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RESEARCH MEMORANDUM

A COMPARISON OF THREE PROCEDURES FOR OPERATIONAL CALIBRATION OF THE ASVAB

D. R. Divgi

A Division of CNA Hudson Institute

CENTER FOR NAVAL ANALYSES
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Scores on new forms of the Armed Services Vocational Aptitude Battery are equated to those on form 8a, using samples of about 2,500 recruits per form. Three equating procedures are compared in terms of how well their results are cross-validated in large applicant samples.

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1. Enclosure (1) is provided as a matter of possible interest.

2. New forms of the Armed Services Vocational Aptitude Battery undergo operational calibration, during which test scores of recruits are used to convert scores on new forms into equivalent scores on the reference form. Three test equating procedures are compared - linear, constrained cubic, and a procedure for choosing among polynomial equating functions. Results from recruit samples are compared with those of equipercentile equating in much larger applicant samples, and the equating method that yields the smallest difference between the equatings is considered to have performed the best. The constrained cubic method is found to work better than the others.

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ABSTRACT

Scores on new forms of the Armed Services Vocational Aptitude Battery are equated to those on form 8a, using samples of about 2,500 recruits per form. Three equating procedures are compared in terms of how well their results are cross-validated in large applicant samples. (FR)

EXECUTIVE SUMMARY

The Armed Services Vocational Aptitude Battery (ASVAB) is used for selection and classification of enlisted personnel. New forms of the ASVAB are developed about every four years, equated to the reference form 8a, and converted to standard scores. Their operational calibration (OPCAL) is based on samples of about 2,500 recruits per form. The ideal outcome is that, during operational use of the ASVAB in the Initial Operational Test and Evaluation (IOT&E), the distribution of standard scores is the same for all forms.

The basic equipercentile equating procedure suffers from large random errors, especially at low scores where data are scant in recruit samples. These can be reduced by fitting a polynomial to the equating function. Another alternative is linear equating, which provides a straight line based on means and standard deviations. The Air Force Human Resources Laboratory (AFHRL) has developed a procedure for choosing among linear equating and three smoothing functions. This procedure was used for the OPCAL of forms 15, 16, and 17, and will be called the OPCAL procedure.

Another procedure, developed later at CNA, is the constrained cubic (CC), in which the equating curve is a cubic function, constrained so that the minimum scores on the two forms are equated to each other, and so are the maximum scores. The purpose of this study is to compare how well the results of OPCAL, linear, and CC procedures perform in IOT&E samples.

DATA

Data used in this study were collected on recruit samples during the OPCAL and on applicant samples during the IOT&E of ASVAB forms 15, 16, and 17. They were provided to CNA by AFHRL. The sample sizes varied from 2,501 to 2,774 in the OPCAL and from 13,010 to 14,963 in the IOT&E. AFHRL also provided raw to standard score conversions based on the OPCAL.

METHODOLOGY

The equipercentile method was applied to the IOT&E samples. The resulting standard scores were used as the criterion. For a specific new form, say 15a, the difference between the criterion standard score and the value from OPCAL was squared, and averaged over all applicants in the IOT&E sample for Form 15a. The square root of this average is the root mean square difference (RMSD) between the OPCAL equating and the criterion. RMSD values for linear and CC equatings were computed the same way. For any given form of a subtest, a method with smaller RMSD was considered to have performed better than one with larger RMSD.

Another summary statistic was the average absolute difference (AAD). It was obtained by computing the mean of the absolute value of the difference. Again, a smaller AAD represents better performance.

RESULTS

With six new forms for each of 11 subtests, each equating method has 66 RMSD and 66 AAD values. The CC method worked better than the OPCAL method in 39 cases in terms of RMSD, and in 37 cases in terms of AAD. It was superior to linear equating in 45 cases in terms of RMSD and in 39 cases in terms of AAD. Thus, it turned out to be the best among the three methods.

It appears that the large amount of computation and personnel time required in the OPCAL procedure did not yield benefits commensurate with the effort. The results do not justify use of the CC procedure for all subtests and forms. However, they do suggest that constrained polynomials of degree higher than the cubic should be explored.

