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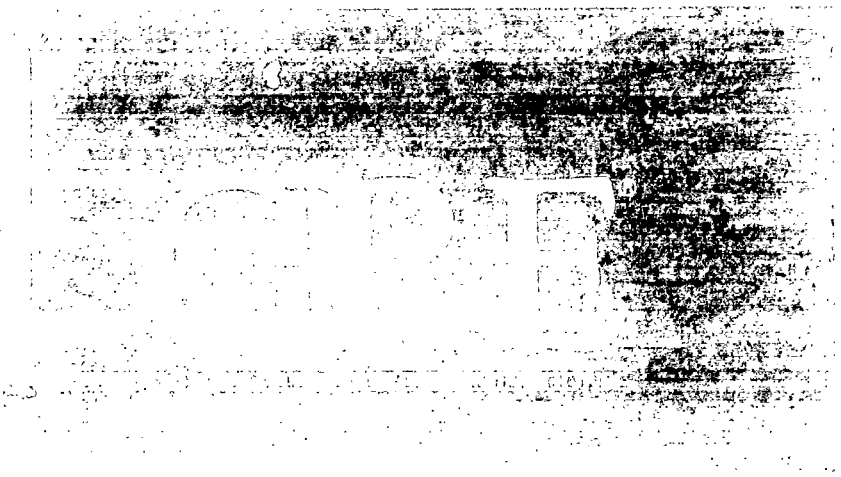
ABSTRACT

This study examined the factor structure of the Graduate Record Examinations (GRE) General Test to appraise the extent to which an analytical factor could be identified that was distinguishable from verbal and quantitative factors. Full-information factor analysis was employed in several groups of undergraduate majors on items from one edition of the GRE General Test. In all, 6,536 students participated. In general, three factors emerged for each group of undergraduate majors. Two of the factors were defined by verbal and quantitative items. A third factor typically had analytical reasoning items loading most heavily on it. No discernible pattern emerged regarding relationships of the logical reasoning items and other items. The magnitudes of the intercorrelations among the verbal, quantitative, and analytical factors generally were similar across groups. Finally, the assessment of the differences among major groups was tentative and not well-defined due to the extent of differences found among randomly equivalent groups of psychology majors. Appendix A lists three-factor Promax-rotated factor loadings, and Appendix B explains a method of obtaining variance explained by factors in an oblique factor solution. (Contains 6 tables and 19 references.) (Author/SLD)



STRENGTH OF THE ANALYTICAL FACTOR OF THE GRE GENERAL TEST IN SEVERAL SUBGROUPS: A FULL-INFORMATION FACTOR ANALYSIS APPROACH

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Neal M. Kingston

GRE Board Professional Report No. 86-7P
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ETS

EDUCATIONAL TESTING SERVICE PRINCETON, NJ

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Abstract

This study examined the factor structure of the GRE General Test to appraise the extent to which an analytical factor could be identified that was distinguishable from verbal and quantitative factors. Full-information factor analysis was employed in several groups of undergraduate majors on items from one edition of the GRE General Test. In general, three factors emerged for each group of undergraduate majors. Two of the factors were defined by verbal and quantitative items. A third factor typically had analytical reasoning items loading most heavily on it. No discernible pattern emerged regarding the relationships of the logical reasoning items and other items. The magnitudes of the intercorrelations among the verbal, quantitative, and analytical factors generally were similar across groups. Finally, the assessment of the differences among major groups was tentative and not well defined due to the extent of differences found among randomly equivalent groups of psychology majors.

Acknowledgments

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Introduction

Review of Analytical Measure

The GRE General Test has evolved considerably over the past decade. Before 1977, scores on the GRE General Test (at that time called the GRE Aptitude Test, were based on a verbal section and a quantitative section. The verbal section consisted of reading comprehension, analogies, antonyms, and sentence completion items. A factor analytic study based on interitem tetrachoric correlations (Powers, Swinton, & Carlson, 1977) supported the structure of the test; the first three factors that emerged in each of two test forms had quantitative items loading most heavily on the first factor, reading comprehension items loading on the second factor, and analogies, antonyms, and sentence completion items loading on the third factor. These three factors accounted for approximately 75 percent of the common item variance.

In 1975 and 1976, seven different analytical item types were administered in experimental sections of GRE General Test forms to appraise their psychometric characteristics. Powers (1978) demonstrated that each analytical item type could be explained largely in terms of verbal and quantitative factors. For example, the analytical reasoning items seemed to contain a general quantitative component, and the logical reasoning items appeared to be dependent on reading comprehension. In addition, there were separate dimensions associated with each item type except logical reasoning. However, because no examinee was administered more than one item type, the relationships among the item types could not be determined. Conrad (1976) also investigated the seven experimental analytical item types and concluded that three of them (analytical reasoning, logical diagrams, and analysis of explanations) showed the most promise for inclusion in a GRE analytical measure.

In October 1977 an analytical section, consisting of analytical reasoning, logical diagrams, and analysis of explanations items, was added to the GRE Aptitude Test. The introduction of the analytical section coincided with shortened verbal and quantitative sections. Swinton and Powers (1980) performed a factor analytic study of this restructured GRE Aptitude Test. Both item-level analyses based on tetrachoric correlations and item-parcel analyses based on product-moment correlations were performed. Results indicated that the factor structure of the verbal and quantitative sections had been relatively unaffected by the changes that were made. In addition, an identifiable analytical factor emerged, but it was strongly related to the other factors, especially reading comprehension. Perhaps more importantly, analytical reasoning and logical reasoning item parcels loaded at least as heavily on the verbal or quantitative factor as on the analytical factor. (However, there were too few analytical reasoning and logical reasoning items to draw definite conclusions.)

Rock, Werts, and Grandy (1982) employed confirmatory factor analysis of item parcels to assess the factor structure of the GRE General Test for a sample of social science majors. A three-factor solution (verbal, quantitative, and analytical) indicated that the analytical factor correlated .92 with the quantitative factor and .77 with the verbal factor when each factor was corrected for error of measurement. The verbal and quantitative factors correlated .64. Even in a four-factor model (vocabulary, reading

comprehension, quantitative, and analytical), the analytical factor was very highly correlated with the other factors, especially quantitative. In particular, analytical reasoning and logical diagrams items had substantial loadings on the quantitative factor.

All the factor analyses discussed so far were based on the preanalytical version of the test or on the original version of the analytical measure. In October 1981 the GRE General Test was restructured into its current form. The revised analytical section included only analytical reasoning and logical reasoning items. These two item types were selected over other analytical item types because of their resistance to practice effects, low correlations with verbal and quantitative scores relative to other analytical item types, and logical defensibility (Wild, Swinton, & Wallmark, 1982). Also, the speededness of the quantitative and (especially) the verbal sections was decreased at this time by allotting more time per item in each section. Finally, test administration directions were altered to reflect that reported scores would be based on the number of items answered correctly, whereas in earlier versions of the test, the reported scores were based on formula scores (number right minus a fraction of the number wrong).

Stricker and Rock (1985) factor analyzed GRE General Test data that included the current analytical measure. They compared several possible factor structures using confirmatory factor analyses of correlations of item parcels. The solution that provided the best fit to the data yielded three factors: verbal, quantitative, and analytical. Across three age groups, the analytical factor correlated .74-.84 with the verbal and quantitative factors, and the verbal and quantitative factors correlated .53-.63. The item parcels for the analytical measure had moderate loadings on the hypothesized analytical factor, noticeably lower than the corresponding loadings of other item parcels on their factors. In addition, factor loadings of supplementary demographic variables, including undergraduate major (humanities, social sciences, and physical sciences), were reported. Humanities had consistently moderate or high positive loadings on the verbal ability factor, social sciences generally had moderate or high negative loadings on the quantitative ability factor, and physical sciences had consistently high positive loadings on this factor. Several models that might have fit the data as well or better were not tried. For example, a model that proposed only verbal and quantitative factors, where logical reasoning items were allowed to load on the verbal factor and analytical reasoning items were allowed to load on the quantitative factor, might have provided a good fit to the data.

