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A confirmatory factor analysis of selected factors of Guilford's Structure-of-Intellect model

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A CONFIRMATORY FACTOR ANALYSIS OF SELECTED FACTORS OF GUILFORD'S STRUCTURE-OF-INTELLECT MODEL

by

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A dissertation submitted to the Graduate Faculty in Educational Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

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ABSTRACT

A CONFIRMATORY FACTOR ANALYSIS OF SELECTED FACTORS OF GUILFORD'S STRUCTURE-OF-INTELLECT MODEL

by

MARTIN A. BUTLER

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LISREL (Joreskog & Sorbom, 1987) was utilized in a confirmatory factor analysis to investigate the validity of J.P. Guilford's Structure-of-Intellect (SOI) model. Three datasets of Guilford's were selected. The datasets were subjected to a series of analyses. Variables were grouped into a number of different models that had the potential to account for the intercorrelations. For the most part, not every dataset was cast into every model. The models included Guilford orthogonal, Guilford oblique, Thurstone oblique, Cattell oblique, g, second-order, multiple third level (Guilford), and hierarchical bi-factor. Various criteria were used to assess fit (X^2, p, GFI, AGFI, NFI, PNFI, RMSR). Support was found for the Guilford oblique, multiple third level, hierarchical bi-factor, and second-order models.

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CHAPTER I

PROBLEM STATEMENT AND REVIEW OF THE LITERATURE

This study is an investigation into the plausibility of a number of theories of intelligence. Earlier factor theories were built upon exploratory factor analytic methods. As solutions obtained from such methods are indeterminate, opposing theorists could argue the merits and validity of their own and other theories. Recent advances in statistical methods have made it possible to obtain factor structures which are more precisely defined.

This chapter presents an overview of intelligence theories and related research. Chapter II provides a discussion of statistical issues such as the types of factor analysis, the statistical program, LISREL, and significance testing. Chapter III outlines the study including the purpose and the datasets analyzed. In Chapter IV, the models analyzed are discussed. Chapter V presents the results and the discussion.

Various theories have been proposed to explain the nature and structure of human intellectual functioning. Some of these involve the use of statistical methods such as factor analysis. Factor analysis explains covariation among observed variables (usually tests) in terms of a smaller number of unobserved latent variables or factors (see Chapter II for a more complete description of factor analysis). Early in this century Charles Spearman (1904) postulated a theory with a general factor of intelligence that he called "g" and a set of specific factors, that he called "s". g was described as the mental energy that drives intellectual activities. Specific factors were the various forms by which the mental energy could be manifested, typically on a test. g, however, does not exert the same amount of influence on each test. These two types of factors, g and s, could account for the observed correlations among test scores.

In 1963 Raymond Cattell developed a theory with two general factors called fluid (g_f) and crystallized (g_c) intelligence. Fluid intelligence was defined as a capacity to perceive relations and integrate them mentally, independent of the senses. It was thought to have more genetic than environmental origins, and was thus largely innate. Tasks such as figural reasoning and abstracting represent fluid intelligence. Fluid tasks were generally conceived of as culture-fair. Crystallized intelligence was considered to be accumulated knowledge and skills. It was mostly environmentally determined. It was a reflection of education and experience, and was highly manifested in verbal tasks such as verbal comprehension. Horn and Cattell (1966) expanded the theory to include (a) general visualization, which represents processes of imagining the way objects move or can be perceived, (b) general speediness, which is measured in simple tasks but enters into most intellectual functions, (c) fluency or facility in the use of concept labels, which is an ability to bring words quickly into awareness from memory, and (d) carefulness, which indicates an unwillingness to make mistakes.

Philip E. Vernon (1950) also developed a theory of mental abilities which included a general factor. Vernon advanced the notion of g at the top of a factor hierarchy. Branching from g were the major group factors v:ed, which represented the verbal-numerical-educational sphere, and k:m, which represented practical, mechanical, spatial and physical abilities. Minor group factors branched off from the major group factors. Branching off from the minor group factors were specific factors. Figure 1 illustrates Vernon's theory.

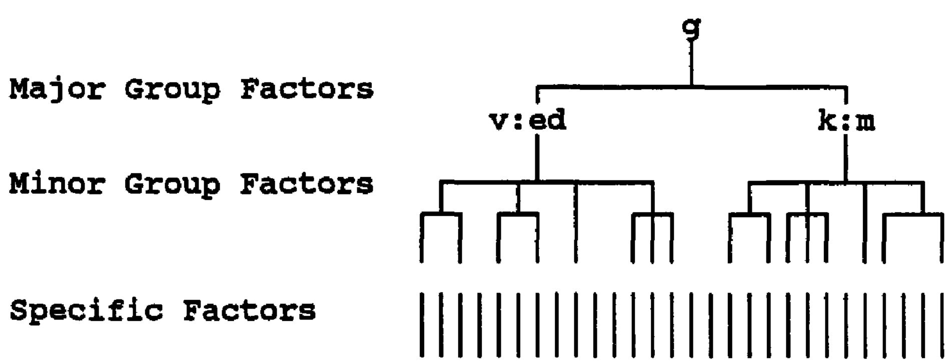

Figure 1. Diagram of Vernon's Hierarchical Structure of Human-Abilities.

Other theorists rejected the notion of a general factor of intelligence. Although Louis L. Thurstone was not the first proponent of the structural model of factor analysis, he is given credit for popularizing the notion of multiple abilities of intelligence (Mulaik, 1986: Guilford, 1972). Thurstone (1941) stated that he could claim no priority for discovering primary mental abilities. They had long been known as special abilities without being isolated factorially. Thurstone's dissatisfaction with the state of psychology in terms of intellectual abilities led him into the development of theory and quantitative methods for describing mental abilities.

In 1938 Thurstone explicated his theory, called Primary Mental Abilities (PMA). The factors he felt were significant at that time are:

Space (S) - facility in spatial and visual imagery;

Perceptual (P)- facility in perceiving detail that is embedded in irrelevant material;

Number (N) - facility in numerical calculation;

Verbal Relations (V) - facility with ideas and meaning of words;

Word Fluency (W) - facility in dealing with words;

Memory (M) - facility in remembering;

Induction (I) - facility with discovering rules or principles;

Reasoning (R) - general reasoning;

Deduction (D) - facility with discovering a rule and applying it.

Thurstone felt that the last two factors (reasoning and deduction) were only tentative, and were not as clear as the other seven factors.

Thurstone and Thurstone (1941) used the PMA factor structure in another study, the primary purpose of which was to extend the theory of primary mental abilities downward from adults to a younger age level. In their analysis of data from eighth grade students the Thurstones found the following factors: numerical, word fluency, space, perceptual, verbal comprehension, memory and induction. There were also three more factors that they named X1, X2 and X3. These X factors showed some similarity among variables within factors but the nature of the factors was not clear enough for them to be considered primary factors. The Thurstones felt confident that only the numerical, word fluency, space, verbal comprehension, memory, and induction factors had definite interpretations. As for the existence of g, a general factor, it could only appear as a second order-factor.

After analyzing perceptual tests, Thurstone (1944) postulated the existence of two closure factors: closure I (speed and strength of closure) and closure II (flexibility of closure).

Multiple-factor analysis was developed by Thurstone (1935, 1947) primarily to discover the number of group factors (factors which are represented by groups of interrcorrelated variables but not the entire set) necessary to account for test intercorrelations, and to determine weights that would indicate how much of the variance of each test was associated with each group factor. Thurstone kept a number of considerations in mind when developing his theory. One concept is that of parsimony or using the simplest possible explanation for phenomena. Simple structure is an example of Thurstone's application of this principle. In rotation of factors, (see Chapter II for a more detailed explanation) axes are located so that there are a maximum number of zero loadings. That is, there should be a large number of zeroes in the factor matrix. In addition, each test should load substantially on as few factors as possible. Thurstone utilized both oblique and orthogonal rotations in determining factor structure.

Thurstone felt that tests should be as factorially simple as possible. Each factor should be overdetermined, that is have numerous indicators. Three or four tests were considered the minimum necessary to enable a factor to be meaningfully interpreted. Although Thurstone felt that the tests he used to measure his factors were "pure" (that is, measured only one factor), other theorists (eg. Guilford, 1972) felt that such a model might not apply to other sets of variables. Guilford also felt that while some of Thurstone's factors represented unique abilities (perceptual speed, verbal comprehension, word fluency, and general reasoning), the other Thurstone factors (space, numerical facility, rote memory, induction, and deduction) were actually composites of two or more unique abilities.

Therefore Guilford (Guilford, 1956, 1959, 1967; Guilford and Hoepfner, 1971) developed a new theory that he called the structure-of-intellect (SOI) theory. This model, like Thurstone's, is a departure from intelligence models with a general factor.

In the original form of SOI there were 120 first level factors. (Guilford used the term "order" instead of "level"; in this study, "level" is used to avoid confusion with higher-order factor analysis models.) The 120 factors were obtained from combinations of one element from each of three dimensions: operations, contents, and products. An operation or psychological process acts upon a certain content or stimulus and this application results in a product. The resulting first level factor is represented by a trigram composed of the symbols for the particular operation, content, and product of interest. Capital letters stand for their respective elements in the trigram. The first letter represents the operation, the second letter the content and the third letter the product. For example, EBU represents the evaluation of behavioral units, and is called a first level factor. Second level factors are indicated by two fixed elements such as EB- or -BU or E-U. A third level factor is one of the elements of a dimension. For example, the operation of evaluation (E) is a third level factor. See Figure 2 for a structural diagram of SOI.

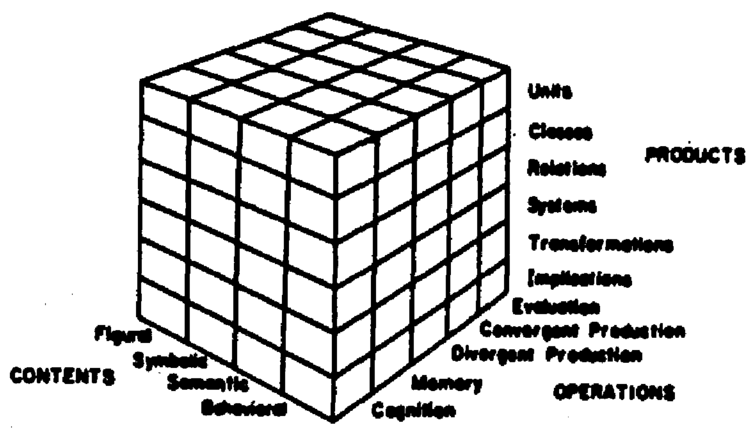

Figure 2. Diagram of Guilford's Structure-of-Intellect Model

Originally there were five kinds of operations, four of contents, and six kinds of products. This resulted in 15 third level factors. The descriptions of the 15 factors as defined by Guilford and Hoepfner (1971) are given below, along with the capital letter in parentheses used to represent that third level factor.

OPERATION

Evaluation (E) - comparison of items of information in terms of variables and making judgments concerning criterion satisfaction (correctness, identity, consistency, etc.); the process of comparing information in terms of known specifications with a given standard of information on the basis of logical criteria such as identity and consistency.

Convergent Production (N) - generation of logical conclusions from given information where emphasis is upon achieving unique or conventionally best outcomes. It is likely that the given (cue) information fully determines the outcome, as in mathematics and logic.

Divergent Production (D) - generation of logical alternatives from given information where the emphasis is upon variety, quantity, and relevance of output from the same source; likely to involve transfer recall (instigated by new cues).