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INTRODUCTION

The Armed Services Vocational Aptitude Battery (ASVAB) is used for selection and classification of enlisted personnel. It contains ten subtests: General Science (GS), Arithmetic Reasoning (AR), Word Knowledge (WK), Paragraph Comprehension (PC), Numerical Operations (NO), Coding Speed (CS), Auto and Shop Information (AS), Mathematics Knowledge (MK), Mechanical Comprehension (MC), and Electronics Information (EI). The Verbal (VE) subtest is defined as the sum of WK and PC. Standard scores rather than raw scores on the subtests are used in all decisions based on the ASVAB. Standard scores are integers from 20 to 80, with mean 50 and standard deviation 10 in the 1980 reference population.

New forms of the ASVAB are developed about every four years, and equated to the reference form 8a. Their operational calibration (OPCAL) is based on samples of about 2,500 recruits per form. Raw scores on each new form of a subtest are converted into equivalent scores on form 8a. Then they are linearly transformed, using means and standard deviations in the 1980 reference population [1], and rounded to standard scores. The ideal outcome is that, during operational use of the ASVAB in the Initial Operational Test and Evaluation (IOT&E), the distribution of standard scores is the same for all forms.

During the IOT&E, each new form and form 8a are administered to at least 10,000 applicants to the military services. These samples are superior to OPCAL samples in three ways—they are larger, they represent the full range of ability among applicants, and there is no reason to doubt the examinees' motivation to perform well on the ASVAB.

The basic equipercentile equating procedure suffers from large random errors, especially at low scores where data are scant in recruit samples. Such errors can be reduced by fitting a polynomial to the equating function. Another alternative is linear equating, which provides a straight line based on means and standard deviations. The Air Force Human Resources Laboratory (AFHRL) has developed a procedure for choosing among linear equating and three smoothing functions. This procedure was used for the OPCAL of forms 15, 16, and 17, and will be called the OPCAL procedure. It involves equipercentile and linear equating; three polynomial fits to the equipercentile by least squares; calculating indices to summarize differences among equipercentile equating and the others; and selection of an equating procedure on the basis of these indices [2].

Another procedure, developed later at CNA, is the constrained cubic (CC) method in which the equating curve is a cubic function, constrained so that the minimum scores on the two forms are equated to each other, and so are the maximum scores. With these constraints, the cubic is determined by means and variances of the two forms [3]. The purpose of this study is to compare how well the results of OPCAL, linear, and CC procedures applied to OPCAL data perform in IOT&E samples.

DATA

Data used in this study were collected on recruit samples during the OPCAL and on applicant samples during the IOT&E of ASVAB forms 15, 16, and 17. They were provided to CNA by AFHRL, after some editing to remove errors such as incorrectly coded form numbers. Because of an error in one item, MK form 15b data collected in November 1987 were discarded. Apart from this, the sample size was the same for all subtests in a given form. The sample sizes varied from 2,501 to 2,774 in the OPCAL and from 13,010 to 14,963 in the IOT&E. AFHRL also provided raw to standard score conversions based on the OPCAL.

METHODOLOGY

The equipercentile method, with five-point rolling average smoothing of score frequencies, was applied to the IOT&E samples. Standard scores obtained from this equating were used as the criterion. Denote them by SS_i. Let SS_0 be standard scores obtained from OPCAL data with the OPCAL procedure. For a specific new form, say 15a, the difference (SS_0-SS_i) at each raw score was squared, and averaged over all possible scores, without attaching any weights to the scores. The square root of this average is the root mean square difference (RMSD) between the OPCAL equating and the criterion. RMSD for the other two procedures was computed the same way. For any given form of a subtest, a method with smaller RMSD was considered to have performed better than one with larger RMSD.

When squared difference is averaged without weighting raw scores, it implies that an error is equally serious whether it occurs at a raw score obtained by many examinees or at a score obtained by very few. One can argue that an error that affects more people should be considered more serious. Therefore, RMSD was also computed with each raw score weighted by its frequency in the IOT&E sample. (This weighted RMSD is similar in spirit but not in detail to the statistic used by Kolen [4].)

Another summary statistic is the average absolute difference (AAD). It is obtained by computing the mean of the absolute value of the difference. Again, a smaller AAD represents better performance. As with RMSD, both unweighted and weighted averages were computed.