Other studies have provided additional information on the possibility of differences among fields in the importance and strength of analytical abilities. Powers and Enright (1986) found that a variety of analytical skills were judged by college faculty to be differentially important for success in six fields of study. On the other hand, Wilson (1984) reported similar correlations among analytical reasoning, logical reasoning, quantitative comparison, and reading comparison items for three fields of study. Kingston (1985), in a study of the incremental validity of the analytical measure, found a "relatively" large increase in validity due to the inclusion of the analytical measure in the regression equation for engineering majors (the multiple correlation increased from .16 to .19 when analytical was added to verbal and quantitative for predicting first-year graduate grades). Smaller effects appeared for other quantitative majors. However,

sample sizes were small in those analyses. Incremental validity was not found in the nonquantitative majors in the study.

Full-Information Factor Analysis

Some of the previous factor analyses were based on item parcels that may conceal information that exists in items; item parcels may not necessarily reflect all the pertinent characteristics of items. Other factor analyses were based on raw tetrachoric correlations that are not fully appropriate for nonnormal distributions and whenever there is guessing (Lord, 1980, p.20). Techniques exist for correcting tetrachorics for guessing (Bock, Gibbons, & Muraki, 1985; Carroll, 1945), but these techniques have not been fully explored and were not used in previous analyses of the GRE General Test.

Full-information factor analysis is a relatively new technique that avoids these limitations as it is designed for binary test items (Bock & Aitkin, 1981; Bock, Gibbons, & Muraki, 1985). The computer program TESTFACT (Wilson, Wood, & Gibbons, 1984) performs full-information factor analysis by using the marginal maximum likelihood method to estimate discrimination and difficulty parameters for multidimensional IRT models. The IRT parameter estimates are then used to estimate the interitem correlation matrix, which is used as the basis for a principal factors analysis. Bayesian priors for model parameters may be used and thus very stable estimates are provided. This procedure is called full-information factor analysis because it accounts not only for the pairwise joint frequencies of correct-incorrect responses, but also for information provided by higher-order joint frequencies in the sample of items scored right or wrong. Finally, TESTFACT performs a stepwise factor analysis that includes a test to determine if any subsequent factor beyond the first is statistically significant. The resulting factor pattern can be rotated orthogonally to the varimax criterion (Kaiser, 1958). With the varimax rotation, the pattern can then be rotated obliquely by the promax method (Hendrickson & White, 1964).

Purpose of the Present Study

The aim of this study was to appraise the extent to which an analytical factor could be identified in the GRE General Test that was distinguishable from the verbal and quantitative factors. To enhance the opportunity for an analytical factor to emerge, full-information factor analysis was employed in several subgroups of undergraduate majors. This analysis would show if a coherent analytical factor existed for any of the undergraduate major groups. Analyses were not performed on the total group.

Design and Analysis

Samples of Examinees and Items

Samples of examinees. GRE General Test data were selected from the approximately 82,000 examinees who took Form 3GGR3 in October 1984, April 1985, or December 1985 and who indicated that English was their best language, that they had not previously taken any GRE test, and that they were in their senior year of college when they took the test. From this group, groups of examinees were selected who indicated one of five undergraduate majors: education, engineering, English, mathematics, or psychology. These majors represent diverse content areas that include the humanities (English), social sciences (education and psychology), and physical sciences (engineering and

mathematics). In addition, relatively large numbers of GRE examinees major in these fields.

Groups of undergraduate majors were created for the analyses. All examinees who listed either education or mathematics were included in the analysis. Samples of approximately 1,000 examinees were randomly selected from the 2,436 engineering majors and from the 1,303 English majors. Finally, three samples of approximately 1,000 psychology majors were randomly selected from a total of 3,325 psychology majors. Differences in factor structures in the randomly equivalent psychology groups would serve as a reference when the factor structures for the five different majors were compared.

Table 1 presents sample sizes and means and standard deviations of scores on the verbal, quantitative, and analytical sections that were scored in this study for each major group. The table shows expected patterns; for example, the three psychology groups had very similar score distributions, and the engineering and mathematics majors performed much better than the other groups on the quantitative section.

Insert Table 1 About Here

Background information supplied by examinees when they took the test was compared for the three psychology groups to further explore the similarity of these groups. These background variables included ethnicity, parents' educational and income levels, and undergraduate grade point average. The three psychology groups differed only slightly on each background variable, supporting the contention that random sampling provided three essentially equivalent groups of psychology majors.

Sample of items. Due to data processing limitations of TESTFACT (a maximum of 150 items), only 93 of the 186 total items (one-half of each item type) were analyzed from one test edition of the GRE General Test. These items consisted of the first of two separately timed parallel sections of verbal, quantitative, and analytical items. This included a total of 38 verbal, 30 quantitative, and 25 analytical (19 analytical reasoning and 6 logical reasoning) items. Items were scored 1 if correct and 0 if wrong or omitted, in keeping with the General Test's number-right scoring directions. Contiguous omitted items at the end of a separately timed section were treated as any other wrong responses, rather than items not reached, thereby permitting the emergence of a speed factor, should one exist.

Analysis

The lower asymptotes of the item response functions were estimated for each item using the LOGIST program (Wingersky, Barton, & Lord, 1982) and then input into the TESTFACT program. LOGIST was run separately on each section of verbal, quantitative, and analytical items for each major group; the three psychology groups were run together.

For each of the seven samples, a full-information factor analysis was run using the TESTFACT program. A four-factor stepwise procedure was performed in some groups to allow for at least verbal, quantitative, and analytical factors to emerge plus the possibility of a more complex structure (e.g., two distinct verbal factors or two distinct analytical factors). Only a three-factor

solution was run on the remaining groups because the fourth factor in the four factor solutions consistently accounted for very little variance and was not interpretable. The maximum numbers of major and minor iterations were set at 15 and 5, respectively. The convergence criterion was set at .01. Both varimax and promax rotations were employed in all groups.

Results

Table 2 lists the results of adding one factor at a time to fit the data in each group. All seven groups generally yielded similar results in terms of the amount of variance explained by each factor in the orthogonal solution. Note that the amount of variance explained by a factor assumes that the factor model is an appropriate one. Each of the three factors significantly improved the fit of the factor model; in particular, the third factor always accounted for a small but significant amount of the variance that was not explained by the two-factor solution. The total variance explained by the three factors ranged from 27-34 percent across groups. The remaining approximately 70 percent of variance can be explained by a combination of variance due to minor factors, specific knowledge inherent to individual questions, and error of measurement. This finding is typical of tests of several developed abilities.

Insert Table 2 About Here

Since the sample sizes are large, a third factor may be statistically significant but have no practical significance. In this study, the third factor typically accounted for about half the variance of the second factor. Even more to the point, the vast majority of analytical reasoning items loaded most heavily on this third factor. These findings appear to indicate the practical significance of the third factor. Other approaches to determining practical significance have been suggested. For example, in one study, Zimowski & Bock (1987) suggested that an additional factor be considered to have practical significance if the change in chi-square is four or five times the change in degrees of freedom. Using this criterion, a two-factor solution would have been chosen for all samples.

The agreement of results among the psychology groups was less than expected. The percent of variance explained by the first factor in group 1 was somewhat less than that for the other two psychology groups. In addition, the percent of variance explained by the third factor was relatively small for psychology group 2 compared to the other two psychology groups. Finally, the factor solution for education majors accounted for somewhat more variance than it did for other major groups.

