Technical Report 1053

ASVAB Correlations Are Lower for Higher Aptitude Groups

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14. ABSTRACT *(Maximum 200 words)*:

Previous research demonstrates that correlations among IQ tests are lower when estimated using higher scoring individuals (Detterman & Daniel, 1989; Lynn, 1990). However, this phenomenon has only been documented using individually administered measures of intelligence, and attempts to extend the demonstration to other specialized aptitudes have failed (Detterman, 1993). The present study divides the 1980 Armed Services Vocational Aptitude Battery (ASVAB) weighted norming sample into five aptitude levels with similar levels of variance. Analyses show that the ASVAB tests are less correlated within higher aptitude groups provided that the scales used to define the groups are psychometrically sound: for three highly skewed ASVAB tests, a ceiling effect prevents this phenomenon; for the remaining seven tests the phenomenon replicates; and the magnitude of the effect is proportional to the skewness of the scale, $r = .85$. These findings support the assertion that cognitive aptitudes are less correlated in higher aptitude groups, imply that greater classification effects can be associated with higher scoring groups, and qualify the use of the multivariate correction for restriction of range.

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FOREWORD

Since 1976, the Armed Services Vocational Aptitude Battery has been used by the military to ensure that the abilities of individuals are effectively utilized and the military is staffed and led by highly competent soldiers. During this same time period, the military has steadily evolved toward a smaller and more technically based force with a concomitant increase in the requirement for higher quality soldiers who must be effectively utilized to maintain force readiness. This report describes a segment of a continuing effort to monitor, refine, and improve the personnel selection and classification system used by the Army and the other military services.

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ASVAB CORRELATIONS ARE LOWER FOR HIGHER APTITUDE GROUPS

EXECUTIVE SUMMARY

Research Requirement:

Previous research demonstrates that correlations among cognitive tests are lower when estimated using higher scoring groups (Detterman & Daniel, 1989; Lynn, 1990). However, this phenomenon has only been documented using individually administered measures of intelligence, and attempts to extend the demonstration to other cognitive aptitudes have failed (Detterman, 1993). The existence of a similar phenomenon within the Armed Services Vocational Aptitude Battery (ASVAB) carries implications for: (1) the identification of new testing domains because the effectiveness of job classification is dependent on the correlational structure of the job classification battery (cf. Brogden, 1959); (2) the use of the multivariate correction for restriction of range, which is used to estimate population correlations based on estimates computed using restricted samples; and (3) the factoring of correlational matrices computed using high-aptitude individuals.

Procedure:

The present study uses each of the 10 ASVAB tests to divide the 1980 ASVAB weighted norming sample into five subsamples varying in aptitude level, thereby producing 10 sets of five correlation matrices. Each set of matrices is analyzed for evidence of a change in correlational structure over aptitude level. In addition, the role of the content domain and the psychometric quality of the scale used to define each set of subsamples is analyzed as to account for the presence or absence of the effect.

Findings:

Analyses show that ASVAB tests are less correlated within higher aptitude groups provided that the scales used to define the groups are psychometrically sound: for three highly skewed ASVAB tests, a ceiling effect prevents this phenomenon; for the remaining seven tests the phenomenon replicates. The magnitude of the effect is proportional to the skewness of the scale, $r = .85$.

Utilization of Findings:

These findings support the assertion that cognitive aptitudes are less correlated in higher aptitude groups, imply that greater classification effects can be associated with higher aptitude groups, and qualify the use of the multivariate correction for restriction of range.

ASVAB CORRELATIONS ARE LOWER FOR HIGHER APTITUDE GROUPS

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Introduction

Positive manifold refers to the well-replicated finding that cognitive tests usually correlate, and frequently at a substantial level, in the general population. The factoring of these correlations results in psychometric *g*. Although not often stated, it is often assumed that positive manifold is constant across aptitude level. Thus if two scales correlate in a high aptitude group characterized by restricted range, i.e., limited variance, then it is usually expected that the scales will correlate at approximately the same level in similarly restricted but lower aptitude groups.