Memory (M) - fixation of newly gained information in storage involving recognition and recall; the operation of memory is to be distinguished from the actual information stored in memory.

Cognition (C) - immediate discovery, awareness, rediscovery, or recognition of information in its various forms; comprehension or understanding.

CONTENT

Figural (F) - pertaining to information in concrete forms as perceived or as recalled in the form of images; the term "figural" minimally implies figure-ground perceptual organization; different sense modalities may be involved - visual, auditory, kinesthetic, and perhaps others.

Symbolic (S) - pertaining to information in the form of denotative signs having no significance in and of themselves, such as letters, numbers, musical notations, codes, and words (as ordered letter combinations).

Semantic (M) - pertaining to information in the form of conceptions or mental constructs to which words are often applied, hence most notable in verbal thinking and verbal communication, but not necessarily dependent upon words; meaningful pictures also convey semantic information.

Behavioral (B) - pertaining to information, essentially nonfigural and nonverbal, involved in human interactions where the attitudes, needs, desires, moods, intentions, perceptions, thoughts, etc. of others and of ourselves are involved.

PRODUCT

Units (U) - relatively segregated or circumscribed items or "chunks" of information having "thing" character; may be close to Gestalt psychology's "figure on a ground".

Classes (C) - conceptions underlying sets of items of information grouped by virtue of their common properties.

Relations (R) - connections between items of information based upon variables or points of contact that apply to them; relational connections are more definable than implicational connections.

Systems (S) - organized or structural aggregates of items of information, complexes of interrelated or interacting parts.

Transformations (T) - changes of various kinds (redefinitions, shifts, transitions, or modifications) in existing information.

Implications (I) - circumstantial connections between items of information, as by virtue of contiguity, or any condition that promotes "belongingness".

Guilford (1981) eventually split the figural content into two parts: Visual (V) and Auditory (A). In 1988 Guilford divided the memory factor in two. Memory recording fits the prior Guilford definition of memory in that it is a fixation process, although aspects of short-term memory are included. Memory retention concerns aspects of remembering and recall, both short- and long-term. These divisions have resulted in 180 first level factors. The number of third level factors now stands at 17. To see how a task is related to a particular first level factor, consider the following examples. With ability NSU (convergent production of symbolic units), the test Number-group Naming requires that a subject states how three numbers of a set are alike. Since one task is to find a common property, the test would be classified as the operation of convergent production. The use of numbers in this instance classifies the test as symbolic. The test Block Rotation is classified as a test of CFT (cognition of figural transformations). In this test the subject is shown a block as a stimulus and then chooses from a group of five different pictures the one which represents the original block after rotation. Recognition of information in its various forms classifies the test as the cognition operation. Blocks as images results in the figural content classification. The transformation product classification results because there is a change in the existing information.

Methodological Issues in SOI Research

SOI was developed over a 20 year period mainly with the Aptitudes Research Project (ARP). Approximately 40 analyses were performed from 1949 to 1969.

In the early years of the Aptitudes Research Project the Zimmerman (1946) method of graphic, orthogonal rotation of axes was used. With this method it was difficult to obtain meaningful and replicable factors.

Later Cliff's (1966) method of rotating toward hypothesized factor targets was the method Guilford used. The targets in the analyses were the expected SOI factors. Factors were still assumed to be orthogonal to each other or uncorrelated.

Eventually Guilford (1981) no longer insisted that factors be orthogonal rather than oblique. Support for the oblique nature of the structure-of-intellect model came from the research of Kelderman, Mellenbergh and Elshout (1981).

Although Guilford's SOI model of mental abilities is quite comprehensive, a number of criticisms have been levelled against it. Horn and Knapp (1973) felt that the factor analytic support for Guilford's theory was no better than the support for other theories of mental abilities. Regarding the use of Procrustes procedures, Horn and Knapp stated that different hypotheses by different investigators could produce different results due to differences in specification in the target matrices. An arbitrary theory would be the result as it is represented by a random target matrix. Horn and Knapp suggested the need for better methods of factor analysis with the inclusion of consideration of the proportion of confirmed hypotheses for a variable to the number of "hits" (total number of hypotheses) attempted, and the proportion of "extras" (factor coefficients in places where not postulated) to the number of hits plus extras. They felt that this would give a clearer picture of the factor structure. Vernon (1950) felt that caution was needed in evaluating Guilford's factors, as many of the factors were based on restricted samples of military personnel. Another criticism is that models such as the SOI cause an unnecessary proliferation of factors (Humphreys, 1962; Undheim and Horn, 1977).

Reanalyses have been called for of the Guilford data (Carroll, 1972; Horn and Knapp, 1973). Khattab, Michael and Hocevar (1982) felt that more rigorous and objective techniques than those used by Guilford are in order.

The few reanalyses of Guilford's data that have been performed have yielded mixed results. Confirmatory factor analyses of factors with transformation product abilities have shown support for this construct (Khattab, Michael and Hocevar, 1982; Khattab, Hocevar and Michael, 1987). In 1982 Khattab analyzed a correlation matrix from Guilford's original data of 46 SOI tests emphasizing the product of transformations. Four alternative models (Model I with five kinds of operations, Model II with four kinds of operations one of which combined cognition and convergent production as one factor, Model III with two types of content: semantic and symbolic, and Model IV with only the transformation product) were tested which considered the third level of SOI in accounting for the intercorrelations among the tests that had been hypothesized to represent first level abilities. Other results indicated that the five third level operations factors are not highly differentiable. Cognition and convergent production, in particular, appear to be very interrelated. Symbolic and semantic content are relatively discrete.

Khattab (1987) chose 35 of 47 tests (only factors defined by three or more tests were used) from an earlier study (Hoepfner, Guilford, and Bradley, 1968) and reanalyzed the intercorrelations utilizing confirmatory factor analysis. Four models were tested: 1) a model in accordance with Guilford's structure but with correlated factors, 2) a null model, 3) a randomly generated multifactor model, 4) a model with one factor. Eleven correlated first level factors were considered which emphasized the product of transformations. Results indicated that the eleven factors are differentiable. In another study of semantic and symbolic content abilities Khattab and Michael (1986) utilized confirmatory factor analysis to investigate the differentiability of these two third level content factors. The SOI tests were balanced so that transformation product did not predominate. The relative frequency of the products of units, class and implications was improved. Results indicated that semantic and symbolic content are easier to differentiate when elements of the tests are balanced.

Roid (1984) analyzed a subset of 26 SOI tests dealing with learning abilities. He performed a multiple group confirmatory factor analysis. Evidence for the construct validity of the content dimensions of figural, symbolic and semantic abilities at Guilford's third level was obtained.

Mace, Michael and Hocevar (1985) utilized confirmatory factor analysis to investigate whether first level factors involving semantic content and the operations of cognition or evaluation would validate first, second, and third level factors involving these dimensions. Support was found for the separateness of the hypothesized abilities at all three levels. The six hypothesized first level products were differentiable, as were the second level factors of cognition of semantic content and evaluation of semantic content. Evidence was found for a single third level or general factor representing semantic content. Thus it appears that evidence can be found for SOI factors when a restricted set of correlations and/or variables is analyzed. This can result in factors that are represented by a set of variables that are more replicable than those based on the larger set of Guilford variables.

CHAPTER II

FACTOR ANALYSIS

The purpose of this chapter is to give an overview of the two types of factor analysis, exploratory and confirmatory. Typically, factor analysis is used to summarize the relationships among a number of observed variables by hypothesizing a relatively small number of unobserved or latent variables.

Exploratory Factor Analysis

An exploratory factor analysis is a study which investigates an underlying factor structure without prior specification of numbers of factors and their loadings. Bentler (1976) describes exploratory factor analysis as the situation in which a theoretical understanding of the nature of factors is sought. There may not be enough previous empirical data or a well developed theory to suggest what possible factors might account for the covariation or correlations among observed variables in a given domain. The number of underlying factors as well as the makeup of these factors may be unknown. The nature of these dimensions may possibly be discovered through the process of theory development, formation of tentative hypotheses, performing an exploratory factor analysis, reformulation of hypotheses, additional exploratory analysis and initial confirmatory factor analyses.

The typical steps given by Bentler in an exploratory factor analysis are described below. First a theoretical analysis is undertaken. The aim is to make as explicit as possible the particular universe of some variables. Variables irrelevant to the domain of interest should be excluded. Previous research or other theories may provide clues as to how variables might cluster; these would compose potential factors. Marker variables (tests which in prior analyses had relatively high loadings on their factors) might be included in the analysis for a given factor. Consistently high loadings from marker variables can be useful in identifying a factor. In general, there should be many variables to measure a particular anticipated factor.

Selection of subjects is the next issue to be considered. There should be a large number of subjects, especially in relation to the number of variables. If there is a sufficiently large number of subjects, the sample could be split in half for the purpose of initial factor analysis followed by cross validation.

After administration of tests to the subjects and scoring the tests, all the intercorrelations among the variables are calculated. These intercorrelations are the input for factor extraction. Covariance matrices may also be analyzed. Factors may be extracted from the correlation matrix by the methods of principal components or factor analysis. Factor analysis includes the use of communalities (the proportion of total variance of a test which is held in common with a factor), whereas principal components does not. With factor analysis extraction methods include maximum likelihood, minimum residual, least squares, and other techniques. Various methods exist for determining the number of factors that should be extracted. One common way is to use the number of eigenvalues greater than one (an eigenvalue represents the amount of variance accounted for by a factor); or a scree plot of the eigenvalues or likelihood ratio X^2 test. Or the investigator can choose the number of factors to be extracted based on theory. Several analyses may be necessary with different numbers of factors extracted. The various solutions can be compared and the best one chosen. Along with statistical considerations, theoretical issues must be considered.

When the method of extraction and the number of factors have been ascertained, the solution is rotated or transformed. Rotation involves selecting meaningful axes to describe a dimensional space defined by factors. The observable criteria for a good rotation include simple structure and positive manifold. With simple structure, any test should be affected by one or very few factors only. Additionally, axes should be so located that there are a maximum number of zero loadings.

Positive manifold indicates that there are no negative correlations between a variable and the factor it loads on. When rotating factors, one may choose between orthogonal and oblique procedures. In an orthogonal procedure, factors are uncorrelated; with oblique procedures, factors are allowed to intercorrelate.

The results of an exploratory factor analysis are interpreted by studying the factor loading matrix to see which variables load highly on which factors. Potential names for the factors may be suggested, as well as a definition or a description of the factor itself. As an additional step, the results of an exploratory factor study may be compared with other factor studies concerning the same concepts.

Confirmatory Factor Analysis

Confirmatory factor analysis is a process in which specific expectations concerning the number of factors and their loadings are tested. One can also impose restrictions on factor correlations and unique variances. The results of an exploratory factor analysis can be tested. Confirmatory studies aid in establishing the factor structure when hypothesized factors and loadings are given statistical support. Findings from a previous study or a series of studies can be cross-validated. The hypothesis that a specific number of factors explains the covariation among the variables can be tested.

A good strategy is to compare the main hypothesis under study with one or more alternate hypotheses (Joreskog, 1974). Alternative hypotheses must be logically nested in order to be directly tested. That is, one model should be a special case of the other such that a restriction placed on one model will turn it into the other model. The hierarchical relationship allows for comparison of pairs of models. For instance, the one factor model is a special case of a group factor model in which the correlations among the group factors are restricted to equal one. Sometimes the alternative hypothesis takes the form of a no factor hypothesis. Or the hypothesis of interest may be conceptualized as a no factor hypothesis that will be tested against an alternative hypothesis.