Factor loadings for the promax-rotated three-factor solutions are provided in the Appendix separately for each major. Item types within the verbal, quantitative, and analytical sections are labeled. The patterns of factor loadings were similar in the varimax and promax solutions, but only the loadings for the promax solutions are presented because of the overwhelming evidence that scores on the item types are substantially correlated.

Each statistically significant factor could be identified based on the items that loaded most heavily on that factor in the promax solution. This was possible in each group; that is, the verbal, quantitative, and analytical items generally loaded most heavily on one of the three factors. Thus, for each major group the three factors were labeled as either a verbal, quantitative, or analytical factor. (There was less evidence for an analytical factor for education majors, however.)

The factor loadings presented in the Appendix are summarized in Table 3 and Table 4. Table 3 presents the percent of items whose loadings were .35 or greater on the appropriate factor. This value was chosen after inspecting the loadings, as it led to a parsimonious description of the findings. Results are also listed separately for the analytical reasoning and logical reasoning item types in the analytical section. Table 4 lists the average factor loading of items on the appropriate factors. Results in both tables are presented separately for each major group.

Insert Table 3 and Table 4 About Here

The data presented in Tables 3 and 4 suggest that the verbal and quantitative factors are rather well defined. Most verbal and quantitative items loaded relatively heavily on their appropriate factor. One exception is that only 39 percent of the verbal items loaded at least .35 on the verbal factor in psychology group 2. However, the average loading of .39 in this group indicates that typically the verbal items are loading only slightly less heavily on the verbal factor than in other groups. A closer inspection of the tables in the Appendix indicates that most of verbal and quantitative items that did not load heavily on the appropriate factor also did not load heavily on either of the other factors. This suggests that these items have nontrivial item-specific variance and are assessing dimensions that are not tapped by any of the three common factors.

The analytical factor appears to be defined primarily by analytical reasoning items; the logical reasoning items generally do not load on this factor. This occurs in most major groups. For education majors, however, the proportions of analytical reasoning and logical reasoning items loading on the analytical factor are about the same; similarly, the average loadings of these two item types on the analytical factor are about the same. English majors had relatively few analytical reasoning items loading .35 or higher on the analytical factor, but several items had loadings only slightly below this criterion. In addition, the average size of the loadings for English majors was similar to the averages for other groups. Mathematics majors had a relatively high average loading for the logical reasoning items on the analytical factor.

The logical reasoning items loaded most frequently on the verbal factor, followed by no factor, the quantitative factor, and finally the analytical factor. The psychology groups differed in the distribution of the logical reasoning items across factors. No pattern emerged regarding the factor loadings for the six logical reasoning items.

Additional analyses examined whether a factor defined primarily by analytical reasoning items was found in most groups because there were more analytical reasoning items than logical reasoning items in the primary

analyses (19 items versus 6 items). Six randomly selected analytical reasoning items and six logical reasoning items were subjected to a two-factor promax-rotated solution in each group. The results indicated that neither factor was defined primarily by either analytical reasoning or logical reasoning items in any groups except psychology groups 1 and 3. In these two psychology groups, the first factor appeared to be defined primarily by analytical reasoning items, and the second factor by logical reasoning items. The analysis did not rule out the possibility that the greater number of analytical reasoning items (compared to logical reasoning items) affected the factor structure in the primary analyses.

Table 5 lists for each group the order of emergence of the verbal factor (V), the quantitative factor (Q), and the analytical factor (A) in the three-factor orthogonal solution, and the factor intercorrelations resulting from the promax rotation. For example, for mathematics majors Q emerged first, followed by V and then A, and the correlation between Q and A factor scores was .62.

Insert Table 5 About Here

In terms of order of emergence of factors and factor intercorrelations, the psychology groups differed more among themselves than was expected. In terms of order of emergence of factors, psychology group 1 was as different from the other two psychology groups as from any other group. Psychology group 2 was much different from the other psychology groups in terms of the V-A correlation. In addition, all three psychology groups differed substantially in terms of the Q-A correlation. These differences in order of emergence and factor intercorrelations may have occured because of the relatively high correlations (multicollinearity) among all the items. When data are highly correlated, standard errors are large, and any of a large number of factor analytic solutions might emerge, due primarily to overfitting of error variance.

The other groups also showed some similarities and differences. The order of emergence of the factors was Q, V, and then A for all groups except for psychology group 1 and engineering majors. The V-Q correlations were in the .60s, except for mathematics majors, who had a .48 correlation. The correlations of V and Q with A were less consistant across groups. The V-A correlations ranged from the mid-.40s to the mid-.60s; the Q-A correlations ranged from .52 to .78 (these two extremes were found for two of the psychology groups). In general, however, the V-Q correlations, the V-A correlations, and the Q-A correlations were similar in magnitude.

The differences in variance explained by each factor in the orthogonal solution might have been due to order of factor extraction. Variances explained by each factor in the oblique solution are not so affected and are presented in Table 6. The variances were calculated using a method suggested by Ledyard R Tucker (personal communication, April 14, 1987; see Appendix B for details). The verbal factor explained the most variance in each of the groups. In all groups except psychology group 1, the analytical factor explained the least amount of variance. Across groups, the percent of variance explained ranged from about 19-27 percent for the verbal factor, 12-22 percent for the quantitative factor, and 10-17 percent for the analytical factor. Thus, order of factor extraction does not appear to

explain the differences in variance explained across groups. Note that because these variances are based on oblique solutions, the sum of the three factor variances is larger than the total variance. (The total variance explained in the oblique solution is the same as the total variance explained in the orthogonal solution.)

Insert Table 6 About Here

Conclusions

Several conclusions may be drawn from this study.

1. Full-information factor analysis, as implemented by TESTFACT on groups of examinees with the same undergraduate major, yielded insight into the relationships among the GRE General Test items that were not evident in previous studies.

2. A relatively weak but statistically significant analytical factor that could be separated from the verbal and quantitative factors was identified in each major group studied, with the possible exception of education majors. The magnitudes of the intercorrelations among the verbal, quantitative, and analytical factors generally were similar. These findings were in contrast to those found in previous studies that reported the analytical factor to be more highly correlated with the verbal and quantitative factors than the verbal and quantitative factors were correlated with each other.

3. The analytical factor appears to be defined by analytical reasoning items and not by logical reasoning items. While most of the analytical reasoning items loaded on the analytical factor, the logical reasoning items generally loaded more frequently on the verbal or quantitative factor than on the analytical factor. Note, however, that since only six logical reasoning items were included in the analysis, overinterpretation should be avoided.

4. No speed factor was found. Thus, if the test is speeded, the percent of variance accounted for by individual differences in speed of test taking is small.

5. Based on the extent of differences found among the randomly equivalent psychology groups, the assessment of the differences among major groups was tentative and not well defined. Evidently, slight differences in samples may lead to different observations regarding factor structures. Perhaps this is due in part to the high correlations among the different item types.

These analyses used an exploratory factor analysis approach. Exploratory analyses can be misleading because of estimation difficulties. McKinley and Kingston (personal communication, July 20, 1987) are developing a confirmatory multidimensional IRT model that should not be subject to these limitations. Use of this approach may clarify the inconsistencies found in the psychology groups. Results from these exploratory analyses, however, provide base models for use with confirmatory multidimensional IRT models.

Implications

This study has suggested that an analytical dimension in the GRE General Test may be defined by the analytical reasoning items and not by the logical reasoning items. This finding raises doubt about the utility of including analytical reasoning and logical reasoning items in the same score. A next step would be to replicate these findings with other editions of the test. Also, these analyses could be performed in other majors to see how anomalous the education major results are. Finally, further correlational analyses could be performed to explore what dimensions, if any, are being tapped by the logical reasoning items.

References

Bock, R. D., & Aitkin, M. (1981). Marginal maximum likelihood estimation of item parameters: An application of the EM algorithm. Psychometrika, 46, 443-445.