The validity of the assumption of constant positive manifold carries implications for using the multivariate correction for restriction of range (Lawley, 1943) to estimate population parameters with a correlation matrix computed on a restricted sample as input (cf. Silva & White, 1994; McHenry, Hough, Toquam, Hanson, & Ashworth, 1990; Ree, Earles, & Teachout, 1994; Legree, 1996). If the assumption is invalid, then the multivariate correction would lead to questionable results. It would be more problematic if some correlations increase while other correlations decrease over aptitude level and less problematic if the assumption was violated by a steady monotonic change in the magnitude of the correlations, i.e., if all scales were less correlated in higher aptitude populations. The first possibility would result in the multivariate correction distorting correlation matrices, while the second possibility would be similar to greater range restriction and would allow a higher level of confidence in the multivariate correction.

Despite the importance of this assumption, little research has addressed its validity for cognitive test batteries. In particular the Armed Services Vocational Aptitude Battery (ASVAB), which is used to select and classify military enlistees, has never been analyzed to validate this assumption.

More than 60 years ago Spearman (1927) published data indicating that positive manifold decreases in more intelligent groups. This decrease in positive manifold was subsequently ignored until Detterman and Daniel (1989) demonstrated the effect using the standardization samples for the Wechsler Intelligence Scale for Children - Revised and the Wechsler Adult Intelligence Scale - Revised. Detterman and Daniel divided the standardization samples into five groups ranging in mean test score from low to high and computed correlation matrices for each of the five groups. Their analyses demonstrate a decrease in the mean correlation among the tests over ability level, i.e., from the highest to the lowest scoring subsamples. In other words, positive manifold is lower in higher ability samples. This decrease has since been replicated using Wechsler Scales and the standardization samples corresponding to Scotland (Lynn, 1990), France (Lynn & Cooper, 1993), and Japan (Lynn & Cooper, 1994). The effect has also been extended to a non-Wechsler scale by Detterman (1993) using the standardization sample of the Kaufman ABC scale.

Although this phenomenon has been demonstrated using individually administered measures of intelligence, it has not been replicated with achievement batteries (Fogarty & Stankov, 1995; Detterman, 1993). Achievement tests do not exhibit a consistent pattern of correlations when the standardization sample is divided into performance levels; instead the mean correlations among achievement tests increase and decrease unpredictably (D.K. Detterman, personal communication, December 4, 1995). One explanation for the failure to replicate is that the effect is difficult to demonstrate and requires psychometrically sophisticated measures, such as the Wechsler scales; a second explanation is that the effect is localized to the abilities measured by Wechsler and Kaufman Intelligence scales and cannot be demonstrated with other aptitude scales.

The ASVAB is sometimes regarded as a measure of intelligence because of its factor structure; therefore, one might expect ASVAB correlations to be lower for higher scoring groups in a manner similar to that observed in analyses of the Wechsler standardization samples. It is somewhat fortuitous that improving the psychometric properties of the ASVAB has been an important priority because of substantial limitations in the procedures originally used to develop and norm the ASVAB (Maier, 1993). Thus analyses of the ASVAB weighted norming sample allow exploration of the possibility that the magnitude of the effect is a function of the psychometric quality of the battery.

On the other hand, the ASVAB was developed as a job classification battery and also assesses diverse content domains that liken it to an achievement battery. If content domain acts as an important moderator, then the decreasing positive manifold effect would not occur among the ASVAB scales. With these considerations in mind, we utilized and modified the Detterman and Daniel procedure (1989) to analyze the ASVAB 1980 weighted norming sample and determine if the mean correlation among ASVAB tests decreases for higher aptitude groups.

Method

Subjects

Subjects were 9,173 non-institutionalized youths, 18 to 23 years old, in the normative sample of the ASVAB. The data were collected in 1980 and are weighted to reflect the reference population demographics of the United States according to the 1980 census (Frankel, McWilliams & Spencer, 1983).

Procedure

The ASVAB tests are multiple choice scales and the battery requires approximately three and one-half hours to administer. The ASVAB consists of 10 tests named for their content domains: Numerical Operations (NO), Coding Speed (CS), General Science (GS), Arithmetic Reasoning (AR), Word Knowledge (WK), Paragraph Comprehension (PC), Auto and Shop Information (AS), Mathematics Knowledge (MK), Mechanical Comprehension (MC), and Electronics Information (EI). All ASVAB scales are power tests except CS and NO, which adopt a speeded format.

Results

Overview of the Statistical Analyses

It may be best to describe the statistical procedure we used by first summarizing the one adopted by Detterman and Daniel (1989). They divided the Wechsler standardization samples into five groups of equal range and similar variance on the basis of performance on one of the tests. Then correlation matrices for the remaining scales were calculated for each of the five subsamples. These correlations were corrected for restriction of range using the bivariate restriction of range formulas (Ree, Carretta, Earles & Albert, 1994) and corresponding values were compared across the five matrices to identify significant decreases or increases via the Fisher-Z statistic. A chi-square statistic compared the number of significant differences to the number expected by chance.