LISREL

The computer program LISREL VI (Joreskog and Sorbom, 1986) was utilized for the analyses. LISREL provides a method of analyzing linear structural relationships through maximum likelihood estimation of the unknown coefficients in a set of linear structural equations. The models that can be analyzed include as special cases path analysis and confirmatory factor analysis.

The variables in the equations may be directly observed variables or unmeasured (latent) variables. The latent variables can be functions of observed variables or other latent variables and can be causes of either observed or latent variables.

There are two parts in the general LISREL model: the measurement model and the structural equation model. The measurement model is used to specify how the observed variables are measured in terms of the latent variables. The structural equation model is used to specify the causal links among the latent variables and describes the causal effects and the amount of unexplained variance.

Three parameter matrices are used in LISREL to specify a first-order factor analytic model. These matrices are called Lambda X (Λ_x), the matrix of factor loadings, Theta Delta ($\Theta\delta$), a matrix of unique factor variances and covariances associated with the observed variables, and Phi (Φ), the matrix of correlations among factors. The basic equation of factor analysis is:

$$X = \Lambda_x ç + \delta \qquad (1)$$

where X is a column vector of the observed variables (nx1), Λ_x is a rectangular matrix of factor loadings (nxq), ç is the column vector of latent variables (qx1), and δ is the column vector of errors (nx1) associated with the observed variables, X. Assuming δ is uncorrelated with ç, there are uncorrelated unique factors, and $\Theta\delta$ is a diagonal matrix, the variance-covariance matrix of the observed variables is expressed as:

$$\Sigma = \Lambda \Phi \Lambda' + \Theta\delta \qquad (2)$$

The matrix $\Theta\delta$ of residual variances and covariances is usually a diagonal matrix with uncorrelated unique factors. The matrix Φ of factor variances and covariances is usually symmetric, and often has fixed values of one in the diagonal, making the off-diagonal elements correlations.

In the LISREL program, the elements within parameter matrices can be fixed to certain values, left free to vary, or constrained to equal other parameters. As an example, consider a case in which there are four measures each of two factors. In the factor loading matrix below, x represents a free element and 0 represents an element fixed at zero. The ability to constrain parameters in LISREL allows for the imposition of a pattern of factor loadings to fit a preconceived hypothesis.

$$\Lambda x = \begin{bmatrix} X & 0 \\ X & 0 \\ X & 0 \\ X & 0 \\ 0 & X \\ 0 & X \\ 0 & X \\ 0 & X \end{bmatrix}$$

In this example, the phi matrix for two correlated factors would be represented as:

$$\Phi = \begin{bmatrix} 1 & \phi_{12} \\ \phi_{21} & 1 \end{bmatrix}$$

and $\phi_{12} = \phi_{21}$.

The residual variance-covariance matrix $\Theta\delta$ with uncorrelated errors would be:

$$\Theta\delta = \begin{bmatrix} \Theta_{\delta 1} & & & & & & & \\ 0 & \Theta\delta_2 & & & & & & \\ 0 & 0 & \Theta\delta_3 & & & & & \\ 0 & 0 & 0 & \Theta\delta_4 & & & & \\ 0 & 0 & 0 & 0 & \Theta\delta_5 & & & \\ 0 & 0 & 0 & 0 & 0 & \Theta\delta_6 & & \\ 0 & 0 & 0 & 0 & 0 & 0 & \Theta\delta_7 & \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \Theta\delta_8 \end{bmatrix}$$

The theta delta values on the diagonal are estimates of the unique variances in the observed variables. The off-diagonal elements are zero.

A second-order factor model results from factoring the intercorrelations of the first-order common factors. If they fit, second-order models are more parsimonious than first-order models. Fewer factors are necessary to explain the intercorrelations among the observed variables. For a second-order factor model, first-order factors are represented by η (qx1), the observed variables by y (nx1), and the vector of second-order factors by ç (rx1). The loadings of the observed variables on the first-order factors are contained in the matrix Λ_y (nxq). The matrix Γ (qxr) contains loadings of the first-order on the second-order factors. The first-order factors' residual variances are contained in the vector ψ; the observed variables' unique variances are contained in vector E (qx1). The equations for the observed variables in the second-order model take the form:

$$y = \Lambda_y \eta + E \qquad (3)$$

The equations for the first-order factors in terms of the second-order factors take the form:

$$\eta = \Gamma ç + \zeta \qquad (4)$$

Assuming that there are uncorrelated unique and common variables, and that the second-order factor's unique and common variables are not correlated with the first-order factor unique and common variables, the observed variance-covariance matrix of the y's is expressed as:

$$\Sigma = \Lambda_y (\Gamma \Phi \Gamma' + \Psi) \Lambda'_y + \Theta_\epsilon \qquad (5)$$

where $(\Gamma \Phi \Gamma' + \Psi)$ is the covariance matrix of the first-order factors, Φ is the covariance matrix of the second-order factors, Ψ is the variance-covariance matrix of the residuals of the first-order factors, and Θ_ϵ is the variance-covariance matrix of the unique variance in the observed variables. ΘE and Ψ are usually diagonal.

As an example, a model with three first-order factors, and three observed measures each is depicted below. In the factor loading matrix, y represents a free element and 0 represents an element fixed at zero.

$$\Lambda_y = \begin{bmatrix} y & 0 & 0 \\ y & 0 & 0 \\ y & 0 & 0 \\ 0 & y & 0 \\ 0 & y & 0 \\ 0 & y & 0 \\ 0 & 0 & y \\ 0 & 0 & y \\ 0 & 0 & y \end{bmatrix}$$

The phi (Φ) matrix for three correlated first-order factors for the above model is represented as:

$$\Phi = \begin{bmatrix} 1 & \phi_{12} & \phi_{13} \\ \phi_{21} & 1 & \phi_{23} \\ \phi_{31} & \phi_{32} & 1 \end{bmatrix}$$

The matrix Γ of the first-order factor loadings on the second-order factors is represented as:

$$\Gamma = \begin{bmatrix} \tau_1 \\ \tau_2 \\ \tau_3 \end{bmatrix}$$

Identification

A parameter is identified if it is uniquely determined (i.e., there are unique values for the parameter that are consistent with the population variances and covariances). Consistent estimates can then be made of that parameter. If all parameters of a model are identified, then the whole model is identified. The specification of fixed, free and constrained parameters, and the specific model determine whether the model is identified. The LISREL program provides an indication of the identification of the model. One necessary but not sufficient condition is that there are more variances and covariances than parameters in the model. If a parameter can be solved from an equation composed of relevant variances and covariances, the parameter is identified. Sufficient conditions for identification include: Φ is a positive definite matrix with diagonal $\Phi = 1$; Λ has at least k-1 fixed zeroes in each column, where k is the number of common factors; Θ is diagonal; Λ^k has rank k-1, where Λ^k (for $k = 1,2,...k$) is the submatrix of Λ consisting of the rows of n that have fixed zero elements in the k^{th} column. There can thus be said to be "rotational uniqueness" in identified models. There are potential problems associated with empirical underidentification especially if some of the factors are not correlated. Empirical underidentification is the condition in which a model is not identified due to certain conditions not holding true or model misspecifications. Small factor loadings and factor correlations near zero or one can also lead to empirical underidentification. Rindskopf (1984) outlines a series of steps for controlling the effects of empirical underidentification.

Assessment of Fit

A variety of statistical methods can be used in assessing which model provides the best fit to the data. Joreskog and Sorbom (1986) provide a number of methods. The chi-square (X^2) statistic is used to assess the overall fit of the model. X^2 compares the variance-covariance matrix implied by the model (Σ) to the variance-covariance matrix of the sample (S). It is valid if all the observed variables have a multivariate normal distribution, the analysis is based on the covariance matrix of the sample, and sample size is large. The chi-square value is evaluated relative to its degrees of freedom. If the chi-square value is much larger than the number of degrees of freedom, the model is typically rejected as not fitting. The formula for the degrees of freedom is given below.

$$df = 1/2k\ (k + 1) - t \qquad (6)$$

where k is the number of observed variables analyzed and t is the total number of independent parameters estimated.

The program gives the probability (p) that a X^2 value larger than the one actually obtained would be found, given that H_0 is true. A probability value close to zero indicates a poorly fitting model.

The goodness of fit index (GFI) is also a measure of overall fit and indicates the relative amount of variances and covariances jointly accounted for by the model. This value should be between zero and one with values close to one, indicative of a well-fitting model. The formula for GFI is:

$$GFI = 1 - tr\ (\Sigma^{-1}\ S - I\ )^2 \ /\ tr\ (\ \Sigma^{-1}\ \ S\ )^2 \qquad (7)$$

where tr is the trace (the sum of the diagonal elements) of the resulting matrix, S is the sample covariance matrix, Σ the fitted covariance matrix, and I is the identity matrix of the same order as S.

The adjusted goodness of fit index (AGFI) also gives an indication of overall fit. It is the GFI adjusted for degrees of freedom. This value is bounded by zero and one. A value close to one indicates a good fit between Σ and S. The formula for AGFI is:

$$AGFI = 1 - [k (k + 1) / 2df] (1 - GFI) \qquad (8)$$

where k is the number of measured variables and df are the degrees of freedom for the model.

The root mean square residual (RMSR) is another measure of overall fit: this is the square root of the average of the squares of residual variances and covariances. A well fitting model would be indicated by a value close to zero. The root mean square residual formula is:

$$RMSR = [\ 2\ \Sigma\Sigma_{ij}\ (s_{ij} - \sigma_{ij})^2 / k (k + 1)\ ]^{½} \qquad (9)$$

where k is defined as before and S_{ij} and σ_{ij} are corresponding elements of $\underline{S}$ and $\underline{\Sigma}$ respectively.

Normalized residuals are standardized to have a mean of zero and a standard deviation of one. (Looking at residuals by themselves can be misleading because they depend on a scaling unit.) They are used to detect the largest residuals, and should be less than the value two. If they are larger than two, a specification error (omission of relevant variables or factors, or inclusion of irrelevant variables or factors) in the model may be indicated. The equation for the normalized residual is defined by:

$$NMR = (S_{ij} - \sigma_{ij}) \;/\; \surd\; (S_{ii}\; S_{jj} + S_{ij}^{2}) \;/\; N \qquad (10)$$

where N is the sample size.

The Normed Fit Index (NFI) (Bentler & Bonett, 1980) is used to indicate if a particular model of interest is an improvement over the no factor model without considerations of sample size and statistical significance test information. An NFI value >.90 indicates that valuable information has been extracted from the data. The formula for the NFI is:

$$NFI = (X^{2}_{n} - X^{2}_{s}) \;/\; X^{2}_{n} \qquad (11)$$

The parsimonious normed-fit index (PNFI) was also considered in assessing fit (Mulaik, James, Van Alstine, Bennet, Lind, and Stilwell, 1989). James, Mulaik, and Brett (1982) noted that the NFI has the drawback of indicating better fit of a substantive model over a null model because the substantive model has a greater number of free parameters. The PNFI adjusts for the difference between the models' parameters. The formula for the PNFI is:

$$PNFI_{(j)} = (\; d_{j} \;/\; d_{0} \;)\; NFI_{(j)} \qquad (12)$$

where d_j equals the degrees of freedom of the substantive model, and d_0 equals the degrees of freedom of the null model.

The LISREL program provides modification indices. These are values which indicate where free parameters can be introduced to relax a model. A modification index provides information about the decrease in the value of the X^2 which will be obtained if a single constraint is relaxed and all other parameters are held fixed at their estimated values. The decrease in the X^2 will be at least as large as the modification index. Only one parameter at a time should be relaxed, usually starting with the largest one, if it makes theoretical sense to relax that parameter. Fit of the model may thus be improved.