RESULTS

Table 1 presents the 66 unweighted RMSD values for all forms of all subtests. They show that the CC method worked better than the OPCAL method in 41 cases, and better than the linear method in 50. Table 2 presents the unweighted AAD values. Again, the superiority of the CC method is evident; its AAD is smaller than those of OPCAL in 42 cases and smaller than linear equatings in 48 cases.

Tables 3 and 4 present weighted RMSD and AAD values, respectively. The CC method is superior to the OPCAL method in 39 cases in terms of RMSD and in 37 cases in terms of AAD.

Table 1. Unweighted root mean square change in standard score from OPCAL to IOT&E

Subtest	Equating procedure	Form					
		15a	15b	16a	16b	17a	17b
GS	OPCAL	0.588	0.620	0.734	0.679	1.240	1.109
	Linear	0.588	0.620	0.734	0.679	1.240	0.899
	Cubic	0.707	0.555	0.480	0.439	0.961	0.734
AR	OPCAL	0.696	0.762	0.648	0.842	0.803	0.475
	Linear	0.696	0.762	1.150	0.842	0.803	1.150
	Cubic	0.539	0.648	0.672	0.568	0.568	0.861
WK	OPCAL	1.236	0.972	0.866	1.093	1.374	1.054
	Linear	1.236	0.972	0.866	1.093	0.782	1.054
	Cubic	1.054	0.898	0.816	0.667	0.745	0.913
PC	OPCAL	0.661	0.829	1.820	0.559	1.581	0.661
	Linear	1.173	1.346	2.549	0.433	1.581	0.935
	Cubic	1.299	1.146	0.866	1.479	0.559	0.829
NO	OPCAL	0.754	0.686	1.566	1.048	0.990	0.443
	Linear	0.754	0.686	1.129	0.542	0.990	0.420
	Cubic	0.505	0.886	0.594	0.505	0.754	0.443
CS	OPCAL	7.500	7.731	7.716	7.407	7.153	7.716
	Linear	7.500	7.731	7.716	7.501	7.195	7.716
	Cubic	7.507	7.738	7.715	7.509	7.181	7.719
AS	OPCAL	1.240	1.519	0.620	0.760	1.092	1.581
	Linear	1.240	1.519	1.387	1.240	0.707	1.581
	Cubic	0.707	0.877	0.620	0.734	0.588	1.056
MK	OPCAL	0.855	0.784	0.679	0.588	0.620	0.620
	Linear	0.920	0.734	0.679	0.588	0.620	0.620
	Cubic	0.707	0.620	0.620	0.480	0.620	0.588
MC	OPCAL	1.271	1.494	1.330	0.784	1.829	0.832
	Linear	1.271	1.494	1.330	1.387	1.829	1.732
	Cubic	0.877	1.056	0.734	0.809	0.981	0.981
EI	OPCAL	1.134	1.069	0.724	0.535	1.175	0.816
	Linear	1.647	1.327	0.873	0.577	1.175	1.069
	Cubic	1.527	1.272	1.069	0.926	1.091	1.069
VE	OPCAL	0.990	2.105	1.221	0.741	1.597	0.700
	Linear	0.990	0.918	1.421	0.741	0.767	0.700
	Cubic	0.767	1.094	0.686	1.010	0.714	1.343

Table 2. Unweighted average absolute change in standard score from OPCAL to IOT&E