Bock, R. D., Gibbons, R., & Muraki, E. (1985). Full-information factor analysis. MRC Report 85-1. Chicago: National Opinion Research Center.

Carroll, J. B. (1945). The effect of difficulty and chance success on correlations between items or between tests. Psychometrika, 10, 1-19.

Conrad, L. (1976). Aptitude test restructuring research: Findings concerning projected development of an abstract reasoning measure. GRE Technical Report. Princeton, NJ: Educational Testing Service.

Hendrickson, A. E., & White, P.O. (1964). PROMAX: A quick method for rotation to oblique simple structure. British Journal of Statistical Psychology, 17, 65-70.

Kaiser, H. F. (1958). The varimax criterion for analytic rotation in factor analysis. Psychometrica, 23, 187-200.

Kingston, N. M. (1985). The incremental validity of the GRE analytical measure for various department types. Paper presented at the annual meeting of the American Educational Research Association, Chicago.

Lord, F. M. (1980). Applications of item response theory to practical testing problems. Hillsdale, NJ: Lawrence Erlbaum Associates.

Powers, D. E. (with Swinton, S., Thayer, D., & Yates, A.) (1978). A factor analytic investigation of seven experimental analytical item types. GRE Board Professional Report No. 77-1P. Princeton, NJ: Educational Testing Service.

Powers, D. E., & Enright, M. E. (1986). Analytical reasoning skills involved in graduate study: Perceptions of faculty in six fields. Draft research report. Princeton, NJ: Educational Testing Service.

Powers, D. E., Swinton, S. S., & Carlson, A. B. (1977). A factor analytic study of the GRE Aptitude Test. GRE Board Professional Report No. 75-11P. Princeton, NJ: Educational Testing Service.

Rock, D. A., Werts, C., & Grandy, J. (1982). Construct validity of the GRE Aptitude Test across populations--An empirical confirmatory study. GRE Board Professional Report No. 78-1P. Princeton, NJ: Educational Testing Service.

Stricker, L. J., & Rock, D. A. (1985). Factor structure of the GRE General Test for older examinees: Implications for construct validity. GRE Board Research Report No. 83-10R. Princeton, NJ: Educational Testing Service.

Swinton, S. S., & Powers, D. E. (1980). A factor analytic study of the restructured GRE Aptitude Test. GRE Board Professional Report No. 77-6P. Princeton, NJ: Educational Testing Service.

Wild, C. L., Swinton, S. S., & Wallmark, M. M. (1982). A summary of the research leading to the revision of the format of the Graduate Record Examinations Aptitude Test in October 1981. GRE Board Research Report No. 80-1aR. Princeton, NJ: Educational Testing Service.

Wilson, D., Wood, R., & Gibbons, R. (1984). TESTFACT: Test scoring and item factor analysis [computer program]. Chicago: Scientific Software.

Wilson, K. M. (1984). The relationship of GRE General Test item-type part scores to undergraduate grades. GRE Board Professional Report No. 81-22P. Princeton, NJ: Educational Testing Service.

Wingersky, M, S., Barton, M. A., & Lord, F. M. (1982). LOGIST 5 [computer program]. Princeton, NJ: Educational Testing Service.

Zimowski, M. F., & Bock, R. D. (1987). Full-information item factor analysis of test forms from the ASVAB CAT pool. MRC Report #87-1 (revised). Chicago: National Opinion Research Center.

Table 1. Descriptive Statistics for Each Major Group

Major Group	Sample Size	Verbal (38 items) Mean	Verbal (38 items) SD	Quantitative (30 items) Mean	Quantitative (30 items) SD	Analytical (25 items) Mean	Analytical (25 items) SD
Psychology- 1	1,002	22.0	5.3	17.0	4.3	13.7	3.6
Psychology- 2	1,001	21.7	5.4	17.0	4.6	13.6	3.6
Psychology- 3	1,003	21.7	5.4	17.0	4.4	13.6	3.7
Education	728	19.0	5.8	15.6	4.8	12.9	3.8
Engineering	999	24.3	5.3	25.1	3.6	16.3	3.7
English	998	25.4	5.4	17.5	4.7	14.6	3.8
Mathematics	805	24.1	5.6	24.6	4.1	16.9	4.0

Table 2. Results of Stepwise Full-Information Factor Analysis

Number of Factors	Latent Root*	Percent Variance Explained*	X^2	df	X^2 Change**	df Change**
		Psychology Majors--Group 1				
1	17.0	19.2	82,493	817	---	--
2	3.7	5.2	81,871	725	621	92
3	2.5	2.8	81,648	634	223	91
		27.2				
		Psychology Majors--Group 2				
1	18.2	22.4	82,918	817	---	--
2	3.4	5.2	82,283	725	635	92
3	2.4	1.8	81,960	634	317	91
		29.4				
		Psychology Majors--Group 3				
1	18.2	22.2	82,343	818	---	--
2	3.2	4.7	82,714	726	629	92
3	2.5	2.4	81,507	635	207	91
		29.3				
		Education Majors				
1	20.3	27.2	61,575	541	---	--
2	3.6	5.2	61,087	449	488	92
3	3.0	2.0	60,894	358	193	91
		34.4				
		Engineering Majors				
1	19.3	23.0	67,752	812	---	--
2	4.0	4.2	67,073	720	679	92
3	3.2	3.1	66,825	629	248	91
		30.3				
		English Majors				
1	19.6	23.1	79,144	813	---	--
2	4.0	5.3	78,366	721	778	92
3	2.6	2.1	78,095	630	270	91
		30.5				
		Mathematics Majors				
1	20.2	24.1	55,163	618	---	--
2	3.9	4.7	54,651	526	512	92
3	2.6	2.3	54,354	435	297	91
		31.1				

* Latent roots and percent variance explained are from the orthogonal three factor solution. The last number in the percent variance explained column is the total.

** Difference between chi-square (X^2) or degrees of freedom for this model and previous model. All changes in X^2 were significant at the .0001 level.

Table 3. Percent of Items with Factor Loadings .35 or Greater on the "Appropriate" Factor

Major Group	Verbal	Quantitative	Analytical		
			AR*	LR*	AR&LR
Psychology- 1	71	57	74	0	56
Psychology- 2	39	57	74	0	56
Psychology- 3	50	80	84	0	64
Education	76	57	32	33	32
Engineering	82	73	63	17	52
English	55	70	47	0	36
Mathematics	68	70	100	33	84

* AR = analytical reasoning, LR = logical reasoning

Table 4. Average Factor Loading of Items on the "Appropriate" Factor

Major Group	Verbal	Quantitative	Analytical		
			AR*	LR*	AR&LR
Psychology- 1	.45	.39	.45	-.11	.32
Psychology- 2	.39	.45	.45	.08	.36
Psychology- 3	.39	.49	.42	.11	.36
Education	.48	.43	.25	.28	.26
Engineering	.46	.48	.46	.07	.37
English	.45	.51	.42	.06	.34
Mathematics	.43	.42	.52	.34	.47

* AR = analytical reasoning, LR = logical reasoning

Table 5. Order of Emergence of Factors in the Three-Factor Solutions and Factor Intercorrelations*

Major Group	Order of emergence of factors	Factor intercorrelations of VQ, VA, QA, respectively
Psychology- 1	A, V, Q	.64, .46, .52
Psychology- 2	Q, V, A	.63, .61, .78
Psychology- 3	Q, V, A	.67, .47, .67
Education	Q, V, A	.63, .65, .70
Engineering	V, Q, A	.61, .63, .60
English	Q, V, A	.68, .59, .74
Mathematics	Q, V, A	.48, .67, .62

* V = verbal, Q = quantitative, A = analytical

Table 6. Percent of Variance Explained by Each Factor in the Promax-Rotated Solution