Consideration is also given to the parameter estimates. There should be no negative variances, correlations greater than one, or covariances or correlation matrices that are not positive definite. Extremely large standard errors and parameter estimates that are highly correlated indicate poor model fit. If this happens the model may be nearly non-identified, and some of the parameters cannot be determined accurately.

Although not really measures of fit, squared multiple correlations (the square of the correlation coefficient expressing the closeness of the linear relationship between two or more variables) indicate the importance of variables in the model. They represent the proportion of variance explained in observed variables based on common factor variables. The LISREL program provides squared multiple correlations for each observed variable separately and for each structural equation. The communality of a variable is its squared multiple correlation with the factors. The coefficient of determination (a measure of the strength of several relationships jointly) is provided by the program for all the observed variables jointly and for all structural equations jointly.

CHAPTER III

THE STUDY

Purpose

The purpose of the present study was to investigate the tenability of part of Guilford's structure-of-intellect model. As noted previously, reanalyses of Guilford's results have been called for in order to address the technical and theoretical issues raised by Guilford's theory. This investigation involved the reanalysis of portions of some of Guilford's datasets in terms of several possible models of intellect.

The data cut across the operations of cognition, evaluation, divergent production, convergent production, and memory; the contents of semantic and symbolic; and the products of units, relations, classes, and implications. Examination of these factors helps to establish their validity.

Datasets

The studies chosen for analysis are the University of Southern California Psychological Laboratory Reports Numbers 22, 33 and 37. Criteria for choosing the studies are as follows: (a) Later studies (post 1958) which were conceptualized within the SOI framework were desired. The factor structure of earlier studies may have been inconsistent with the fully explicated model, or the factors themselves may have been measured by invalid or unreliable tests. Guilford felt that some of the factors in the earlier studies were inappropriate for finding common factors within a study.

(b) The factors hypothesized by Guilford had to be supported by his results. If results did not turn out as Guilford expected, the possibility of confounding influences on the factors excluded a lab report from the current study. (c) Within each study the factors of interest are defined by a minimum of two tests. At least three tests are necessary for identification of parameters for uncorrelated factors; two tests are necessary for identification of parameters with correlated factors.

(d) The factors proposed by the USC reports must be transformable into factors recognized by other theorists (Thurstone and Cattell).

(e) The chosen studies must have only one correlation matrix each. Those studies with multiple batteries were not considered.

(f) Studies with a figural content were avoided, because this has been split into the dimensions of visual and auditory contents. These new contents have not been heavily investigated. Also avoided were areas that have been researched extensively (i.e. transformation products, Khattab, Michael and Hocevar, 1982, 1987).

The following studies fit the above criteria:

(a) USC Laboratory Report Number 22 is a factor analytic study of problem solving abilities conducted by Merrifield, Guilford, Christensen and Frick (1960). Fourteen factors were extracted from 42 variables. Of these fourteen factors, six factors comprised of 22 variables were used in the analysis. The sample employed by Guilford consisted of 219 naval air cadets and aviation officer candidates. See Appendix A for the correlation matrix for dataset 22.

(b) Symbolic evaluation factors were studied in Laboratory Report Number 33 by Hoepfner, Guilford and Merrifield (1964). Twenty factors were extracted from a correlation matrix of 58 variables. Four factors comprised of 13 variables were chosen for this study. The test sample consisted of 225 students from a California high school senior class (86 males, 139 females). The mean age of the students was 17.4. The estimated mean IQ was 110.4, with IQ's ranging from 80 to 151. See Appendix A for the correlation matrix for dataset 33.

(c) Brown, Guilford and Hoepfner (1966) investigated semantic memory abilities in Lab Report Number 37. A correlation matrix of 59 variables yielded 17 factors. For the current analysis, twenty variables, which load on five factors, were chosen. A native English-speaking eleventh grade population of 175 students (88 males, 87 females) in California comprised the sample upon which analyses were based. They reportedly showed no evidence of behavioral or motivational problems. See Appendix A for the related correlation matrix.

The factors chosen for analysis, their denotative trigrams and the variable numbers and names associated with them are listed in Appendix B. Variables used for analysis load at least .30 on their respective factors. Although the factors hypothesized by Guilford were borne out, not all of the tests designed to measure them loaded as hypothesized. In the current study, the variables and factors were put into models in accordance with the factor structure that resulted from Guilford's research, not as the original models were hypothesized. Appendix C gives a description of the tests for the three datasets.

CHAPTER IV

THE MODELS

The variables in each reduced correlation matrix were conceptualized in terms of a number of models that might explain the intercorrelations among the variables.

Model I is in accordance with Guilford's theory as he developed it. Each factor represents a first level in the theory (i.e., a specific combination of operation, content, and product). The factors are orthogonal. Tables 1 through 3 show the structure of Model I for the three datasets.

Model II is an oblique model. The factors are composed as in Model I, but are allowed to be correlated. Tables 1 through 3 show the structure of these group factors. Again factors at Guilford's first level (e.g. CMU) were considered.

The third class of models is also a group factor model, but is based upon Thurstone's work. For the most part the number of expected factors is smaller than for Guilford's model, although the number of variables is the same. Datasets number 22 and 37 were analyzed in the Thurstone framework, because the datasets contain factors of Guilford's which can be conceptualized and grouped into a Thurstone model. Dataset 33 contains Guilford factors that transform into Thurstone's model on a one-for-one basis. Thus for dataset 33, a Guilford group factor model and a Thurstone group factor model are the same structurally. Tables 4 and 5 indicate how Guilford's variables load on Thurstone factors.

The fourth model tested is one based on Cattell's theory. Table 6 shows how variables from Guilford's datasets load on Cattell's factors. Dataset 22 appears to contain variables from three of Cattell's factors: g_f, g_c and fluency.

Factors g_f and g_c also seem to be in evidence in dataset 33. Table 7 indicates how the Guilford variables load on the Cattell factors. In dataset 37 the variables sort into two factors on the same lines as they do for the Thurstonian model. Thus a test of a Cattell model for dataset 37 is redundant.

The fifth set of models is in some ways similar to the multitrait-multimethod model in which each variable is a measure of one trait and one method factor. Analyses were performed on Guilford's third level of factors (e.g. C, M, D, E,). Each observed variable loads on at least one operation, content, and product factor hypothesized for the test. The third level factors were allowed to intercorrelate. This model is the multiple third level model. Tables 8 through 10 indicate which of Guilford's variables were expected to load on specific factors.

A model in which all variables are allowed to load on one single factor is the sixth class of model tested. This could represent a general factor. This model is actually nested within the fifth set of models. Tables 11 through 13 indicate the variables loading on one factor for a particular dataset.

Models composed of group factors which are allowed to intercorrelate to measure a single second-order factor is the seventh class of model considered. For dataset 22 the factors that were considered to be verbal in Thurstone's theory are grouped into three first-order factors. The first verbal factor is composed of variables that incorporate a generative component. The second verbal factor deals with understanding problems. The third verbal factor concerns understanding the meaning of words and concepts. Table 14 indicates the first- and second-order factors. This model was not testable as the second-order structure is just identified.

In dataset 33 the same variables load on the same factors in the Thurstone and Guilford models. A second-order general factor was tested for from the four factors at the first-order level (see Table 15.) Only dataset 33 had a testable second-order factor model.

In dataset 37 two memory factors appeared to be in evidence from the variables Thurstone would consider to be measures of a memory factor. The first memory factor involves remembering associated content. The second memory factor involves memory of facts and information. Table 16 indicates the first- and second-order factor structure. This model was not testable as the second-order structure is not identified.

A hierarchical bi-factor model also was tested. In this model the variables load on group factors and also on a general factor. The general factor is uncorrelated with the group factors. The group factors were the same ones outlined for the second-order factor models. For dataset 22, variables loaded on three verbal factors and on one general factor. In dataset 33, the variables load on four group factors and on one general factor. In dataset 37, variables load on two memory factors and on one general factor. Tables 17 to 19 show the structure of Model VIII for the three datasets. Table 20 shows which models were tested on a particular dataset.

CHAPTER V

Results

Results are organized by dataset. Within each dataset, model fit is indicated. A summary table is presented for each dataset such that for each model, fit is indicated by five indices: GFI, AGFI, NFI, PNFI and X^2. Joreskog and Sorbom (1986) indicate that a value approaching 1.0 on a scale ranging from 0 to approximately 1.0 for the GFI and AGFI indices indicates good fit of a model. Bentler and Bonett (1980) use a value of .90 or greater to indicate good fit for the NFI. James et al. (1982) indicate that the PNFI value should fall between zero and unity, but is typically less than the NFI value as it compensates for the increase in fit due to the estimation of a model with more parameters.

Dataset 22

Results for the seven models tested on dataset 22 are described below. Dataset 22 has a sample of 219 subjects. This is large enough to ensure that poor fit of a model is not due to a small sample size. X^2, p, and RMSR results are indicated. Table 21 lists GFI, AGFI, NFI, PNFI, and X^2

results.

Model I: Guilford Orthogonal

The Guilford orthogonal model does not explain the intercorrelations among the observed variables. $X^2 = 857.48$ (df = 216) = 216), $p = 0.0$, RMSR = 0.206. The GFI, AGFI, NFI, and PNFI values also indicate that the model fits poorly. Adjustments to the original model based on modification indices did not improve the fit of the model.

Model II: Guilford Oblique

The Guilford model with intercorrelations permitted among the factors provides a potential model to adequately explain intercorrelations among the observed variables. $X^2 = 312.31$ (df = 193), $p = 0.0$, RMSR = 0.071. The GFI and AGFI values indicate fairly good fit. The NFI value, however, does not indicate good fit. The PNFI value for this model is the highest obtained for this dataset. This indicates relatively good fit.

Model III: Thurstone

The Thurstone model with regrouped variables does not explain the observed data. $X^2 = 570.46$ (df = 208), $p = 0.0$, RMSR = 0.091. The GFI, AGFI, NFI, and PNFI values do not indicate good fit. Introduction of parameters based upon modification indices did not improve fit of the model.

Model IV: Cattell

Fit measures for the Cattell model indicate that this model does not explain the intercorrelations among the observed tests. X^2 = 474.42 (df = 206), p = 0.0, RMSR = 0.083. The GFI, AGFI, NFI, and PNFI values indicate poor fit. No better fit was achieved by introducing additional parameters.

Model V: Multiple Third Level

The multiple third level model fits the data well. X^2 = 183.65 (df = 159), p = 0.088, RMSR = 0.048. GFI and AGFI values indicate good fit. The NFI value indicates fairly good fit. The PNFI value for this model is the second highest value obtained for this dataset. This indicates relatively good fit.

Model VI: g

The single factor model also did not fit the observed data. X^2 = 587.46 (df = 209), p = 0.0, RMSR = 0.091. GFI, AGFI, NFI, and PNFI values indicate poor fit.

Model VIII: Hierarchical bi-factor

Certain fit values for the hierarchical bi-factor model indicate that this model provides an adequate explanation for the intercorrelations among the observed variables. Although X^2 = 393.28 (df = 188), p = 0.0, and RMSR = 0.113, the GFI value indicates good fit. However, AGFI, NFI, and PNFI values also indicate poor fit.

Dataset 33

Dataset 33 results are described below. Seven models were tested on this dataset. The sample size for this dataset is 225. This number of subjects is large enough to avoid problems of poor fit due to small sample size. X^2, p, and RMSR results are indicated. Table 22 lists the GFI, AGFI, NFI, PNFI, and X^2 results.