It was not possible to follow the procedure used by Detterman and Daniel for defining five aptitude groups because the ASVAB scores are not uniformly distributed. This lack of uniform distribution is apparent in Table 1, which contains range and skewness estimates for each of the 10 ASVAB tests. Although each test has a mean score of 50 and a standard deviation of 10, the maximum scores for the different ASVAB tests range from 61 to 72, which corresponds to +1.1 to +2.2 standard deviation units (SDU) above the mean, while the minimum scores range from 20 to 29, which corresponds to -3.0 to -2.1 SDU below the mean.

Table 1.

Subtest Characteristics

Subtest	Mean	SD	Skewness	Minimum	Maximum
NO	50.04	9.98	-.79	20	62
CS	49.98	10.01	-.39	22	72
GS	49.90	10.01	-.32	20	68
AR	49.96	10.01	-.01	26	66
WK	49.98	9.96	-1.00	20	61
PC	50.04	10.04	-1.01	20	62
AS	49.97	10.00	.07	24	69
MK	50.01	9.99	.22	29	68
MC	50.00	10.04	.07	24	70
EI	49.97	10.00	-.17	23	70

For this project, one ASVAB test was used to define five subsamples with similar variance on that scale. This was accomplished by identifying four points that would divide the weighted population into five subsamples, each with a similar level of variance. This process was repeated using each of the ten ASVAB tests as the selection instrument, thereby creating 10 sets of 5 correlation matrices.

Within each set of 5 matrices, correlations computed using lower aptitude groups were compared to values associated with higher aptitude groups to: (1) determine if these values differed significantly, and (2) estimate the magnitude of the difference. In addition, the correlations were corrected using the bivariate corrections for restriction of range (Ree, Carretta, Earles & Albert, 1994) to estimate the parameters that would be calculated had the variance of the variables corresponded to those defined for the population. These comparisons were repeated for each of the 10 sets of matrices.

Factor analytic procedures were also used to analyze changes in the correlational structure of the matrices. Using the procedure described in Joreskog and Sorbom (1993), we submitted 5 of the 10 sets of matrices to LISREL to test the equality of the factor structure over the five aptitude levels.

Seven Replications of Decreasing Correlations

The decreasing positive manifold effect was replicated across sub-populations defined by 7 of the 10 ASVAB scales. The 7 scales assess the following domains and have been interpreted as loading primarily on the indicated factor (Kass, Mitchell, Grafton & Wing, 1983): General Science - Verbal Factor; Arithmetic Reasoning and Mathematics Knowledge - Quantitative Factor; Auto and Shop Information, Mechanical Comprehension, and Electronics Information - Technical Factor; Coding Speed - Speed Factor. Figure 1 graphs mean subsample correlations, which were computed using Fisher Z transformations, against aptitude level, and Figure 2 graphs mean corrected correlation against aptitude level.

The Chi-square statistics demonstrate that the decreasing positive manifold trends are statistically significant for these 7 replications; the Chi-square statistics range from ($\chi^2(2)=2789.6$, $p<.0001$) to ($\chi^2(2)=6210.5$, $p<.0001$). Figure 2 also indicates that for four of the seven scales the trend of decreasing correlations reverses in comparisons of the highest and second-highest groups, i.e., the mean corrected correlation of the highest aptitude group is slightly greater than that of the second-highest group.

Three Non-Replications of Decreasing Correlations

A much different pattern of correlations was obtained using the remaining three ASVAB tests to define groups: Numerical Operations - Speed factor; and Paragraph Comprehension and Word Knowledge - Verbal factor. Although the Chi-square statistics for these analyses demonstrate that the correlations are not constant over aptitude level and range from ($\chi^2(2)=2092.7$, $p<.0001$) to ($\chi^2(2)=2996.5$, $p<.0001$), the mean correlation values did not evidence a steady increasing or decreasing pattern. Instead the correlations follow a sporadic pattern, as shown in Figures 3 and 4.

