALIZED HIERARCHICAL 7 FACTOR PRINCIPAL COMPONENT FACTOR ANALYSIS

	Factor							
	H-1	L-1	L-2	L-3	L-4	L-5	L-6	L-7
VA	691	057	-560	-070	004	035	-006	-127
AR	748	494	-051	-002	027	001	-012	-048
RC	663	068	-629	011	029	-002	-006	016
DI	723	401	-090	096	172	010	039	075
WK	573	-069	-725	021	012	008	008	038
MK	724	520	018	-071	-079	038	032	-066
MC	738	080	-092	244	-198	016	118	-276
EM	632	-009	013	-025	-022	007	742	024
SR	776	320	030	084	296	094	059	-061
IC	681	013	050	518	152	020	120	-087
BC	759	002	-104	021	356	042	161	-329
TR	590	118	-081	067	675	058	019	-007
AI	544	-024	-020	730	-035	018	-056	011
RB	705	028	-005	027	-016	039	-023	-622
GS	658	212	-197	226	-365	046	083	000
HF	664	-021	008	-013	-014	730	-010	014

Factor Intercorrelations

	I	II	III	IV	V	VI	VII
I							
II	463						
III	307	507					
IV	-369	-563	-598				
V	284	392	456	-337			
VI	-289	-302	-640	429	-404		
VII	464	405	497	-262	571	-568	

Note. Decimal points and diagonal omitted. H indicates higher-order factor and L indicates residualized lower-order factor. Roman numerals indicate first-order factors.

TABLE 7. FACTOR LOADINGS OF THE SCHMID-LEIMAN RESIDUALIZED HIERARCHICAL 6 FACTOR PRINCIPAL COMPONENT FACTOR ANALYSIS

	Factor						
	H-1	L-1	L-2	L-3	L-4	L-5	L-6
VA	700	098	-540	-052	-035	111	027
AR	750	481	-086	009	040	-001	-011
RC	677	071	-628	015	034	-003	002
DI	728	362	-131	094	218	-054	024
WK	589	-065	-717	022	018	002	015
MK	721	501	-032	-054	-061	033	028
MC	741	129	-076	259	-272	140	153
EM	629	-044	-021	-019	-003	-040	724
SR	774	322	013	092	299	106	074
IC	687	022	058	507	129	049	133
BC	757	104	-032	049	240	239	238
TR	591	143	-050	069	662	085	051
AI	558	-048	-036	702	-020	-018	-070
RB	699	194	094	075	-217	384	090
GS	664	170	-256	224	-328	-005	056
HF	635	-068	-068	-106	004	096	-032

Factor Intercorrelations

	I	II	III	IV	V	VI
I						
II	264					
III	-555	-343				
IV	530	340	-382			
V	437	520	-306	472		
VI	532	600	-592	389	550	

Note. Decimal points and diagonal omitted. H indicates higher-order factor and L indicates residualized lower-order factor. Roman numerals indicate first-order factors.

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TABLE 8. FACTOR LOADINGS OF THE SCHMID-LEIMAN RESIDUALIZED HIERARCHICAL 5 FACTOR PRINCIPAL COMPONENT FACTOR ANALYSIS

	Factor					
	H-1	L-1	L-2	L-3	L-4	L-5
VA	693	062	580	-038	-062	129
AR	750	359	-245	-024	267	-100
RC	668	090	637	034	035	026
DI	724	414	-203	079	-120	-099
WK	578	-009	679	056	113	068
MK	722	305	-211	-085	365	-072
MC	749	-057	-168	273	329	113
EM	609	090	162	124	-439	154
SR	772	453	-042	078	-136	080
IC	694	157	075	523	-061	064
BC	753	292	-003	078	-156	298
TR	582	582	024	068	169	136
AI	573	-020	-066	689	069	-055
RB	711	009	-051	057	-386	328
GS	669	-086	370	229	-269	-056
HF	645	036	-156	-020	-007	644

Factor Intercorrelations

	I	II	III	IV	V
I					
II	-619				
III	419	-395			
IV	175	-007	-034		
V	730	-429	542	179	

Note. Decimal points and diagonal omitted. H indicates higher-order factor and L indicates residualized lower-order factor. Roman numerals indicate first-order factors.

Tables 9 through 11 show the Schmid-Leiman residualized factor pattern matrices of the AFOQT subtests for 5, 6, and 7 factors using the principal factors method. Factor correlations are also shown.