Model I: Guilford Orthogonal

The Guilford orthogonal model does not explain the intercorrelations among the observed variables. $X^2 = 281.15$ (df = 60), p = 0.0, RMSR = 0.199. GFI, AGFI, NFI, and PNFI values indicate poor fit. No fit was achieved by introduction of new parameters.

Model II: Guilford Oblique (and Model III: Thurstone)

Some fit values for the Guilford oblique model indicate that this model does fit the observed data well. $X^2 = 83.99$ (df = 54), p = 0.006, RMSR = 0.047. GFI, AGFI, NFI and PNFI values indicate good fit.

Model IV: Cattell

The Cattell model does not explain the intercorrelations among the observed variables for dataset 33. $X^2 = 242.25$ (df = 64), p = 0.0, RMSR = 0.090. The GFI, AGFI and NFI indicate poor fit. The PNFI value is the second highest obtained for this dataset. No fit was achieved by introducing parameters based on the modification indices.

Model V: Multiple Third Level

The multiple third level model provides a plausible explanation for the observed intercorrelations based on certain fit indices. $X^2 = 64.20$ (df = 26), RMSR = 0.034. The third level operation element, evaluation, was deleted from this study to obtain fit. Although $p = 0.0$, the GFI, AGFI and NFI values indicate good fit. The PNFI value indicates poor fit as it is the lowest for this dataset.

Model VI: g

The g model does not explain the intercorrelations among the observed variables. $X^2 = 216.88$ (df = 65), $p = 0.0$, RMSR = 0.091. GFI, AGFI and NFI values indicate poor fit. The PNFI value is among the highest such values for this dataset, however.

Model VII: Second-order Factor

The introduction of a second-order factor helps to adequately explain the observed intercorrelations. $X^2 = 111.59$ (df = 56), RMSR = 0.050. Although $p = 0.0$, the GFI value indicates good fit; the AGFI and NFI values indicate fairly good fit was achieved (these values are just under .90). The PNFI value for this model is one of the highest PNFI values obtained for this dataset.

Model VIII: Hierarchical bi-factor

The hierarchical bi-factor model does provide a possible explanation for the observed variables' intercorrelations. $X^2 = 88.44$ (df = 46), $p = 0.0$, RMSR = 0.043. GFI and NFI values indicate good fit and the AGFI value indicates fairly good fit. The PNFI value is relatively low.

Dataset 37

The results of the models tested on dataset 37 are presented below. Six models were tested on this dataset. There are 175 subjects for dataset 37. A sample of this size is large enough to avoid the problems associated with small sample size such as lack of fit. X^2, *p*, and RMSR values are indicated. Table 23 lists the GFI, AGFI, NFI, PNFI, and X^2 values.

Model I: Guilford Orthogonal

This orthogonal model of Guilford's does not give a plausible explanation for the observed intercorrelation among the variables. $X^2 = 683.38$ (df = 175), *p* = 0.0, RMSR = 0.322. The GFI, AGFI, NFI, and PNFI values indicate a poorly fitting model. Introduction of new parameters did not produce a fitting model.

Model II: Guilford Oblique

The Guilford oblique model nearly provides an adequate explanation for the observed data. $X^2 = 236.13$ (df = 159), *p* = 0.0, RMSR = 0.055. Fairly good fit is also indicated by the GFI, AGFI and NFI values which approach .90. The PNFI value is the highest such value obtained for this dataset. This indicates relatively good fit.

Model III: Thurstone (and Model IV: Cattell)

Fit values for the Thurstone model do not indicate a plausible explanation for the observed intercorrelations. $X^2 = 343.70$ (df = 169), $p = 0.0$, RMSR = 0.068. GFI, AGFI values indicate poor fit. The PNFI value is the second highest value obtained for this dataset. This indicates relatively good fit. No fitting model was obtained by relaxing restrictions placed upon the model.

Model V: Multiple Third Level

The multiple third level model gives a plausible explanation for the observed data. Good fit was obtained per the following values: $X^2 = 121.85$ (df = 117), $p = 0.247$, RMSR = 0.037. GFI, AGFI and NFI values also indicate good fit. The PNFI value which is the lowest such value for this dataset indicates relatively poor fit. The third level product element of class was deleted to obtain fit for this model.

Model VI: g

The single factor model does not adequately explain the intercorrelations among the observed variables. $X^2 = 438.75$ (df = 170), $p = 0.0$, RMSR = 0.077. GFI, AGFI, and NFI values indicate poor fit. The PNFI value is the third highest such value obtained for this dataset.

Model VIII: Hierarchical bi-factor

Explanation of the observed intercorrelations was provided by the hierarchical bi-factor model. $X^2 = 134.53$ (df = 75), $p = 0.0$, RMSR = 0.046. The GFI, AGFI and NFI values also indicate good fit. The PNFI value is the fourth highest value obtained for this dataset.

A X^2 likelihood ratio test between the two nested models (Guilford oblique and Guilford/Thurstone hierarchical bi-factor) which each gave a good fit to the observed data was performed. $X^2 = 4.45$ (df = 8). The second-order factor model for dataset 33 is a restricted version of the Guilford oblique model for the same dataset. A comparison of the X^2 statistics for the two models yields a significant $X^2 = 27.6$ (df = 2).

Discussion

This study was an attempt to resolve the problem of choosing among certain theories of intelligence. Early theorists were in conflict over what factor model was "correct" for cognitive data. They could not resolve the conflict. One reason for the lack of resolution was the statistical methodology used. The statistical tools to correctly ascertain which model was more plausible than another did not exist. Some models might be equivalent and could not be discriminated. We now do have such tools. LISREL provides such a tool with its ability to exactly define factor model parameters. Thus this study is not just a series of testing of models, but an investigation into the plausibility of actual intelligence theories.

Results of confirmatory factor analyses of the Guilford datasets modelled after Guilford and other theorists were all of the same trend. Certain of the models were confirmed or shown to provide a plausible explanation for the data. Fit values indicated whether or not a model explained the intercorrrelations among the observed variables. Indices utilized were X^2, $\underline{p}$, GFI, AGFI, RMSR, NFI, and PNFI. These results seem to be in accord with the Kelderman (1981) and Khattab (1982) studies which found equivocal support for Guilford's theory.

Inspection of the LISREL estimates for the factor loading matrices indicates that the the observed variables usually tended to load where hypothesized with estimates of .30, even when overall indicators demonstrated poor fit. There were no problems with identification or convergence.

For models that did not fit the data on the initial analysis, fit was not achieved even when the models were relaxed by the freeing additional parameters indicated by modification indices. For models that fit, new parameters were not always introduced automatically to try to achieve a better fit. Models with many additional parameters introduced were too different from the hypothesized model, and too close to a saturated model to be considered a viable alternative model. Such a model would have represented a compromise and the aim of this study was to investigate the plausibility of various theories, not necessarily to find a well fitting model. Other studies have been performed with highly selected variables. This study was more interested in highly selected factors.

There are several possible reasons why some models did not provide a plausible explanation of the data. There may not have been enough variability among the subjects. Restriction of range may have contributed to lack of fit. Military subjects comprised the sample in one of the datasets and high school students were the subjects in the other two datasets. Ability levels of tested subjects should cover a substantial range of individual differences in order to properly test correlational theories of intelligence by such techniques as factor analysis (Sternberg, 1977). Even for the well fitting models, the question of generalizability to other populations is unresolved.

Another reason for lack of fit may be possible confounding within the tests used by Guilford. That is, any one test may be a measure of more than one factor. Such variables could not be expected to become distinguished clearly.

Other theories might better explain the intercorrelations among the observed variables. Only a small sample of intelligence theories was utilized in testing Guilford's data. There is thus the possibility that another theory or a variant of one could adequately explain the data. Guilford himself was considering revisions of his model shortly before his death (Guilford, 1988).

A problem with intelligence models in general is indicated by the results. Can an abstract construct be quantified when there is much disagreement over how it is qualified or defined? The fall from favor of Guilford's model of intelligence and of intelligence theorizing in general could be due to the lack of a universally agreed-upon definition of this concept. Sternberg's (1977, 1986, 1986) investigation of intelligence through componential analysis and demonstration of abilities will most likely provide the next major definition of intelligence. Or it may be that Guilford's model represents only a component of another model as in Gustafsson's HILI-model (1984).

The present investigation hopefully sheds some light into the plausibility of Guilford's theory as a viable model of intelligence or at least as a starting point for building such a model. As Sternberg (1986) points out, a theory such as Guilford's indicates the many ways in which a person can be intellectually gifted.

Across the three datasets, one model that tended to fit according to GFI, AGFI, and NFI criteria was the Guilford oblique factor model. Thus, there is some support for the validity of factors CMU, EMI, CMR, DMR, CMC, and NMI in dataset 22. For dataset 33, factors CSU, MSI, NSI and ESU received some support. Factors MMU, MMI, MMR, DMC, and DMI are supported in dataset 37. This suggests that a plausible explanation of the observed data would be provided by models allowing correlated group factors from Guilford's theory. This result is similar to Kelderman's (1981) findings. A different regrouping of the variables according to some salient features other than the ones used might a yield an even better fitting model.

The original Guilford model is multiplicative. There are 120 first level factors resulting from the cross-tabulation of the operations, contents and products. The multiple third level model is additive, summing the operations, contents and products.

The good fit achieved by the multiple third level models for the three datasets gives support to the hierarchical nature of SOI. While the higher factors do not necessarily represent a higher order, they do seem to be of a broad nature. The first level factors appear to group in a fashion indicative of Guilford's overall abilities. Multiple third level factor models are less parsimonious here because of the limited number of third level elements. In dataset 22, the only content element is semantic; symbolic is the only content in dataset 33 and semantic is the only content in dataset 37. Thus, these models contain a general factor also.

Eventhough the PNFI indicates relative fit, the degrees of freedom indicate a greater number of parameters for Model

II (Guilford oblique) compared to Model V (multiple third level) for all three datasets. One would expect Model V to have the greater number of parameters as it contains more loadings.

Use of fit indices other than X^2 gives a clearer picture of fit. The GFI, AGFI, NFI, and PNFI are not so bound with considerations of sample size as is the X^2. The NFI values for the fitting models indicate a substantial improvement over the no factor model and there is little of importance to be explained by the remaining data. The PNFI typically yielded lower values in adjusting for parsimony. The reduction in fit was sometimes so great as to indicate relative lack of fit even for models that appeared to fit well based on other criteria.

The hierarchical bi-factor models also provide good explanations for the observed intercorrelations. Once again, the measures most relevant for indicating fit are the GFI, AGFI, NFI, and PNFI. For dataset 22, correlated Thurstone verbal factors and an uncorrelated general factor seem to be in evidence. In dataset 33, support was found for correlated Guilford/Thurstone factors along with an uncorrelated general factor. In dataset 37, correlated Thurstone memory factors and an uncorrelated general factor received some support. The second-order factor model for dataset 33 with Guilford/Thurstone first-order factors and one second-order factor also fit the data. These results indicate that the best explanation for Guilford's data might be a model which contains a single factor from correlated group factors. However, the X^2 likelihood ratio test performed between dataset 33 Guilford oblique and hierarchical models would tend to support the conclusion that the simpler Guilford oblique model should be accepted. The significant result of the comparison between the second-order model and the Guilford oblique models for dataset 33 indicates that neither model model can be said to be more plausible than the other.

Guilford's original model with correlations among factors can provide a parsimonious explanation for the intercorrelations among the observed variables in terms of the number of factors. Comparing the multiple third level model to the hierarchical bi-factor model indicates a reduced number of factors can explain observed variables' intercorrelations.