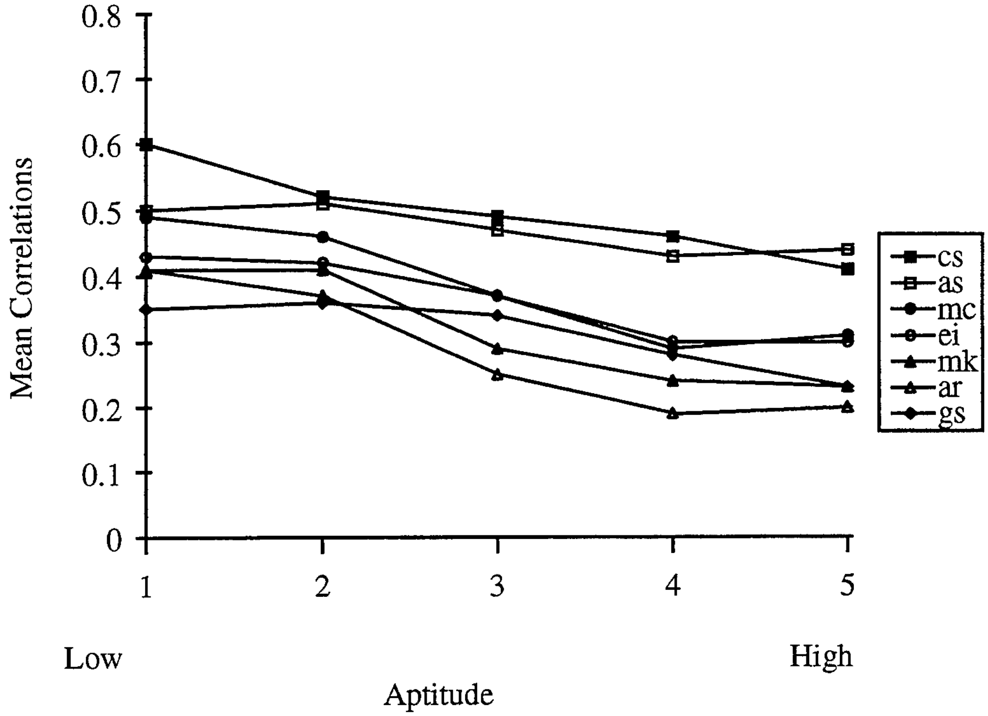

Figure 1. Mean Correlations by Aptitude for the Psychometrically Stronger Scales

<u>Intervening Variables</u>

A partial replication, i.e., demonstrating the effect for groups defined using seven of the ten ASVAB tests, was unexpected and difficult to explain as a function of content domain. Therefore, two indices of psychometric quality, skewness and kurtosis, were analyzed to determine if the absence or presence of the effect could be associated with the quality of the scale used to identify groups. Skewness and kurtosis estimates are reported in Table 1 and the comparisons suggest that: (1) the presence or absence of the effect (Figures 1 and 2 versus Figures 3 and 4) is associated with the skewness of the scales used to define the groups, and (2) the presence of highest versus second-highest reversals, "fish hooks", is associated with the kurtosis of the scales (Figure 2).

To test the presence of the skewness effect, we calculated the slopes of the ten regression lines presented in Figures 1 and 3. The slopes were correlated with the skewness and kurtosis estimates corresponding to the scales used to define the groups to determine if a relationship exists between the size of the effect and the psychometric quality of the subtest. All three correlations were significant: $r_{skew,b}$=-.85 (p<.001), $r_{skew,kurtosis}$=-.95 (p<.001), $r_{kurtosis,b}$=.73 (p<.01). To estimate the independent effect of skewness and kurtosis on the magnitude of the effect, i.e., slope, kurtosis and skewness were partialled: $r_{b,skew.kurtosis}$=-.73 (p<.05), and $r_{b,kurtosis.skew}$=.32 (ns).