Major Group	Verbal	Quantitative	Analytical
Psychology- 1	19.2	12.3	15.6
Psychology- 2	22.4	14.9	10.0
Psychology- 3	22.2	21.7	16.8
Education	27.2	18.7	10.4
Engineering	23.0	19.2	13.5
English	23.1	17.4	10.0
Mathematics	24.1	20.3	17.4

Appendix A*

Three-Factor Promax-Rotated Factor Loadings

Psychology Majors (Group 1)

Verbal Items		Factors I	II	III	Quantitative Items		Factors I	II	III	Analytical Items		Factors I	II	III
V SC	1	.2	.1	.1	Q QC ARI	1	.1	-.1	.2	A AR	1	.5	-.0	.1
V SC	2	-.2	.5	.2	Q QC ARI	2	.1	.1	.2	A AR	2	.4	-.1	.2
V SC	3	-.1	.5	.0	Q QC ALG	3	.3	-.2	.2	A AR	3	.5	.1	-.2
V SC	4	.0	.1	.3	Q QC GEO	4	.1	.0	.2	A AR	4	.1	.1	.4
V SC	5	.1	.3	-.1	Q QC ALG	5	.1	-.1	.4	A AR	5	.3	-.0	.2
V SC	6	.1	.5	-.1	Q QC ARI	6	.2	-.0	.3	A AR	6	.4	-.0	.2
V SC	7	-.0	.8	-.2	Q QC GEO	7	.1	-.1	.6	A AR	7	.3	.1	.1
V ANL	8	.3	.2	.1	Q QC ALG	8	.1	-.0	.5	A LR	8	.1	.4	.2
V ANL	9	.2	.4	-.1	Q QC ARI	9	.1	-.1	.4	A LR	9	.3	.2	-.0
V ANL	10	-.0	.3	.0	Q QC GEO	10	-.1	-.0	.5	A LR	10	.0	.3	.2
V ANL	11	.2	.5	-.1	Q QC ALG	11	.2	.3	-.1	A AR	11	.5	-.0	.1
V ANL	12	.1	.5	-.2	Q QC GEO	12	.1	-.0	.5	A AR	12	.5	.1	.3
V ANL	13	.0	.5	.1	Q QC ARI	13	.1	.2	.4	A AR	13	.5	-.1	.2
V ANL	14	-.0	.3	.1	Q QC ALG	14	.1	.1	.4	A AR	14	.5	.1	-.0
V ANL	15	-.0	.1	.4	Q QC GEO	15	-.1	-.2	.7	A AR	15	.8	-.2	-.0
V ANL	16	-.3	.4	.2	Q DQ ARI	16	.4	-.2	.3	A AR	16	.6	.2	-.1
V RC	17	.1	.7	-.2	Q DQ ARI	17	.2	-.1	.2	A AR	17	.6	.0	-.1
V RC	18	.2	.5	-.1	Q DQ ALG	18	.1	-.1	.5	A AR	18	.7	.0	.1
V RC	19	.2	.3	.0	Q DQ GEO	19	.2	.0	.4	A AR	19	.6	-.3	.2
V RC	20	.1	.4	.0	Q DQ ALG	20	.2	-.2	.6	A AR	20	.6	-.0	.3
V RC	21	.3	.5	-.1	Q DI	21	.4	-.1	.3	A AR	21	.0	.0	.3
V RC	22	.1	.3	-.0	Q DI	22	.3	-.1	.3	A AR	22	.2	.2	.2
V RC	23	.0	.2	.2	Q DI	23	.1	-.0	.3	A LR	23	-.3	.5	.2
V RC	24	.2	.2	-.0	Q DI	24	.2	.1	.4	A LR	24	-.2	.3	.3
V RC	25	.2	.4	.1	Q DI	25	.2	.0	.3	A LR	25	-.5	.3	.4
V RC	26	.0	.4	.0	Q DQ GEO	26	-.2	-.0	.4					
V RC	27	.2	.4	-.0	Q DQ ARI	27	.0	-.4	.8					
V ANT	28	.1	.7	.0	Q DQ ALG	28	.1	.2	.3					
V ANT	29	.1	.4	-.0	Q DQ GEO	29	.1	.2	.4					
V ANT	30	-.0	.4	.1	Q DQ ALG	30	-.1	-.1	.6					
V ANT	31	.0	.8	-.2										
V ANT	32	-.1	.5	.1										
V ANT	33	.1	.6	-.1										
V ANT	34	-.2	.5	.2										
V ANT	35	-.2	.6	.0										
V ANT	36	-.0	.7	.1										
V ANT	37	-.2	1.0	-.2										
V ANT	38	-.2	.6	.1										

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*LEGEND

V = verbal
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ANL = analogy
RC = reading comprehension
ANT = antonym

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QC = quantitative comparison
DQ = discrete quantitative
DI = data interpretion
ARI = arithmetic
ALG = algebra
GEO = geometry

A = analytical
AR = analytical reasoning
LR = logical reasoning

Appendix A* (continued...)

Three-Factor Promax-Rotated Factor Loadings

Psychology Majors (Group 2)

Verbal Items		Factors I	II	III	Quantitative Items		Factors I	II	III	Analytical Items		Factors I	II	III
V SC	1	.3	.2	.0	Q QC ARI	1	.3	-.2	.1	A AR	1	-.0	.1	.4
V SC	2	.1	.4	.1	Q QC ARI	2	.4	.0	.1	A AR	2	.2	-.2	.5
V SC	3	.1	.2	.1	Q QC ALG	3	.2	-.2	.3	A AR	3	.5	-.4	.2
V SC	4	.2	.2	.0	Q QC GEO	4	.4	.1	.0	A AR	4	.3	.0	.2
V SC	5	.1	.2	-.0	Q QC ALG	5	.6	.0	-.0	A AR	5	.1	.0	.5
V SC	6	.1	.2	.3	Q QC ARI	6	.2	-.1	.3	A AR	6	.1	-.1	.4
V SC	7	-.3	.7	.1	Q QC GEO	7	.8	-.1	-.0	A AR	7	-.1	-.1	.6
V ANL	8	.3	.1	.1	Q QC ALG	8	.7	-.1	-.1	A LR	8	.1	.4	.3
V ANL	9	.1	.2	.3	Q QC ARI	9	.7	.0	-.1	A LR	9	-.0	.2	.3
V ANL	10	-.1	.3	.1	Q QC GEO	10	.3	.0	.2	A LR	10	.1	.2	.2
V ANL	11	.2	.3	.0	Q QC ALG	11	.2	-.1	.1	A AR	11	-.2	-.1	.6
V ANL	12	.0	.2	.1	Q QC GEO	12	.7	-.1	-.0	A AR	12	.3	-.1	.5
V ANL	13	.3	.3	-.1	Q QC ARI	13	.3	.1	.2	A AR	13	.1	-.1	.6
V ANL	14	.0	.1	.4	Q QC ALG	14	.8	-.1	-.1	A AR	14	-.2	-.1	.7
V ANL	15	.6	.0	-.0	Q QC GEO	15	.7	-.2	.0	A AR	15	-.2	-.3	.9
V ANL	16	.6	.3	-.1	Q DQ ARI	16	.4	.0	.1	A AR	16	.1	.1	.4
V RC	17	.1	.3	.2	Q DQ ARI	17	.3	.0	.2	A AR	17	-.0	-.1	.5
V RC	18	.3	.2	.0	Q DQ ALG	18	.6	.0	-.1	A AR	18	.2	-.1	.5
V RC	19	.1	.2	.2	Q DQ GEO	19	.3	-.1	.3	A AR	19	-.1	-.0	.6
V RC	20	-.0	.2	.5	Q DQ ALG	20	.8	-.2	-.0	A AR	20	.4	-.0	.3
V RC	21	.3	.3	.0	Q DI	21	.1	.1	.4	A AR	21	.5	-.2	.2
V RC	22	.0	.1	.2	Q DI	22	.2	.1	.2	A AR	22	.2	.2	.2
V RC	23	.0	.1	.4	Q DI	23	.1	.2	.1	A LR	23	.5	.3	.0
V RC	24	-.1	.1	.2	Q DI	24	.3	.0	.1	A LR	24	.4	.2	-.2
V RC	25	.1	.5	.1	Q DI	25	.4	.2	.0	A LR	25	.2	.5	-.2
V RC	26	.2	.2	.0	Q DQ GEO	26	.2	.1	.1					
V RC	27	-.2	.4	.4	Q DQ ARI	27	.7	-.0	-.1					
V ANT	28	-.3	1.1	-.2	Q DQ ALG	28	.5	.1	.1					
V ANT	29	-.2	.9	-.2	Q DQ GEO	29	.7	-.5	.1					
V ANT	30	.1	.8	-.2	Q DQ ALG	30	.7	-.1	.0					
V ANT	31	-.2	.8	.0										
V ANT	32	-.1	.6	.0										
V ANT	33	-.2	.8	.1										
V ANT	34	.3	.6	-.2										
V ANT	35	-.2	.7	-.0										
V ANT	36	.4	.5	-.3										
V ANT	37	-.2	.9	-.0										
V ANT	38	.1	.7	.0										