The Guilford orthogonal model did not fit the data. The other models in which good fit was not achieved were the single factor model and the Cattell model.

In sum, on the basis of the results, I conclude that the Guilford model of intelligence with correlations allowed among the factors provides a plausible explanation for the intercorrelations among the observed variables. Support has been found for Guilford's factors with an oblique structure. Those models with correlated group factors and a single factor (second-order and hierarchical bi-factor) also provide plausible explanations for the observed data. There is also very strong support for the hierarchical nature of Guilford's SOI model as indicated by the results of the multiple third level models. By extension, support has also been garnered for Thurstone's PMA model. Fit for models with overlapping Guilford and Thurstone factors was obtained.

Guilford's theory may provide a generally acceptable taxonomy of human abilities. It certainly appears comprehensive enough. The results reported here provide support for his theory. His theory can thus point to areas to be utilized in theory building, test construction, assessment and remediation. All of his datasets have not been reevaluated. Thus it is possible that more support for his theory would be obtained if additional confirmatory factor analyses were conducted.

Table 1

Dataset 22 Variables and First Level Factors

Variable Number	Factor Name: CMU	EMI	CMR	DMR	CMC	NMI
3	X			X		
5						X
6				X		
16			X			
17	X					
19					X	
20				X		
24		X				
25		X				
26		X				
27					X	
28						X
30				X		
31	X					
32		X				
33			X			
34			X			
35					X	
36					X	
37	X					
38	X					
39	x					

Table 2

Dataset 33 Variables and First Level Factors: Guilford

	Factor Name			
Variable Number	CSU	MSI	NSI	ESU
2			x	
9	x			
11				x
12	x			
14			x	
19			x	x
20			x	x
24		x	x	
31		x	x	x
36				x
41		x		
44	x			
47		x		

An x means that a particular variable is loading on a specific factor.

Table 3

Dataset 37 Variables and First Level Factors: Guilford

Variable Number	MMU	MMI	MMR	DMC	DMI
	Factor Name				
1				X	
4		X			
6		X			
10			X		
14					X
18	X				
21			X		
22			X		
23		X			
26	X				
27					X
30					X
32			X		
33	X				
34		X			
35			X		
43	X				
44	X				
47				X	
50	X				

Table 4

Dataset 22 Variables and Factors: Thurstone Model

	Factor Name	
Variable Number	Verbal	Deduction
3	x	
5		x
6	x	
16	x	
17	x	
19	x	
20	x	
24	x	
25	x	
26	x	
27	x	
28		x
30	x	
31	x	
32	x	
33	x	
34	x	
35	x	
36	x	
37	x	
38	x	
39	x	

Table 5

Dataset 37 Variables and Factors: Thurstone Model

Variable Number	Factor Name: Memory	Factor Name: Word Fluency
1		x
4	x	
6	x	
10	x	
14		x
18	x	
21	x	
22	x	
23	x	
26	x	
27		x
30		x
32	x	
33	x	
34	x	
35	x	
43	x	
44	x	
47		x
50		x

Table 6

Dataset 22 Variables and Factors: Cattell Model

Variable Number	Cattel Factor g_f	g_c	fluency
3		x	
5		x	
6			x
16	x		
17		x	
19		x	
20			x
24		x	
25		x	
26		x	
27		x	
28		x	
30			x
31		x	
32		x	
33	x		
34	x		
35		x	
36		x	
37		x	
38		x	
39		x	

Table 7

Dataset 33 Variables and Factors: Cattell Model

	Cattell Factor	
Variable Number	g_f	g_c
2		x
9	x	
11	x	
12	x	
14		x
19		x
20		x
24		x
31		x
36	x	
41		x
44	x	
47	x	

Table 8
Dataset 22 Variables and Factors: Multiple Third Level

	Third Level Factor								
Variable	Operation				Content	Products			
Number	C	E	D	N	M	U	I	R	C
3	x		x		x	x		x	
5				x	x		x		
6			x		x			x	
16	x				x			x	
17	x				x	x			
19	x				x				x
20			x		x			x	
24		x			x		x		
25		x			x		x		
26		x			x		x		
27	x				x				x
28				x	x		x		
30			x		x			x	
31	x				x	x			
32		x			x		x		
33	x				x			x	
34	x				x			x	
35	x				x				x
36	x				x				x
37	x				x	x			
38	x				x	x			
39	x				x	x			

Table 9

Dataset 33 Variables and Factors: Multiple Third Level

Variable Number	Operation C	M	N	E	Content S	Products U	I
	Third Level Factor						
2			x		x		x
9	x				x	x	
11				x	x	x	
12	x				x	x	
14			x		x		x
19			x	x	x	x	x
20			x	x	x	x	x
24		x	x		x		x
31		x	x	x	x	x	x
36				x	x	x	
41		x			x		x
44	x				x	x	
47	x				x		

Table 10

Dataset 37 Variables and Factors: Multiple Third Level

Variable Number	Third Level Factor: Operation M	D	Content M	Products U	I	R	C
1		x	x				x
4	x		x		x		
6	x		x		x		
10	x		x			x	
14		x	x		x		
18	x		x	x			
21	x		x			x	
22	x		x			x	
23	x		x		x		
26	x		x	x			
27		x	x		x		
30		x	x		x		
32	x		x			x	
33	x		x	x			
34	x		x		x		
35	x		x			x	
43	x		x	x			
44	x		x	x			
47		x	x				x
50	x		x	x			

Table 11

Dataset 22 Variables and Factors: Single Factor Model

Variable Number	Single Factor
3	x
5	x
6	x
16	x
17	x
19	x
20	x
24	x
25	x
26	x
27	x
28	x
30	x
31	x
32	x
33	x
34	x
35	x
36	x
37	x
38	x
39	x

Table 12

Dataset 33 Variables and Factors: Single Factor Model

Variable Number	Single Factor
2	x
9	x
11	x
12	x
14	x
19	x
20	x
24	x
31	x
36	x
41	x
44	x
47	x

Table 13

Dataset 37 Variables and Factors: Single Factor Model

Variable Number	Single Factor
1	x
4	x
6	x
10	x
14	x
18	x
21	x
22	x
23	x
26	x
27	x
30	x
32	x
33	x
34	x
35	x
43	x
44	x
47	x
50	x

Table 14

Dataset 22 First- and Second-Order Factors

First-Order Factor	Second-Order Factor
Verbal 1	x
Verbal 2	x
Verbal 3	x

Table 15

Dataset 33 First- and Second-Order Factors

	Second-Order Factor
First-Order Factor	
CSU	x
MSI	x
NSI	x
ESU	x

Table 16

Dataset 37 First- and Second-Order Factors

	Second-Order Factor
First-Order Factor	
Memory 1	x
Memory 2	x

Table 17

Dataset 22 Variables and Factors: Hierarchical Model

Variable Number	General Factor	Verbal 1	Verbal 2	Verbal 3
3	x	x		
6	x	x		
16	x			x
17	x			x
19	x			x
20	x	x		
24	x		x	
25	x		x	
26	x		x	
27	x			x
30	x	x		
31	x			x
32	x		x	
33	x			x
34	x			x
35	x			x
36	x			x
37	x			x
38	x			x
39	x			x

Table 18

Dataset 33 Variables and Factors: Hierarchical Model

Variable Number	General Factor	CSU	MSI	NSI	ESU
2	x			x	
9	x	x			
11	x				x
12	x	x			
14	x			x	
19	x				x
20	x				x
24	x		x		
31	x			x	
36	x				x
41	x		x		
44	x	x			
47	x	x			

Table 19

Dataset 37 Variables and Factors: Hierarchical Model

Variable Number	General Factor	Memory 1	Memory 2
4	x	x	
6	x		x
10	x	x	
18	x		x
21	x	x	
22	x	x	
23	x	x	
26	x		x
32	x	x	
33	x		x
34	x	x	
35	x	x	
43	x		x
44	x		x
50	x		x

Table 20

Models Within Datasets

Dataset	I	II	III	IV	V	VI	VII	VIII
22	x	x	x	x	x	x		x
33	x	x		x	x	x	x	x
37	x	x	x		x	x		x

Table 21

Dataset 22 Fit Indices

	Index				
	GFI	AGFI	NFI	PNFI	X^2_c, df
Model					
I	.70	.65	.37	.35	X^2 = 857.48 (216)
II	.88	.84	.77	.64	X^2 = 312.31 (193)
III	.77	.72	.58	.52	X^2 = 570.46 (208)
IV	.81	.77	.65	.58	X^2 = 474.42 (206)
V	.93	.89	.86	.59	X^2 = 183.65 (159)
VI	.77	.72	.57	.52	X^2 = 587.46 (209)
VIII	.85	.80	.68	.55	X^2 = 393.28 (188)
Null (for Models I, II, III, IV, V, VI)					X^2 = 1354.99 (231)
Null (for Model VIII) *					X^2 = 1241.36 (190)

* Model VIII has a different number of degrees of freedom because Guilford factor NMI was deleted as is does not conform to a Thurstone verbal factor.

Table 22

Dataset 33 Fit Indices

	Index				
	GFI	AGFI	NFI	PNFI	X^2, df
Model					
I	.81	.73	.68	.52	X^2 = 281.15 (60)
II	.93	.89	.90	.62	X^2 = 83.99 (54)
III/IV	.85	.78	.72	.59	X^2 = 242.25 (64)
V	.96	.86	.93	.31	X^2 = 64.20 (26)
VI	.82	.75	.75	.62	X^2 = 215.88 (65)
VII	.93	.89	.87	.62	X^2 = 111.59 (56)
VIII	.94	.89	.90	.53	X^2 = 88.44 (46)
Null (for Models I, II, IV, V, VI, VII, VIII)					X^2 = 879.53 (78)

Table 23

Dataset 37 Fit Indices

	Index				
	GFI	AGFI	NFI	PNFI	X^2, df
Model					
I	.74	.68	.58	.53	$X^2 = 683.38$ (175)
II	.88	.84	.85	.71	$X^2 = 236.13$ (159)
III/IV	.83	.78	.79	.70	$X^2 = 343.70$ (169)
V	.93	.89	.92	.35	$X^2 = 121.85$ (112)
VI	.78	.73	.73	.65	$X^2 = 438.75$ (170)
VIII	.90	.84	.89	.64	$X^2 = 134.53$ (75)
Null (for Models I, II, III, V, VI)					$X^2 = 1621.89$ (190)
Null (for Model VIII)*					$X^2 = 1179.55$ (105)

* Model VIII has a smaller number of degrees of freedom because Guilford factors DMC and DMI were deleted as they do not conform to memory factors.