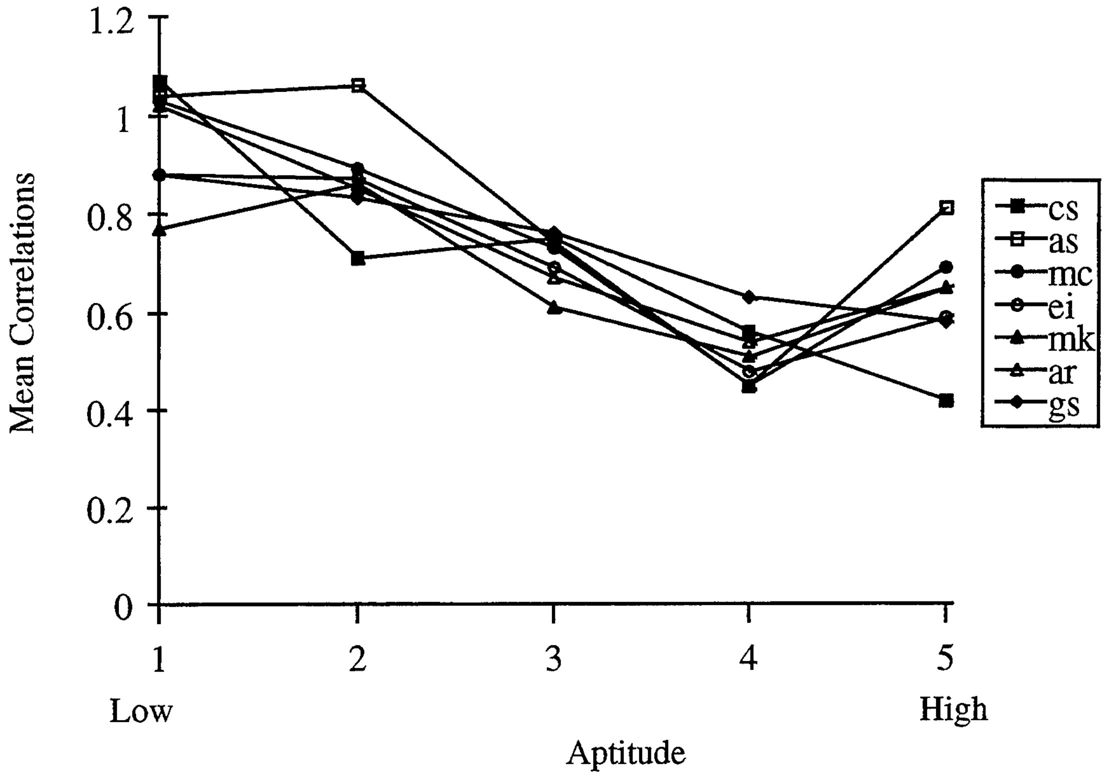

Figure 2. Mean Corrected Correlations for the Psychometrically Stronger Scales

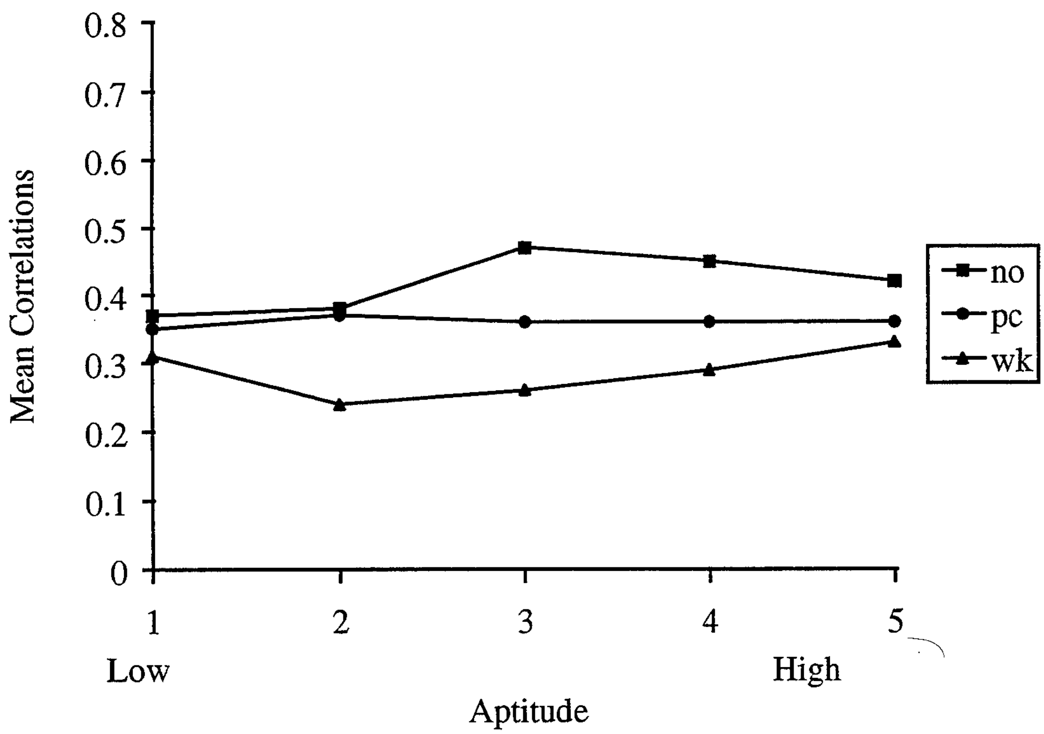

Figure 3. Mean Correlations by Aptitude for the Three Psychometrically Weaker Scales