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*LEGEND

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DI = data interpretion
ARI = arithmetic
ALG = algebra
GEO = geometry

A = analytical
AR = analytical reasoning
LR = logical reasoning

Appendix A* (continued...)

Three-Factor Promax-Rotated Factor Loadings

Psychology Majors (Group 3)

Verbal Items		Factors I	II	III	Quantitative Items		Factors I	II	III	Analytical Items		Factors I	II	III
V SC	1	.1	.2	.2	Q QC ARI	1	.3	-.2	-.0	A AR	1	-.1	.1	.4
V SC	2	.1	.3	.1	Q QC ARI	2	.3	.0	.1	A AR	2	.2	-.2	.5
V SC	3	.2	.4	-.0	Q QC ALG	3	.0	.1	.3	A AR	3	.0	-.1	.4
V SC	4	.2	.1	.1	Q QC GEO	4	.4	-.0	.1	A AR	4	.3	.1	.2
V SC	5	-.1	.2	.2	Q QC ALG	5	.7	-.2	-.0	A AR	5	.1	.0	.4
V SC	6	.2	.3	.2	Q QC ARI	6	.4	.1	.0	A AR	6	.1	-.1	.4
V SC	7	.4	.6	-.2	Q QC GEO	7	.7	-.1	.0	A AR	7	.1	-.2	.5
V ANL	8	.3	.1	.1	Q QC ALG	8	.7	-.2	.1	A LR	8	.2	.2	.2
V ANL	9	.1	.3	.3	Q QC ARI	9	.6	-.1	.1	A LR	9	.1	.0	.3
V ANL	10	-.0	.3	.0	Q QC GEO	10	.5	.1	-.0	A LR	10	.2	.2	.3
V ANL	11	.3	-.0	.2	Q QC ALG	11	.4	-.1	.1	A AR	11	-.2	.0	.6
V ANL	12	.1	.4	-.2	Q QC GEO	12	.8	-.0	-.2	A AR	12	.2	-.0	.5
V ANL	13	.4	.4	-.3	Q QC ARI	13	.4	.3	-.0	A AR	13	.2	-.1	.5
V ANL	14	.2	.2	-.1	Q QC ALG	14	.5	.0	.2	A AR	14	-.1	-.0	.5
V ANL	15	.6	.1	-.1	Q QC GEO	15	.8	-.0	-.2	A AR	15	-.3	-.1	.8
V ANL	16	.2	.4	.1	Q DQ ARI	16	.4	-.1	.1	A AR	16	.1	-.0	.4
V RC	17	-.1	.4	.3	Q DQ ARI	17	.3	-.1	.1	A AR	17	.1	-.1	.5
V RC	18	.0	.1	.3	Q DQ ALG	18	.7	-.2	.0	A AR	18	.2	.1	.4
V RC	19	.3	.2	-.0	Q DQ GEO	19	.5	-.2	.3	A AR	19	.1	.1	.3
V RC	20	.2	.4	.0	Q DQ ALG	20	.8	-.3	.2	A AR	20	.1	.3	.4
V RC	21	.3	.1	-.0	Q DI	21	.4	-.2	.2	A AR	21	.1	-.0	.5
V RC	22	.1	.1	.2	Q DI	22	.5	-.2	.1	A AR	22	.5	-.0	.0
V RC	23	.1	.0	.2	Q DI	23	.3	-.1	.1	A LR	23	.6	.2	-.1
V RC	24	-.1	.2	.2	Q DI	24	.3	.1	.1	A LR	24	.4	-.0	.0
V RC	25	.1	.4	.2	Q DI	25	.5	.0	.1	A LR	25	.4	.2	-.0
V RC	26	.1	.3	.0	Q DQ GEO	26	.5	.0	-.1					
V RC	27	-.1	.3	.3	Q DQ ARI	27	.5	.1	.1					
V ANT	28	-.4	1.1	.1	Q DQ ALG	28	.5	.2	.3					
V ANT	29	-.1	.7	.1	Q DQ GEO	29	.5	.2	-.3					
V ANT	30	-.0	.7	-.1	Q DQ ALG	30	.4	.1	.0					
V ANT	31	-.1	.8	.0										
V ANT	32	-.1	.7	.0										
V ANT	33	-.1	.7	-.0										
V ANT	34	-.2	.7	.0										
V ANT	35	-.1	.7	-.0										
V ANT	36	.0	.7	.1										
V ANT	37	.1	.8	-.2										
V ANT	38	.1	.7	-.1										

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AR = analytical reasoning
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Appendix A* (continued...)