APPENDICES

APPENDIX A
DATASET 22 CORRELATION MATRIX

Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Apparatus Test (drastic)																	
2. Apparatus Test (minor)	01																
3. Associational Fluency I	00	21															
4. Attribute Listing I	-07	18	26														
5. Attribute Listing II	-04	30	31	12													
6. Brick Uses (shifts)	18	24	24	19	21												
7. Cartoons - Part I	28	21	08	09	11	20											
8. Cartoons - Part II	29	22	14	03	11	19	44										
9. Common Needs	05	-03	09	00	11	04	11	16									
10. Contingencies	15	30	26	23	21	17	22	14	07								
11. Differences	12	31	17	16	25	24	20	25	09	29							
12. Episodes	16	12	11	13	14	13	04	19	11	18	19						
13. *Figure Concepts (uncommonness)*	16	08	13	16	16	28	15	26	13	19	28	15					
14. Gestalt Transformation	-02	04	15	16	07	19	07	04	02	17	14	03	15				
15. *Ideational Fluency I*	14	25	20	20	16	33	22	28	06	32	45	24	28	16			
16. Logical Reasoning	08	02	32	18	16	18	05	13	29	04	01	05	18	20	06		
17. Missing Links	07	22	36	21	19	25	17	25	18	06	26	23	25	12	34	22	
18. Multiple Grouping	08	23	23	16	22	36	12	21	13	22	29	27	29	11	31	15	20
19. Object Naming (shifts)	16	16	22	16	14	24	08	17	-08	19	17	11	17	-04	28	10	14
20. Object Synthesis III	11	30	29	21	15	39	28	26	12	30	30	16	24	11	39	13	22
21. Paired Similarities	12	18	24	11	23	18	23	20	18	22	22	07	14	15	23	17	21
22. Pertinent Questions	28	29	31	22	36	28	31	30	21	35	32	26	27	04	29	08	32
23. Possibilities	14	21	32	21	27	23	14	22	05	25	27	19	20	07	25	32	25
24. Predicaments	12	30	21	13	12	14	18	15	11	31	25	23	05	11	26	13	20
25. Seeing Problems - Part I	10	14	18	15	24	22	26	17	03	26	30	18	26	01	33	14	26
26. Seeing Problems - Part II	07	28	21	22	28	25	29	18	12	28	25	13	12	06	30	24	30
27. Sentence Pairs	05	03	32	12	14	00	05	10	11	17	06	16	05	15	15	23	14
28. Sequential Association	-09	06	10	04	21	04	-05	-02	19	14	10	03	14	13	01	30	19
29. Ship Destination Test	-04	03	15	14	26	12	02	07	19	02	18	15	10	19	09	31	20
30. Similarities	13	31	24	26	15	43	12	20	01	30	31	17	24	18	46	08	20
31. Transitions (coherence)	19	15	22	10	25	17	21	23	15	18	33	24	16	08	29	23	32
32. Transitions (logical aspects)	13	18	11	11	14	11	28	22	10	27	22	13	16	09	26	02	17
33. Verbal Analogies I - Part I	04	04	28	21	26	14	-02	02	13	18	06	14	26	32	09	46	20
34. Verbal Analogies I - Part II	-01	-03	26	12	19	12	08	-07	11	04	08	07	10	12	02	40	22
35. Verbal Classification - Part I	00	04	28	10	21	09	-05	12	18	16	-14	18	24	12	16	33	25
36. Verbal Classification - Part II	03	-07	26	07	19	03	-09	02	14	11	10	14	18	16	08	34	23
37. Verbal Comprehension	-08	06	38	21	23	06	-13	-04	13	13	14	17	14	19	11	45	24
38. Vocabulary Completion - Part I	15	17	40	27	24	15	-03	10	24	28	26	21	12	26	22	36	27
39. Vocabulary Completion - Part II	01	18	28	29	23	12	-01	14	14	26	18	14	16	21	27	34	24
40. Word Grouping	04	13	24	17	24	20	01	16	12	09	22	18	36	10	23	[illegible]	22
41. Group Indicator	12	15	09	13	19	12	18	04	14	25	10	10	10	07	15	-01	17
42. Random Variable	-01	04	-09	00	03	-07	04	06	-02	01	10	05	05	07	-06	-01	-04

* Decimal points have been omitted.

DATASET 22 CONT'D

18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
14																								
31	28																							
23	17	19																						
22	22	34	19																					
13	25	30	17	30																				
22	20	28	22	38	24																			
24	19	26	26	38	22	27																		
21	17	22	19	41	26	35	-48																	
15	26	14	18	18	20	27	13	16																
16	00	04	18	02	12	08	.04	22	-02															
09	18	05	09	24	12	21	16	15	23	24														
36	23	34	23	26	26	31	32	26	17	09	08													
22	15	15	20	27	28	16	.26	26	22	06	09	12												
19	10	15	22	40	01	31	38	33	10	-04	08	21	30											
16	13	15	13	18	19	16	05	21	17	33	26	05	15	02										
09	02	18	12	11	21	04	20	20	08	29	22	01	13	03	48									
17	24	17	26	16	17	22	21	23	23	18	21	07	22	10	32	·29								
09	21	09	18	12	17	08	18	11	26	23	30	01	17	02	30	35	40							
22	12	04	16	12	11	17	14	23	24	28	25	13	25	01	40	35	35	38						
27	11	15	25	29	24	26	13	22	21	20	25	19	34	11	40	25	26	28	47					
27	14	04	18	27	28	23	06	15	19	19	19	20	33	06	34	21	24	31	49	72				
23	22	10	19	24	05	12	18	15	15	11	21	24	19	23	16	02	16	13	24	32	29			
01	-06	14	-01	32	06	23	15	17	04	-05	02	10	14	24	16	04	-05	-06	01	29	08	17		
04	-06	05	08	-07	05	-04	-05	-12	-07	06	-01	-14	-09	-06	11	04	-01	00	00	10	10	-02	-07	

DATASET 33 CORRELATION MATRIX

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1. Abbreviations																								
2. Best Letter Set	[illegible]																							
3. Best Number Class	[illegible]	[illegible]																						
4. Best Number Pairs	[illegible]	[illegible]	[illegible]																					
5. Camouflaged Words	[illegible]	[illegible]	[illegible]	[illegible]																				
6. Circle Reasoning	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																			
7. Correct Letter Orders	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																		
8. Correct Number Spans	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																	
9. Correct Spelling	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																
10. Decoding	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]															
11. Deductions	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]														
12. Disemvowelled Words	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]													
13. Familiar Letter Combinations	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]												
14. Form Reasoning	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]											
15. Identical Forms	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										
16. Jumbled Words	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]									
17. Letter Problems	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
18. Letter Triangle	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]							
19. Letter U	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
20. Marking Speed	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
21. Number Classification	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
22. Number Grouping	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
23. Number-Group Naming	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
24. Numerical Operations	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
25. Operations Sequence	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26. Perceptual Speed	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27. Related Words I	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28. S Test	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29. Seeing Trends II	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30. Series Solutions	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31. Sign Changes	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
32. Sign Changes II	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
33. Similar Pairs	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
34. Sound Grouping	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
35. Symbol Grouping	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
36. Symbol Identities	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
37. Symbol Manipulation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
38. Symbol Reasoning	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
39. Typing Errors	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40. Varied Symbols	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
41. Way-Out Numbers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
42. Word Changes	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
43. Word Chains	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
44. Word Combinations	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
45. Word Patterns	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
46. Word Relations	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
47. Word Transformation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
48. Rating Test Liking	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
49. Rating Booklet Effort	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50. Sex	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
51. Prediction-Achievement Discrepancy	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
52. ITED General Vocabulary	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
53. PSAT Verbal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
54. SCAT Verbal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
55. Mathematics Experience	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
56. Typing Experience	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
57. Shorthand Experience	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
58. Test Administrator	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*Decimal points omitted.

DATASET 33 CONT'D

25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
28																																	
49	31																																
16	16	60																															
70	23	35	32																														
55	13	36	07	41																													
50	29	39	06	22	38																												
49	19	35	16	20	34	33																											
44	27	30	04	04	41	24	28																										
43	19	00	08	38	39	17	41	40																									
45	37	40	18	31	47	35	42	47	38																								
37	32	30	17	32	74	34	25	34	25	27																							
50	19	49	00	04	65	16	39	51	40	43	14																						
55	28	41	12	47	51	29	40	48	66	64	33	36																					
40	15	32	10	22	31	21	23	33	25	16	19	30	32																				
21	12	14	22	14	11	15	18	09	15	09	10	05	31	11																			
38	19	33	10	35	42	44	39	34	26	36	33	30	49	30	01																		
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39	23	40	31	31	32	28	33	41	30	39	26	64	30	19	15	25	30																
33	18	25	00	36	35	17	26	37	00	32	30	26	35	23	13	25	40	32															
41	28	19	16	32	27	27	26	26	33	34	36	39	31	37	21	14	16	36	31														
40	30	39	09	52	48	34	41	55	07	43	35	45	34	31	26	40	30	44	43	34													
37	19	27	09	36	38	28	33	33	07	27	26	36	33	26	20	24	40	57	47	41	40												
29	01	22	09	22	27	12	14	31	28	16	09	10	30	00	05	14	19	16	22	30	23	25											
-04	-01	02	-13	02	00	-08	-06	01	-04	-06	00	01	-03	-03	-06	-04	01	-03	00	-01	02	06	35										
13	-10	-14	-03	-09	10	07	06	-15	-12	-02	-45	-03	05	-04	-03	11	-14	-10	-14	03	-06	-01	-04	-09									
07	08	-02	-09	07	10	06	-02	07	-12	-05	13	01	00	07	-13	04	04	02	00	-02	-01	00	-12	-03	-03								
37	22	43	16	54	42	17	18	30	60	64	35	40	37	27	10	35	43	37	39	30	44	43	21	-02	-01	11							
28	26	26	-09	55	32	12	19	35	52	23	26	44	52	26	00	20	53	24	40	27	38	44	21	04	-06	23	71						
37	24	33	01	46	44	02	30	41	36	19	33	30	42	19	05	20	34	35	32	32	31	45	03	-12	06	10	63	66					
51	10	22	30	35	09	47	45	31	37	43	33	33	33	36	16	33	40	31	32	35	30	31	22	-07	30	17	57	50	31				
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-12	00	-02	02	-15	-14	03	-20	-01	-08	-07	00	-10	-11	06	31	-09	-09	-09	00	-02	-11	01	00	-01	-31	-04	-22	-19	-33	-20	40		
-01	06	12	-15	13	13	-03	-03	10	08	06	00	05	16	00	01	10	01	10	03	-09	16	05	05	14	-01	32	12	06	-02	-01	-09	-09	