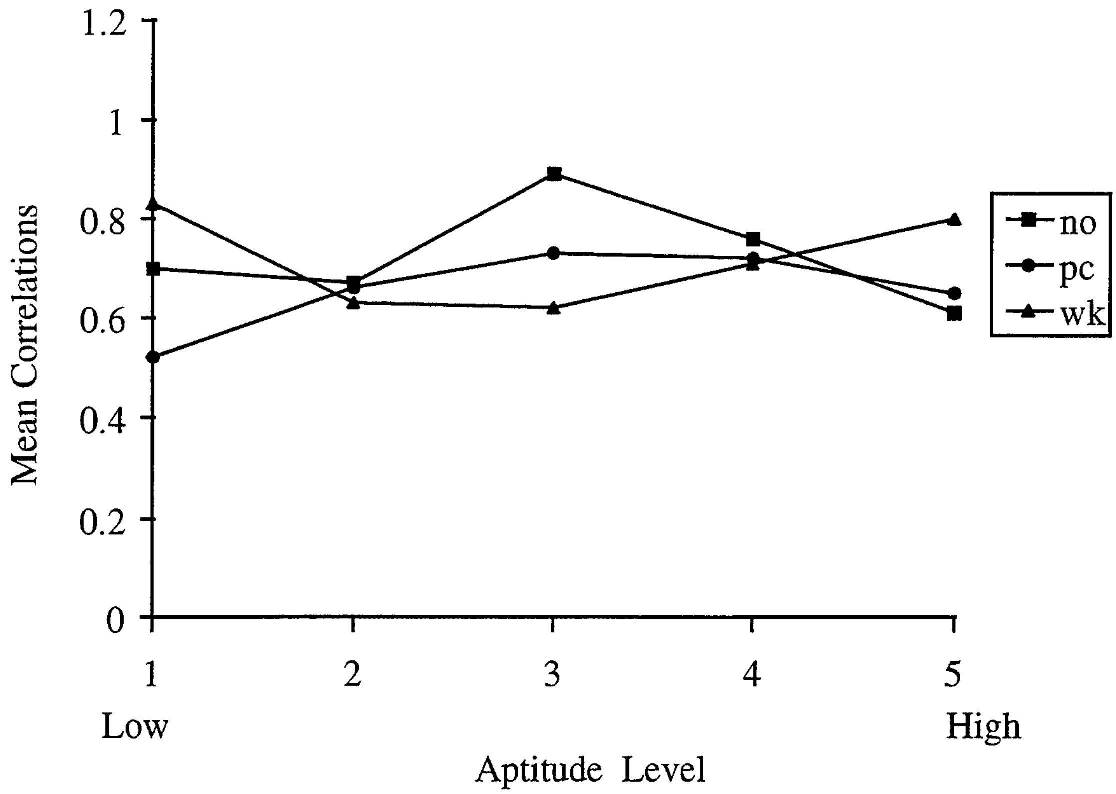

Figure 4. Mean Corrected Correlations for the Psychometrically Weaker Scales

Factor Analyses

Five of the seven sets of correlation matrices were analyzed to determine if the factor structure of the ASVAB varies over aptitude level. All of the LISREL analyses produced similar results and indicate that the factor structure of the ASVAB is not constant over the five aptitude levels. The Arithmetic Reasoning (AR) based analyses are presented because the response distribution for this scale evidenced very little skewness, -.01 (Refer to Table 1.)

The most restrictive model, A, adopted a four factor solution with fixed error variances, factor loadings and factor covariances. In Model B the fit was improved by freeing the error variances. The fit was further improved in Model C by freeing the error variances and the factor loadings. The best fit was obtained for Model D by freeing the error variances, the factor loadings, and the factor covariance matrix. Although no model could be associated with a non-significant Chi-square, other indices of fit indicate substantial improvements as the additional constraints were freed (Refer to Table 2). The analyses for Model D also suggest that the first-order factors were less correlated within the higher aptitude groups (Refer to Table 3).

Table 2.