Three-Factor Promax-Rotated Factor Loadings

Education Majors

Verbal Items		Factors I	II	III	Quantitative Items		Factors I	II	III	Analytical Items		Factors I	II	III
V SC	1	-.1	.4	.3	Q QC ARI	1	.2	-.0	.1	A AR	1	.2	.2	.2
V SC	2	.1	.7	-.1	Q QC ARI	2	.4	.1	.0	A AR	2	.2	.1	2
V SC	3	-.2	.6	.0	Q QC ALG	3	.2	.1	.2	A AR	3	.0	-.1	.6
V SC	4	.2	.3	.1	Q QC GEO	4	.3	.2	.1	A AR	4	.4	.2	.1
V SC	5	.1	.4	.0	Q QC ALG	5	.6	.0	.1	A AR	5	.3	.1	.2
V SC	6	.1	.5	-.1	Q QC ARI	6	.5	-.0	.1	A AR	6	.3	.0	.4
V SC	7	.3	-.7	.6	Q QC GEO	7	.8	-.1	.0	A AR	7	.3	-.0	.2
V ANL	8	-.0	.5	.1	Q QC ALG	8	.6	.0	.0	A LR	8	.2	.6	-.1
V ANL	9	.1	.3	.2	Q QC ARI	9	.7	-.3	.3	A LR	9	.0	.4	.1
V ANL	10	-.1	.2	.2	Q QC GEO	10	.4	.1	-.1	A LR	10	.2	.5	.0
V ANL	11	-.0	.4	.2	Q QC ALG	11	.3	-.3	-.1	A AR	11	.1	.0	4
V ANL	12	.2	.5	.3	Q QC GEO	12	1.0	-.0	-.3	A AR	12	.5	.1	-.0
V ANL	13	.2	.4	-.1	Q QC ARI	13	.1	.5	.2	A AR	13	.3	.1	.2
V ANL	14	-.1	.7	-.1	Q QC ALG	14	.6	.1	.0	A AR	14	.3	.1	.2
V ANL	15	.3	.3	-.1	Q QC GEO	15	.7	.2	-.1	A AR	15	.1	.1	.4
V ANL	16	.3	.3	-.5	Q DQ ARI	16	.4	.1	.2	A AR	16	1.0	-.3	-.2
V RC	17	-.1	.4	.3	Q DQ ARI	17	.3	-.0	.3	A AR	17	-.1	-.1	6
V RC	18	-.1	.6	.0	Q DQ ALG	18	.5	.1	.0	A AR	18	3	.2	2
V RC	19	.1	.4	-.0	Q DQ GEO	19	.4	.0	.1	A AR	19	.2	.1	2
V RC	20	-.0	.7	.0	Q DQ ALG	20	.8	-.3	.1	A AR	20	.3	.1	3
V RC	21	.0	.4	.2	Q DI	21	.2	-.0	.5	A AR	21	.4	-.1	0
V RC	22	-.3	.3	.4	Q DI	22	.2	.1	.4	A AR	22	-.1	.0	.6
V RC	23	.1	.2	.2	Q DI	23	.2	.1	.2	A LR	23	-.0	.3	.6
V RC	24	-.2	.3	.4	Q DI	24	.2	.2	.1	A LR	24	1	-.0	.7
V RC	25	-.0	.6	.1	Q DI	25	.4	-.1	.5	A LR	25	-.0	.4	.3
V RC	26	.1	.3	.0	Q DQ GEO	26	.2	.0	.0					
V RC	27	.0	.4	.1	Q DQ ARI	27	.7	-.1	.2					
V ANT	28	-.1	.6	.1	Q DQ ALG	28	.1	-.1	.3					
V ANT	29	-.2	.8	.1	Q DQ GEO	29	.3	.1	.5					
V ANT	30	.1	.7	-.2	Q DQ ALG	30	.6	-.0	.1					
V ANT	31	-.1	.7	-.0										
V ANT	32	.0	.5	-.1										
V ANT	33	.0	.8	-.1										
V ANT	34	-.2	.5	.2										
V ANT	35	-.2	.8	-.0										
V ANT	36	-.0	.7	.-1										
V ANT	37	-.1	.9	-.0										
V ANT	38	.0	.7	-.0										

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Appendix A* (continued...)

Three-Factor Promax-Rotated Factor Loadings

Engineering Majors

Verbal Items		Factors I	II	III	Quantitative Items		Factors I	II	III	Analytical Items		Factors I	II	III
V SC	1	.1	.1	.1	Q QC ARI	1	-.1	.2	.2	A AR	1	.2	-.1	.3
V SC	2	.7	-.0	.0	Q QC ARI	2	.2	.4	.1	A AR	2	-.1	.2	.4
V SC	3	.4	-.1	.2	Q QC ALG	3	.2	.0	.2	A AR	3	.2	-.0	.2
V SC	4	.4	-.1	.1	Q QC GEO	4	-.1	.6	-.1	A AR	4	.3	.3	.5
V SC	5	.4	-.0	-.1	Q QC ALG	5	.1	.4	-.0	A AR	5	.3	-.0	.3
V SC	6	.6	.0	.0	Q QC ARI	6	.1	.3	.1	A AR	6	.0	.0	.4
V SC	7	.5	.2	-.1	Q QC GEO	7	-.2	.4	.1	A AR	7	.2	-.0	.3
V ANL	8	.3	.1	.1	Q QC ALG	8	.1	.6	-.0	A LR	8	.4	-.2	.4
V ANL	9	.3	-.1	.2	Q QC ARI	9	-.0	.3	.1	A LR	9	.5	.1	-.0
V ANL	10	.5	-.0	-.1	Q QC GEO	10	-.1	.6	.1	A LR	10	.4	.2	.0
V ANL	11	.6	-.3	.2	Q QC ALG	11	.1	.6	-.2	A AR	11	.1	-.1	.3
V ANL	12	.4	.2	-.0	Q QC GEO	12	-.2	.5	.0	A AR	12	-.0	.1	.7
V ANL	13	.4	.2	-.1	Q QC ARI	13	.2	.4	.1	A AR	13	-.0	.0	.6
V ANL	14	.5	.2	-.3	Q QC ALG	14	.1	.7	-.1	A AR	14	-.1	-.1	.8
V ANL	15	.1	.3	.1	Q QC GEO	15	.0	.9	-.2	A AR	15	-.2	-.2	.9
V ANL	16	.6	.2	-.3	Q DQ ARI	16	-.1	.6	.2	A AR	16	-.0	.2	.4
V RC	17	.5	-.1	.2	Q DQ ARI	17	.1	.3	.0	A AR	17	-.1	.1	.6
V RC	18	.4	-.1	.2	Q DQ ALG	18	-.0	.6	-.1	A AR	18	-.1	.1	.6
V RC	19	.4	-.1	.0	Q DQ GEO	19	-.0	.5	.1	A AR	19	-.2	.1	.6
V RC	20	.5	.0	.1	Q DQ ALG	20	-.1	.6	.1	A AR	20	.3	.1	.5
V RC	21	.6	.1	-.0	Q DI	21	-.0	.2	.3	A AR	21	.0	.1	.5
V RC	22	.4	.1	-.0	Q DI	22	-.1	.4	.2	A AR	22	.3	-.1	.3
V RC	23	.1	.0	.1	Q DI	23	-.0	.2	.2	A LR	23	.6	.1	.0
V RC	24	.2	-.2	.2	Q DI	24	-.0	.4	.2	A LR	24	.5	.1	-.1
V RC	25	.6	.1	.0	Q DI	25	-.0	.5	.2	A LR	25	.6	.0	.1
V RC	26	.3	.0	.0	Q DQ GEO	26	.1	.3	.2					
V RC	27	.4	-.0	.2	Q DQ ARI	27	-.1	.7	-.0					
V ANT	28	.7	-.2	.3	Q DQ ALG	28	.0	.8	.0					
V ANT	29	.4	.0	-.0	Q DQ GEO	29	.1	.7	-.1					
V ANT	30	.7	-.1	.2	Q DQ ALG	30	.1	.7	-.1					
V ANT	31	.7	-.0	-.1										
V ANT	32	.5	.1	-.1										
V ANT	33	.5	-.0	-.0										
V ANT	34	.6	.1	-.1										
V ANT	35	.4	-.0	.2										
V ANT	36	.7	.2	-.3										
V ANT	37	1.0	-.1	-.2										
V ANT	38	.4	.3	-.1										

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*LEGEND

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ALG = algebra
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AR = analytical reasoning
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Appendix A* (continued...)