Subtest	Equating procedure	Form 15a	15b	16a	16b	17a	17b
GS	OPCAL	0.346	0.308	0.385	0.385	0.923	0.769
	Linear	0.346	0.308	0.385	0.385	0.923	0.731
	Cubic	0.500	0.231	0.231	0.192	0.692	0.538
AR	OPCAL	0.419	0.452	0.290	0.452	0.516	0.226
	Linear	0.419	0.452	0.742	0.452	0.516	0.742
	Cubic	0.290	0.419	0.452	0.194	0.323	0.548
WK	OPCAL	0.917	0.667	0.639	0.861	0.944	0.778
	Linear	0.917	0.667	0.639	0.861	0.500	0.778
	Cubic	0.722	0.639	0.556	0.444	0.500	0.722
PC	OPCAL	0.438	0.563	1.438	0.313	1.000	0.313
	Linear	0.875	1.063	1.875	0.188	1.000	0.625
	Cubic	1.188	0.813	0.625	1.188	0.313	0.563
NO	OPCAL	0.451	0.431	1.000	0.824	0.588	0.196
	Linear	0.451	0.431	0.804	0.294	0.588	0.176
	Cubic	0.255	0.588	0.353	0.255	0.490	0.196
CS	OPCAL	1.047	1.306	1.071	1.212	1.447	1.071
	Linear	1.047	1.306	1.071	1.071	1.153	1.071
	Cubic	1.129	1.353	1.035	1.165	1.094	1.118
AS	OPCAL	0.923	1.000	0.308	0.346	0.654	0.885
	Linear	0.923	1.000	0.615	0.615	0.423	0.885
	Cubic	0.500	0.538	0.385	0.462	0.346	0.654
MK	OPCAL	0.577	0.538	0.462	0.346	0.385	0.385
	Linear	0.538	0.538	0.462	0.346	0.385	0.385
	Cubic	0.500	0.385	0.385	0.231	0.385	0.346
MC	OPCAL	1.000	1.000	0.923	0.615	1.192	0.462
	Linear	1.000	1.000	0.923	1.077	1.192	1.154
	Cubic	0.692	0.808	0.538	0.654	0.731	0.731
EI	OPCAL	0.810	0.857	0.524	0.286	0.905	0.571
	Linear	1.286	0.905	0.667	0.333	0.905	0.857
	Cubic	1.190	0.857	0.857	0.667	0.810	0.857
VE	OPCAL	0.745	1.490	0.941	0.510	1.098	0.490
	Linear	0.745	0.686	1.118	0.510	0.510	0.490
	Cubic	0.549	0.725	0.471	0.863	0.510	1.020

Table 3. Weighted root mean square change in standard score from OPCAL to IOT&E

Subtest	Equating procedure	Form 15a	15b	16a	16b	17a	17b
GS	OPCAL	0.483	0.353	0.541	0.560	0.978	0.721
	Linear	0.483	0.353	0.541	0.560	0.978	0.778
	Cubic	0.656	0.221	0.490	0.423	0.920	0.618
AR	OPCAL	0.561	0.567	0.375	0.490	0.586	0.510
	Linear	0.561	0.567	0.691	0.490	0.586	0.672
	Cubic	0.527	0.638	0.615	0.246	0.507	0.595
WK	OPCAL	1.056	0.980	0.863	0.915	0.800	1.145
	Linear	1.056	0.980	0.863	0.915	0.657	1.145
	Cubic	0.916	0.858	0.862	0.781	0.618	0.859
PC	OPCAL	0.654	0.679	1.076	0.430	0.717	0.536
	Linear	0.841	0.898	1.366	0.121	0.717	0.612
	Cubic	1.056	0.726	0.703	0.958	0.591	0.616
NO	OPCAL	0.454	0.532	0.685	0.654	0.356	0.440
	Linear	0.454	0.532	0.722	0.585	0.356	0.436
	Cubic	0.539	0.599	0.665	0.581	0.412	0.421
CS	OPCAL	4.702	4.888	4.845	4.326	5.167	5.225
	Linear	4.702	4.888	4.845	4.376	5.240	5.225
	Cubic	4.701	4.886	4.844	4.378	5.238	5.225
AS	OPCAL	0.844	0.881	0.497	0.534	0.619	0.582
	Linear	0.844	0.881	0.465	0.595	0.592	0.582
	Cubic	0.709	0.674	0.510	0.569	0.616	0.618
MK	OPCAL	0.831	0.814	0.678	0.518	0.600	0.644
	Linear	0.826	0.754	0.678	0.546	0.600	0.644
	Cubic	0.696	0.696	0.562	0.328	0.630	0.610
MC	OPCAL	0.897	0.778	0.790	0.782	0.821	0.578
	Linear	0.897	0.778	0.790	0.890	0.821	0.841
	Cubic	0.855	0.766	0.682	0.771	0.732	0.684
EI	OPCAL	0.794	0.868	0.599	0.411	0.767	0.732
	Linear	1.085	0.905	0.648	0.376	0.767	0.851
	Cubic	1.084	0.904	0.833	0.618	0.848	0.931
VE	OPCAL	0.859	0.937	0.928	0.744	0.810	0.805
	Linear	0.859	0.951	0.997	0.744	0.677	0.805
	Cubic	0.750	0.705	0.731	0.943	0.736	0.879