Summary Statistics for the Confirmatory Factor Analyses

Model	Chi Square Statistics Value	DF	p	Goodness of Fit Index	Root Mean Square Res
A	2602	244	.0001	.92	.12
B	1856	204	.0001	.95	.13
C	1633	150	.0001	.96	.11
D	667	126	.0001	.99	.026

Table 3.

Factor Correlation Matrices for Model D

Sub-Population		Verbal	Quantitative	Technical	Speed
1 (Low)	Verb	1.00	.68	.72	.74
	Quan		1.00	.58	.62
	Tech			1.00	.44
2	Verb	1.00	.73	.52	.59
	Quan		1.00	.73	.58
	Tech			1.00	.14
3	Verb	1.00	.59	.24	.33
	Quan		1.00	.39	.47
	Tech			1.00	-.20
4	Verb	1.00	.75	.01	.34
	Quan		1.00	-.12	.47
	Tech			1.00	-.36
5 (High)	Verb	1.00	.68	.03	.17
	Quan		1.00	.02	.37
	Tech			1.00	-.26

Discussion

Cognitive Aptitudes Correlations Are Lower

These data support the conclusion that cognitive aptitudes are less correlated within higher aptitude groups. This is an important demonstration because the earlier analyses (Detterman & Daniel, 1989; Lynn, 1990; Lynn & Cooper, 1993; Lynn & Cooper, 1994) only utilized Wechsler and Kaufman Intelligence scales that: (1) were developed to measure intelligence, (2) are individually administered, and (3) are primarily utilized to quantify individual differences among less intelligent groups. Because of these similarities, the earlier analyses cannot adequately address the possibility that the decreasing positive manifold effect may represent a measurement artifact and be specific to those intelligence scales.

The ASVAB data demonstrated the decreasing positive manifold effect using a test battery that: (1) is group administered, (2) is designed to assess a broad range of aptitudes, and (3) was intended to measure individual differences across a wide range of human aptitudes for the purpose of job classification. The fact that the effect could be demonstrated using scales that assess knowledge domains not traditionally measured by intelligence scales extends the generality of the phenomenon and increases confidence in the conclusion that cognitive aptitudes are less correlated among more intelligent individuals who perform better on cognitive tests.

The most likely explanation for the fact that the correlations did not decrease across groups defined using the three psychometrically problematic scales is that those scales lack the power required to identify groups of subjects with similar levels of measurement error. Although the procedure used to identify sub-populations guarantees that the five groups will be of similar variance, the procedure can not ensure a similar level of measurement error across the groups. Unequal measurement error would result in some groups being more heterogeneous than is indicated by the observed variance estimates; this heterogeneity would increase the magnitude of the correlation estimates for the affected groups and would result in an unpredictable pattern of correlations over aptitude level. A similar phenomenon may explain the presence of the fish hooks in Figure 2.

Because error estimates cannot be calculated for the groups, it is not possible to directly address the impact and possibility of differential measurement error. However, measurement error cannot be constant over aptitude because the highly skewed scales have very few difficult items. Figure 5 graphs the distributions for the three problematic scales and shows that a large proportion of the subjects have maximum or near maximum scores. Because very few items are available to discriminate among high scoring individuals, an increase in measurement error for the highly skewed tests is certain for higher scoring individuals. Fortunately, the other seven scales are not highly skewed and the decreasing positive manifold effect is apparent across the sub-populations defined with those scales.