Three-Factor Promax-Rotated Factor Loadings

English Majors

Verbal Items		Factors I	II	III	Quantitative Items		Factors I	II	III	Analytical Items		Factors I	II	III
V SC	1	-.0	.3	.1	Q QC ARI	1	.4	-.1	.0	A AR	1	.2	-.1	.3
V SC	2	.0	.4	.1	Q QC ARI	2	.4	.1	-.1	A AR	2	.2	.0	.3
V SC	3	.1	.5	-.0	Q QC ALG	3	.1	-.1	.2	A AR	3	.1	.2	.2
V SC	4	.0	.2	.1	Q QC GEO	4	.3	.1	.1	A AR	4	.3	.2	.1
V SC	5	.0	.3	-.0	Q QC ALG	5	.4	.0	.1	A AR	5	.4	.0	.1
V SC	6	.2	.3	-.0	Q QC ARI	6	.3	.2	.1	A AR	6	.1	-.0	.3
V SC	7	-.1	.7	- 1	Q QC GEO	7	.7	-.0	-.1	A AR	7	.1	-.0	.3
V ANL	8	-.0	.2	.2	Q QC ALG	8	.7	.0	-.2	A LR	8	-.0	.7	-.1
V ANL	9	.1	.2	.1	Q QC ARI	9	.5	.1	-.1	A LR	9	-.2	.5	.1
V ANL	10	.2	.3	-.1	Q QC GEO	10	.7	-.1	-.0	A LR	10	.1	.2	.2
V ANL	11	-.1	.5	.1	Q QC ALG	11	.8	-.2	-.3	A AR	11	-.1	.1	.5
V ANL	12	-.2	.2	.3	Q QC GEO	12	.7	-.2	.2	A AR	12	.3	-.1	.5
V ANL	13	.2	.5	-.1	Q QC ARI	13	.5	.0	-.1	A AR	13	.1	-.2	.8
V ANL	14	.1	.2	.1	Q QC ALG	14	.9	-.1	-.1	A AR	14	.1	-.1	.7
V ANL	15	.3	.2	-.1	Q QC GEO	15	.6	-.0	-.1	A AR	15	-.4	-.0	1.0
V ANL	16	0	.3	.2	Q DQ ARI	16	.3	.1	.3	A AR	16	.3	-.1	4
V RC	17	.2	.5	-.1	Q DQ ARI	17	.3	-.0	.1	A AR	17	.1	-.0	.3
V RC	18	.3	3	-.1	Q DQ ALG	18	.5	-.0	.0	A AR	18	.2	-.0	.5
V RC	19	-.1	.2	.2	Q DQ GEO	19	.5	-.0	.0	A AR	19	.2	-.2	.5
V RC	20	.3	.4	-.1	Q DQ ALG	20	.7	-.1	.0	A AR	20	-.0	-.0	8
V RC	21	.2	.3	.0	Q DI	21	.2	.0	.5	A AR	21	.6	-.1	.1
V RC	22	.1	.3	.1	Q DI	22	.3	.0	.3	A AR	22	.3	-.0	.2
V RC	23	.3	.0	-.1	Q DI	23	.5	-.0	-.1	A LR	23	.4	.2	.1
V RC	24	.2	.2	-.1	Q DI	24	.2	.1	.2	A LR	24	.3	.3	1
V RC	25	.2	.4	-.0	Q DI	25	.5	.0	.1	A LR	25	.4	.3	.0
V RC	26	.0	.4	.0	Q DQ GEO	26	.2	-.0	.2					
V RC	27	.0	.4	.2	Q DQ ARI	27	.9	-.2	-.1					
V ANT	28	-.4	1.0	-.0	Q DQ ALG	28	.8	-.2	.1					
V ANT	29	-.2	.7	-.1	Q DQ GEO	29	1.0	-.4	.1					
V ANT	30	-.0	.8	-.2	Q DQ ALG	30	.5	.1	.0					
V ANT	31	-.3	.9	.1										
V ANT	32	-.1	.5	-.0										
V ANT	33	-.1	.7	.0										
V ANT	34	.0	.8	-.2										
V ANT	35	-.4	.9	.0										
V ANT	36	.1	6	.1										
V ANT	37	-.3	.9	-.0										
V ANT	38	-.0	.8	-.2										

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Appendix A* (continued...)

Three-Factor Promax-Rotated Factor Loadings

Mathematics Majors

Verbal Items		Factors I	II	III
V SC	1	-.1	.1	.3
V SC	2	.1	.4	.1
V SC	3	-.1	.4	.2
V SC	4	.2	.1	.0
V SC	5	-.1	.4	.1
V SC	6	.1	.4	.1
V SC	7	.1	.6	-.1
V ANL	8	-.1	.5	.1
V ANL	9	-.1	.3	.4
V ANL	10	-.1	.7	-.2
V ANL	11	-.2	.1	.5
V ANL	12	-.1	.4	.0
V ANL	13	.0	.7	-.1
V ANL	14	-.2	.3	.2
V ANL	15	.2	.5	-.1
V ANL	16	.0	.4	.1
V RC	17	-.1	.4	.3
V RC	18	-.0	.3	.3
V RC	19	.1	.3	.2
V RC	20	-.1	.5	.2
V RC	21	.0	.4	.2
V RC	22	.2	.4	-.1
V RC	23	.2	.0	.2
V RC	24	-.1	.1	.2
V RC	25	-.1	.3	.3
V RC	26	-.1	.3	.2
V RC	27	-.1	.3	.4
V ANT	28	.1	.4	.2
V ANT	29	-.1	.4	.2
V ANT	30	-.0	.6	.2
V ANT	31	-.1	.7	.1
V ANT	32	.2	.5	-.2
V ANT	33	.0	.4	.1
V ANT	34	.2	.9	-.4
V ANT	35	.0	.5	-.0
V ANT	36	.1	.7	-.1
V ANT	37	-.2	1.0	-.1
V ANT	38	..	.7	.2

Quantitative Items		Factors I	II	III
Q QC ARI	1	.2	-.1	.2
Q QC ARI	2	.4	.1	.0
Q QC ALG	3	.3	.2	-.0
Q QC GEO	4	.5	.1	.1
Q QC ALG	5	.2	.1	.3
Q QC ARI	6	.2	.2	.2
Q QC GEO	7	.2	-.1	.3
Q QC ALG	8	.3	-.1	.3
Q QC ARI	9	.3	-.2	.3
Q QC GEO	10	.6	.3	-.2
Q QC ALG	11	.6	.1	.1
Q QC GEO	12	.4	.2	-.0
Q QC ARI	13	.4	.2	.1
Q QC ALG	14	.4	.2	.1
Q QC GEO	15	.4	.3	-.0
Q DQ ARI	16	.4	-.3	.4
Q DQ ARI	17	.1	-.0	.2
Q DQ ALG	18	.5	-.1	-.0
Q DQ GEO	19	.5	-.0	.2
Q DQ ALG	20	.6	-.3	.3
Q DI	21	.7	-.0	.1
Q DI	22	.6	-.2	.2
Q DI	23	.1	-.1	.3
Q DI	24	.4	-.1	.2
Q DI	25	.5	.1	.1
Q DQ GEO	26	.4	.0	.1
Q DQ ARI	27	.5	.1	-.1
Q DQ ALG	28	.8	.2	-.1
Q DQ GEO	29	.7	-.0	-.0
Q DQ ALG	30	.7	-.2	.0

Analytical Items		Factors I	II	III
A AR	1	-.1	.1	.4
A AR	2	.0	0	.5
A AR	3	-.1	-.1	.4
A AR	4	.2	-.0	.4
A AR	5	-.0	.1	.5
A AR	6	.1	-.1	.5
A AR	7	.2	-.0	.4
A LR	8	-.1	.2	.4
A LR	9	-.0	.2	.5
A LR	10	.0	.3	.3
A AR	11	-.0	-.1	.5
A AR	12	.2	-.1	.6
A AR	13	.2	-.1	.4
A AR	14	.1	-.1	.5
A AR	15	-.0	-.2	.6
A AR	16	.2	.0	.4
A AR	17	.1	-.1	.5
A AR	18	.2	-.1	.6
A AR	19	.2	-.1	.5
A AR	20	.2	-.1	.7
A AR	21	.2	.0	.4
A AR	22	.2	-.0	.7
A LR	23	.2	.3	.2
A LR	24	.3	.3	.2
A LR	25	.4	.3	.3

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Appendix B

Method of Obtaining Variance Explained by Factors in an Oblique Factor Solution

Ledyard R Tucker (personal communication, April 14, 1987) provided the following method of obtaining variance explained by factors in an oblique factor solution.

Let B be the matrix of factor loadings on primary factors,
C be the correlation matrix of primary factors, and

D^{-1} be the square root of the diagonal of C^{-1}.

Then, G = BD, where G is the matrix of structure loadings on reference factors,

and the sum of squares of the structure loadings for each factor taken from G equals the total variance accounted for by that factor.