TABLE 9. FACTOR LOADINGS OF THE SCHMID-LEIMAN RESIDUALIZED HIERARCHICAL 7 FACTOR PRINCIPAL FACTORS ANALYSIS

	Factor								
	H-1	H-2	L-1	L-2	L-3	L-4	L-5	L-6	L-7
VA	726	-060	025	-491	018	-044	096	-031	-026
AR	833	-248	254	-048	-002	-058	016	-003	-013
RC	716	000	037	-553	007	-010	-030	010	020
DI	789	-161	153	-097	039	-029	-021	014	104
WK	609	084	-012	-597	004	016	-028	021	020
MK	822	-309	039	-005	027	-392	-006	-006	031
MC	804	272	059	-050	011	-014	239	118	-024
EM	615	033	021	089	077	-056	180	031	072
SR	845	-218	124	009	036	-023	061	007	197
IC	717	335	-002	-010	490	-021	006	-007	-007
BC	791	-127	027	-060	051	009	240	-020	167
TR	631	-262	014	-026	004	-034	-001	-001	309
AI	590	469	022	-036	189	044	003	139	014
RB	723	022	024	-041	052	-047	298	003	003
GS	735	257	-007	-160	002	-153	043	142	-005
HF	619	-049	-005	-104	030	-029	158	004	114

Factor Intercorrelations

	I	II	III	IV	V	VI	VII
I							
II	-343						
III	520	-389					
IV	439	-527	327				
V	-756	408	-597	-430			
VI	409	-244	240	264	-524		
VII	-460	371	-296	-524	497	-465	

Note. Decimal points and diagonal omitted. H indicates higher-order factor and L indicates residualized lower-order factor. Roman numerals indicate first-order factors.

TABLE 10. FACTOR LOADINGS OF THE SCHMID-LEIMAN RESIDUALIZED HIERARCHICAL 6 FACTOR PRINCIPAL FACTORS ANALYSIS

	Factor						
	H-1	L-1	L-2	L-3	L-4	L-5	L-6
VA	742	025	473	024	-004	075	110
AR	818	006	057	-036	-001	396	006
RC	729	-024	534	-023	026	052	-031
DI	778	-136	102	-094	-002	233	-028
WK	627	-023	576	-027	040	-043	-032
MK	786	-045	007	072	133	292	055
MC	780	056	072	-163	129	050	216
EM	608	-106	-091	-077	084	041	199
SR	830	-266	003	-071	009	174	049
IC	709	-084	-019	-347	002	029	119
BC	790	-247	073	-027	004	005	241
TR	615	-388	032	-005	016	035	-013
AI	600	032	025	-565	024	-010	-036
RB	722	001	056	-049	025	058	328
GS	747	007	044	-021	473	005	-018
HF	618	-152	106	-022	037	-003	163

Factor Intercorrelations

	I	II	III	IV	V	VI
I						
II	-360					
III	361	-374				
IV	-302	581	-570			
V	-619	568	-376	553		
VI	-531	276	-462	456	518	

Note. Decimal points and diagonal omitted. H indicates higher-order factor and L indicates residualized lower-order factor. Roman numerals indicate first-order factors.

TABLE 11. FACTOR LOADINGS OF THE SCHMID-LEIMAN RESIDUALIZED HIERARCHICAL 5 FACTOR PRINCIPAL FACTORS ANALYSIS

	Factor						
	H-1	H-2	L-1	L-2	L-3	L-4	L-5
VA	733	-145	-009	-405	-044	-047	079
AR	798	055	000	-040	012	-323	-018
RC	741	-185	005	-486	021	-056	-020
DI	777	124	036	-079	078	-235	-014
WK	642	-235	003	-536	031	028	-008
MK	744	007	-027	-005	-046	-312	039
MC	733	-267	-054	-077	137	-031	202
EM	565	051	-003	075	063	-048	213
SR	819	294	063	006	058	-197	093
IC	697	-041	018	026	281	-022	131
BC	762	256	050	-061	-007	-006	286
TR	610	366	084	-035	016	-108	086
AI	612	-325	-004	-028	493	009	-020
RB	670	-022	-020	-031	007	-016	276
GS	672	-375	-066	-167	138	-096	057
HF	594	095	022	-096	009	-010	186

Factor Intercorrelations

	I	II	III	IV	V
I					
II	-012				
III	-030	-390			
IV	-185	614	-425		
V	189	-422	545	-729	

Note. Decimal points and diagonal omitted. H indicates higher-order factor and L indicates residualized lower-order factor. Roman numerals indicate first-order factors.

Using the rule of extracting as many factors as there are values in the eigenvector equal to or greater than one, the higher-order factor analyses solutions for both the principal components and principal factors yielded only one second-order factor in four of the six analyses. These factors were responsible for a majority of the factor variance. In each case these were the estimates of **g**. In the analyses where two higher-order factors were found (the 5 and 7 factor principal factors hierarchical solutions), the first factor was the estimate of **g**.

With the exception of the first unrotated principal component and first unrotated principal factor, none of the other unrotated components or unrotated factors was easily interpreted except when it seemed to primarily represent the uniqueness of a single subtest.