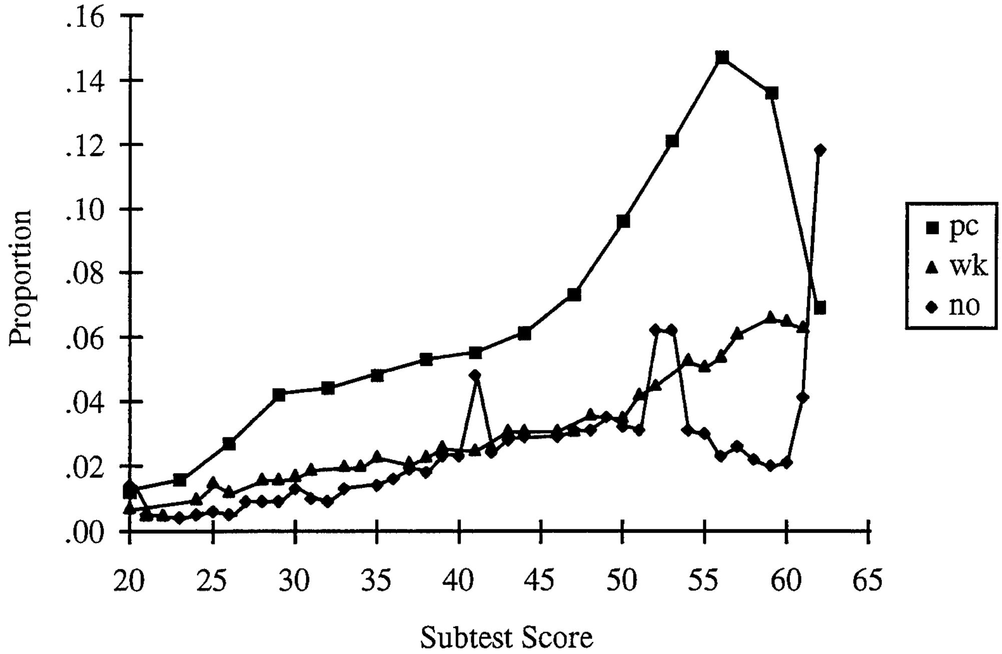

Figure 5. Score Distributions for the Psychometrically Weaker Scales: NO, PC, and WK

Implications for Understanding Exceptional Performance

The finding that cognitive aptitudes are less correlated among higher aptitude groups may help explain why some researchers in the field of intelligence have expected human cognitive aptitudes to be relatively uncorrelated (e.g., Sternberg & Wagner, 1993; Gardner, 1983). These analyses suggest that mental aptitudes may appear less correlated to individuals who interact primarily with high aptitude individuals because cognitive aptitudes really are less correlated among these individuals. If it can be expected that the life-time experiences of psychologists are reflected in the theories of intelligence individuals propose, then psychologists who interact primarily with high aptitude groups might be expected to place less emphasis Psychometric *g* in explaining human behavior and in their theoretical notions concerning aptitudes and intelligence.

The demonstration that cognitive aptitudes are less correlated among high aptitude groups is consistent with our personal experiences. The finding suggests that many highly successful individuals could be described as "Sophomoric Savants" because they excel in a few circumscribed domains while having substantial, although variable, amounts of knowledge and expertise in many other areas. From this perspective it seems reasonable to speculate that highly eminent scientists in one field would tend to be much less successful in other fields, e.g., a world-class physicist might be expected to be a mediocre historian. This interpretation suggests that it is important to match the aptitudes of highly aptitude individuals with appropriate careers to ensure more productive professionals.

Stated otherwise, an important implication of these analyses is that potential classification efficiency should be greater for higher aptitude populations. Potential classification efficiency (PCE) refers to the improvement in performance that can be realized by assigning a population of individuals to multiple jobs through a procedure that optimizes performance relative to a procedure based on random job assignment (Johnson & Zeidner, 1991). Much of the theory surrounding the estimation of PCE is based on a proof (Brogden, 1959) showing that the PCE inherent to a test battery is proportional to: $R(1-r)^{1/2}$, where R corresponds to the mean validity of a set of full least squares composites predicting performance for multiple jobs, and r to the mean correlation between the predictor composites. The proof shows that PCE is greater for either higher levels of R (mean validity) or lower levels of r (mean correlation between predictor composites). Because full least square composites utilize a common test battery, the minimal value of r will be generally limited by magnitude of the correlations among the tests in the battery. It follows that for higher aptitude groups, r will be generally lower and potential classification effects will be greater. This reasoning suggests that personnel classification is particularly important when matching careers and highly capable individuals.

<u>Implications for the Multivariate Correction</u>

These analyses are equivocal on the use of the multivariate correction for restriction of range (cf. Lawley, 1943). This correction is usually used to estimate a population correlation matrix when: (1) population correlations are available for a set of developed tests but not for a set of experimental tests, and (2) sample-based correlations can be calculated for an entire set of experimental and developed tests. Implicit to this correction is the assumption that the correlational structure of the sample will be similar to that of the population with the exception that the sample estimates will be attenuated due to restriction in range.

Although these analyses indicate that the correlations among higher aptitude samples will be attenuated to a greater extent than expected on the basis of range restriction, the analyses also indicate that the effect is fairly constant over various aptitudes and the magnitude of the effect is primarily a function of the psychometric quality of the scales used to define the sub-populations. Thus the correction is not likely to provide misleading estimates if data are collected using a test battery with adequately developed scales.

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