Table 4. Weighted average absolute change in standard score from OPCAL to IOT&E

Subtest	Equating procedure	Form 15a	15b	16a	16b	17a	17b
GS	OPCAL	0.234	0.124	0.292	0.281	0.690	0.517
	Linear	0.234	0.124	0.292	0.281	0.690	0.553
	Cubic	0.431	0.048	0.240	0.179	0.653	0.382
AR	OPCAL	0.315	0.322	0.141	0.239	0.334	0.260
	Linear	0.315	0.322	0.419	0.239	0.334	0.423
	Cubic	0.277	0.407	0.378	0.060	0.257	0.351
WK	OPCAL	0.689	0.740	0.636	0.733	0.540	0.933
	Linear	0.689	0.740	0.636	0.733	0.432	0.933
	Cubic	0.564	0.661	0.634	0.610	0.382	0.647
PC	OPCAL	0.427	0.395	0.691	0.185	0.282	0.283
	Linear	0.649	0.624	0.754	0.015	0.282	0.363
	Cubic	1.039	0.455	0.473	0.694	0.349	0.364
NO	OPCAL	0.205	0.282	0.455	0.418	0.116	0.194
	Linear	0.205	0.282	0.490	0.342	0.116	0.190
	Cubic	0.290	0.346	0.442	0.337	0.169	0.177
CS	OPCAL	0.473	0.769	0.512	0.585	0.620	0.556
	Linear	0.473	0.769	0.512	0.483	0.582	0.556
	Cubic	0.462	0.749	0.500	0.491	0.567	0.560
AS	OPCAL	0.616	0.624	0.246	0.281	0.371	0.300
	Linear	0.616	0.624	0.189	0.298	0.349	0.300
	Cubic	0.502	0.453	0.260	0.321	0.379	0.375
MK	OPCAL	0.553	0.579	0.460	0.268	0.360	0.414
	Linear	0.442	0.568	0.460	0.298	0.360	0.414
	Cubic	0.485	0.485	0.316	0.108	0.397	0.373
MC	OPCAL	0.761	0.541	0.550	0.612	0.518	0.330
	Linear	0.761	0.541	0.550	0.721	0.518	0.571
	Cubic	0.727	0.572	0.465	0.594	0.526	0.460
EI	OPCAL	0.492	0.691	0.359	0.169	0.543	0.534
	Linear	0.804	0.589	0.417	0.142	0.543	0.681
	Cubic	0.832	0.588	0.571	0.340	0.564	0.724
VE	OPCAL	0.570	0.639	0.700	0.554	0.460	0.647
	Linear	0.570	0.756	0.745	0.554	0.401	0.647
	Cubic	0.562	0.495	0.535	0.860	0.541	0.721

CONCLUSIONS

To interpret these results, one must keep in mind the differences between the CC and OPCAL methods. The CC method uses only the means and standard deviations of the two forms being equated; once these four numbers are available, it is completely automatic. The OPCAL method, in contrast, requires extensive computation and subjective judgment. Linear and equipercentile equatings are performed, the latter smoothed three ways, and several deviation measures calculated to quantify the differences among these equating functions. Since there are no statistical criteria for choosing among the functions, a stepwise judgmental procedure is used [2]. (The subjectivity of the procedure is shown by the fact that different functional forms were used for GS forms 17a and 17b, even though they contain the same items in slightly different orders.) It appears that the large amount of computation and man hours required by the OPCAL method did not provide benefits commensurate with the effort.

Although the CC method worked better than the OPCAL procedure for forms 15, 16, and 17, it is too simple to be used with all subtests and forms. It differs from linear equating only in the constraints added at minimum and maximum scores. The improvement due to this modification suggests that similarly constrained polynomials of higher degree are likely to provide a satisfactory equating procedure.

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1. The number in parentheses is a CNA internal control number.