In general, quantitative, verbal, and special pilot knowledge factors were found in the residualized hierarchical factor analyses. The spatial-perceptual subtests failed to aggregate and they spread themselves out among the other factors. Regardless of the factor structure found, in all analyses the first factor showed positive loadings for all the subtests. These loadings were at least moderate and did not vary greatly indicating that each subtest contributes almost equally to the measurement of **g**.

Relationships among the Estimates of g

Table 12 shows the correlations of the estimates of **g** below the diagonal. Despite the measurement of space perception, the specialized flying information, the more varied topology and content than ASVAB, and the greater factorial richness, the positive manifold and the six added subtests (above the ten in ASVAB) placed the AFOQT squarely within the realm of the Wilks theorem and a narrow range of correlations of **g** was found.

The highest correlation (.999) was found for the estimates from the hierarchical analysis based on principal components with five factors versus six factors and six factors versus seven factors. The lowest correlation in the matrix was .980 between the **g** estimates based on the seven factor principal components hierarchical factor solution and the unrotated principal factors solution. The usual factor analytic solution for AFOQT (Skinner & Ree, 1987) is a five-factor principal factors analysis. The correlations of **g** estimated from the hierarchical solution of this five-factor analysis and the principal components and principal factors **g** were both .994--unity for practical purposes.

TABLE 12. INTERCORRELATIONS (BELOW THE DIAGONAL) AND COEFFICIENTS OF CONGRUENCE (ABOVE THE DIAGONAL) OF THE ESTIMATES OF G

	g Estimates							
	Pg	Fg	P7	P6	P5	F7	F6	F5
Pg		999	950	951	950	947	949	950
Fg	998		948	948	948	945	947	948
P7	987	980		999	999	999	999	999
P6	991	985	999		999	999	999	998
P5	989	983	998	999		999	999	998
F7	994	993	985	988	989		999	998
F6	996	994	987	991	991	994		999
F5	994	994	983	988	988	994	993	

Note. P indicates principal components hierarchical factor analysis and F indicates principal factors hierarchical factor analysis. The number indicates the number of factors in the lower-order factor analysis. For example F7 is a seven first-factor principal factors analysis. Pg and Fg are the unrotated first principal component and principal factor respectively. Decimal points and diagonal omitted.

While all the solutions did not yield exactly the same estimates, the magnitudes of the correlations (nearly 1.0) indicated that they would all rank individuals in almost the same order. Thus they could be used interchangeably in practice. This finding is consistent with those of Jensen (1987) and Ree and Earles (1991). It is also consistent with the Wilks (1938) theorem. Wilks proved that the correlation of two linear composites of variables will tend toward one under commonly found conditions. These conditions, all present in the estimation of **g**, are: (1) all variables are positively correlated, (2) all weights are positive, and (3) several variables are used. Under these conditions the Wilks theorem applies, and **g** may be found not only by unrotated principal components, unrotated principal factors, or hierarchical factor analysis, but also by any other reasonable set of positive weights. For instance, the average correlation of the unit weighted sum of the subtest standard scores and the other estimates of **g** was .993 and the average correlation of **g** estimated using the digits of our telephone number as weights (repeating the first six digits to provide 16 weights) and the estimates of **g** was .988.

The coefficients of congruence were also quite high with 13 of 28 at .999. Congruence of **g** estimates of both the principal components and principal factors analyses with those of the entire set of hierarchical analysis was relatively less high. The lowest value was .945 for the congruence of the first unrotated principal factor and the **g** estimate from the 7 factor hierarchical principal factors analysis.

The Pearson correlation of the coefficients of congruence and their analogous correlations (computed with a greater number of significant digits than in the table) was .15. The Spearman rank-order (Spearman's rho) correlation was .25 for the same data indicating some lack of linearity in the relationship. The coefficients of correlation and congruence were not strongly related in these data where more than half the coefficients of congruence were .999.

The Wilks (1938) theorem makes these results mandatory and generalizable to **g** estimates from any measures of human cognitive aptitude regardless of their surface content as long as the measures display positive manifold. The lower average subtest correlation (.45 for AFOQT versus .59 for ASVAB) and the additional different content areas of spatial perception and special pilot interest did not lead to any different conclusion about estimating psychometric **g** than previously found for the ASVAB, a test frequently noted as being mostly **g**. All commonly applied methods for estimating **g** arrived at the same solution and all subtests were shown to more-or-less equally contribute to **g**.

Because of these findings, it is reasonable to speculate that aptitude batteries which are supplemented by new paper-and-pencil or computer-based tests will not lose their important **g** component. The DOD aptitude measurement community is interested in the use of computer-based tests currently being investigated by the Uniformed Services' cognitive psychologists. Adding a set of new cognitive measures to the existing ASVAB or AFOQT will preserve a strong **g** measure, and likely a **g** which comes more-or-less equally from all subtests, old and new. Further, any of several methods will still estimate, up to scale, psychometric **g**.

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