DATASET 37 CORRELATION MATRIX

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1. Alternate Uses																									
2. Associational Fluency	44																								
3. Best Word Class	28	30																							
4. Books and Authors	33	41	30																						
5. Class Name Selection	27	16	33	31																					
6. Classified Information	35	24	30	41	26																				
7. Concept Recall	31	37	28	41	37	29																			
8. Consequences (obvious)	24	34	10	11	24	08	04																		
9. Consequences (remote)	33	36	07	19	27	13	23	14																	
10. Descriptions	45	27	35	28	33	30	25	10	19																
11. Double Meanings	38	20	32	32	31	49	33	-02	18	42															
12. Expressional Fluency	33	40	15	24	20	34	28	29	23	37	19														
13. Homonyms	47	45	39	39	34	31	33	20	33	45	48	33													
14. Ideational Fluency	36	32	26	33	20	21	40	43	31	17	31	42	37												
15. Learned Information (classes)	39	45	33	45	40	34	27	16	37	43	31	30	45	30											
16. Learned Information (systems)	35	29	19	37	26	26	29	26	28	33	16	30	29	32	30										
17. Memory for Definitions	42	35	24	31	35	37	21	16	33	31	37	32	31	30	36	26									
18. Memory for Facts	42	49	37	45	42	37	37	27	39	30	42	32	34	39	18	40	40								
19. Memory for Text Order	18	32	17	29	23	37	27	21	19	29	31	34	40	38	46	43	30	44							
20. Memory for Word Meanings	27	34	35	24	37	44	36	14	25	44	47	10	47	36	45	26	31	49	36						
21. Memory for Word Selections	43	38	32	38	37	31	28	15	26	44	48	26	35	33	38	30	43	44	30	38					
22. Outcomes	40	29	34	33	35	47	24	27	28	34	40	29	36	25	30	29	44	18	40	37	47				
23. Paired Associates Recall	30	36	30	43	35	46	30	03	13	35	35	33	42	26	31	29	38	49	32	33	30	52			
24. Picture Arrangement	35	13	12	11	16	07	16	00	19	13	13	09	13	05	09	12	10	10	-04	02	15	08	07		
25. Picture Class Memory	37	33	30	26	21	32	31	05	25	28	22	13	28	26	31	27	23	30	12	25	37	26	26	19	
26. Picture Memory	24	35	26	38	18	34	34	12	21	34	26	21	43	33	30	38	29	47	44	29	38	33	43	00	30
27. Planning Elaboration II	39	31	23	36	20	37	38	42	39	21	21	41	37	44	42	41	22	38	39	29	36	26	12	00	25
28. Plot Titles (clever)	12	37	03	33	06	12	26	26	32	15	07	26	13	27	28	33	10	18	24	11	23	15	19	17	20
29. Plot Titles (nonclever)	19	35	02	01	17	08	16	40	26	-02	05	30	13	49	17	36	02	16	20	23	10	07	06	08	07
30. Possible Jobs	40	40	32	37	19	30	20	27	29	28	25	26	32	47	24	16	12	39	25	29	18	35	18	23	23
31. Problem Solving	31	18	40	12	33	19	08	10	18	11	16	03	34	10	29	35	33	13	08	34	30	26	06	22	24
32. Recalled Analogies	39	29	34	32	28	28	40	20	20	40	40	27	44	35	47	17	33	47	34	29	49	41	39	34	36
33. Recalled Words	37	39	28	48	24	31	31	15	18	26	21	27	39	37	38	31	29	40	31	32	33	33	40	11	09
34. Related Alternatives	34	33	30	19	42	32	27	11	29	30	33	26	48	37	31	34	45	32	29	26	40	44	45	10	28
35. Remembered Relations	36	32	28	30	24	30	37	11	19	45	33	13	45	19	37	25	26	39	13	31	43	11	36	06	22
36. Remembering Classes	37	28	33	29	32	41	26	13	15	41	31	26	37	25	29	33	30	43	18	17	37	32	25	16	32
37. Remembering Puns	43	30	32	31	42	30	42	16	31	34	31	37	41	43	41	38	33	72	44	43	49	40	39	15	32
38. Sentence Memory	30	35	30	34	29	37	19	23	21	44	39	30	12	30	61	33	49	35	31	37	46	48	36	15	32
39. Sentence Order	37	30	31	29	29	32	27	19	26	43	32	23	44	29	40	35	49	44	39	26	31	47	33	19	22
40. Ship Destination Test	25	21	22	20	11	27	01	05	21	31	18	06	43	13	39	37	39	37	14	32	25	27	28	09	19
41. Simile Insertions	37	49	34	36	32	35	25	25	34	38	36	35	44	40	31	37	44	49	33	28	41	40	45	17	26
42. Simile Interpretations	30	21	15	11	22	20	20	21	20	17	23	30	29	26	22	09	27	32	19	15	39	23	18	16	08
43. Substitutions	44	34	40	30	31	36	30	23	26	43	38	27	40	29	35	31	48	31	42	38	44	30	37	16	35
44. Test Name Recall	31	42	33	49	21	39	32	16	21	39	29	38	41	30	32	37	43	60	31	31	43	44	42	01	26
45. Unusual Answers	47	40	37	40	42	45	40	28	[illegible]	49	43	35	16	28	62	36	48	72	34	45	27	40	44	21	17
46. Utility Test (fluency)	41	46	18	17	16	07	25	47	26	07	06	41	30	41	18	30	18	23	31	21	18	15	13	18	12
47. Utility Test (shifts)	49	44	15	21	19	15	27	34	37	25	06	35	26	39	25	27	30	30	33	25	37	28	26	22	27
48. Verbal Comprehension	38	42	30	25	35	34	32	20	23	43	37	24	45	22	37	31	33	34	27	35	41	38	38	12	27
49. Word Completion	35	54	46	30	44	43	27	24	35	34	47	33	33	39	31	28	39	43	29	37	40	49	43	26	36
50. Word Recognition	18	37	12	23	19	32	26	09	17	31	23	15	20	15	31	14	24	34	21	37	22	30	40	05	18
51. Academic Anxiety	-00	10	-06	06	03	07	05	03	07	-09	01	05	-00	13	07	-05	-01	05	08	-10	-01	-00	05	-06	07
52. Academic Goals	20	19	20	17	17	19	18	17	11	16	22	23	29	18	22	02	16	33	11	18	25	05	11	01	13
53. Academic Attitude	-11	02	-08	-01	-05	02	-09	-03	-12	-02	02	07	01	01	06	-02	-07	01	-01	-09	01	-06	-05	-07	02
54. Academic Interest	14	16	11	11	11	19	06	09	08	23	20	06	18	16	21	16	14	29	12	15	20	05	10	01	12
55. Incidental Memory	17	25	19	17	20	08	33	11	13	21	60	25	30	24	32	13	31	33	31	27	16	24	13	02	11
56. Long-Term Memory	21	37	29	41	19	28	26	16	20	31	32	21	39	28	34	22	16	45	37	35	23	26	33	06	20
57. Rating of Memory	06	11	24	21	17	25	10	11	-01	16	21	17	34	22	17	30	31	21	19	10	27	13	21	12	13
58. Sex	-07	-10	-03	-27	-16	-25	-12	03	-06	-15	-21	-16	-11	-31	-20	-00	-02	-22	-24	-19	-13	-1[illegible]	-24	03	-07
59. College Instruction	22	23	23	13	13	16	06	20	24	18	20	13	37	21	20	34	31	29	16	20	28	22	09	06	13

DATASET 37 CONT'D

26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
31																																	
27	34																																
08	48	-06																															
30	34	10	22																														
33	22	12	-01	33																													
41	36	26	08	40	24																												
44	24	12	16	25	-09	28																											
42	26	20	03	21	29	38	32																										
30	21	17	00	26	36	42	21	36																									
28	35	12	03	33	28	31	22	30	27																								
45	39	17	08	43	21	32	47	36	41	35																							
22	42	14	09	47	26	40	22	39	26	34	43																						
20	23	18	01	40	26	36	28	34	20	31	34	47																					
18	16	07	-01	22	44	21	12	32	28	22	29	42	20																				
31	41	31	18	43	22	42	33	47	31	24	38	38	43	31																			
32	31	06	26	40	05	28	37	30	39	22	30	31	20	09	45																		
49	33	20	16	37	30	47	42	38	41	33	37	41	42	35	43	17																	
40	35	26	05	29	08	45	36	40	36	39	38	39	30	26	31	20	46																
43	41	16	20	40	17	43	47	47	32	32	26	38	35	20	49	28	32	36															
22	36	38	31	47	17	38	20	35	10	12	30	29	22	05	33	32	26	17	28														
26	38	19	30	28	26	20	26	20	10	13	29	33	26	11	39	25	30	26	28	47													
19	23	09	05	22	25	39	26	36	36	33	37	44	47	30	40	13	49	36	49	16	23												
26	33	20	13	43	32	44	36	44	38	30	40	40	33	38	30	28	44	43	61	35	45	70											
29	10	21	06	16	08	19	19	20	26	16	28	17	26	26	11	13	27	27	21	18	15	12	22										
00	03	-06	17	-01	-21	03	05	03	-10	-06	-03	-04	-11	-12	01	06	-02	02	02	07	07	-06	-03	08									
16	22	-07	13	13	04	11	16	13	07	23	23	27	13	12	22	16	12	26	17	18	13	27	26	06	01								
03	07	08	-01	04	-16	-17	-02	-11	-08	07	00	01	-25	00	-03	06	-12	-00	-04	-06	-08	-06	-05	-11	02	39							
05	17	10	07	10	-16	-04	06	03	-06	25	29	22	31	03	18	08	09	21	18	10	06	26	27	07	-00	37	37						
20	20	12	17	15	07	17	26	10	18	26	15	17	29	06	23	08	27	21	26	18	06	26	29	03	-00	19	-05	02					
37	28	13	11	21	16	27	22	37	26	37	42	33	21	11	31	05	26	41	40	21	18	28	40	11	06	28	11	22	36				
26	27	17	06	20	27	23	17	30	16	29	27	19	15	19	29	13	25	26	20	15	07	10	23	12	01	23	10	17	17	30			
16	-21	-00	-13	-12	26	-06	-31	-21	11	-13	-23	-04	-07	20	-15	-12	-05	-26	-24	-05	00	-05	-03	-06	-19	-02	-13	-29	-13	-07	06		
33	33	-00	12	17	30	13	00	23	23	12	27	35	17	27	23	16	27	20	19	22	22	29	27	12	-06	40	05	16	-02	27	21	18	

APPENDIX B
DATASET 22 FACTORS

CMU (verbal comprehension)

39.	Vocabulary Completion, Part I	.59
38.	Vocabulary Completion, Part II	.52
37.	Verbal Comprehension	.52
31.	Transitions (coherence)	.38
3.	Associational Fluency	.38
17.	Missing Links	.34

EMI (sensitivity to problems)

32.	Transitions (logical aspects)	.53
26.	Seeing Problems, Part II	.51
25.	Seeing Problems, Part I	.49
24.	Predicaments	.31

CMR (eduction of conceptual relations)

33.	Verbal Analogies I, Part I	.57
34.	Verbal Analogies I, Part II	.55
16.	Logical Reasoning	.42

DMR (associational fluency)

6.	Brick Uses (shifts)	.46
30.	Similarities	.44
3.	Associational Fluency	.43
20.	Object Synthesis III	.37

CMC (conceptual classification)

36.	Verbal Classification, Part III	.47
35.	Verbal Classification, Part I	.42
27.	Sentence Pairs	.39
19.	Object Naming (shifts)	.35

NMI (deduction)

28.	Sequential Association	.48
5.	Attribute Listing II	.30

DATASET 33 FACTORS

CSU (cognition of symbolic units)

12.	Disemvowelled Words (CSU)	.53
9.	Correct Spelling (ESU)	.42
47.	Word Transformation (NST)	.37
44.	Word Combinations (CSU)	.34

MSI (memory for symbolic implications)

24.	Numerical Operations (MSI)	.60
41.	Way-Out Numbers (ESS)	.34
31.	Sign Changes (NSI)	.33

NSI (convergent production of symbolic implications)

14.	Form Reasoning (NSI)	.49
31.	Sign Changes (NSI)	.35
2.	Best Letter Set (ESS)	.34
24.	Numerical Operations (MSI)	.33
20.	Marking Speed (MOT)	.31
19.	Letter "U" (ESU)	.31

ESU (evaluation of symbolic units)

36.	Symbol Identities (ESU)	.62
19.	Letter "U" (ESU)	.55
20.	Marking Speed (MOT)	.36
11.	Derivations (ESU)	.34
31.	Sign Changes (NSI)	.32

DATASET 37 FACTORS

MMU (memory for semantic units)

26.	Picture Memory (MMU)	.51
44.	Test Name Recall (MMU)	.51
33.	Recalled Words (MMU)	.47
50.	Word Recognition (MMU)	.40
43.	Substitution (MMT)	.35
18.	Memory for Facts (MMS)	.34

MMI (memory for semantic implications)

34.	Related Alternatives (MMI)	.62
4.	Books and Authors (MMI)	.57
23.	Paired Associates Recall (MMI)	.56
6.	Classified Information (MMC)	.33

MMR (memory for semantic relations)

35.	Remembered Relations (MMR)	.50
10.	Descriptions (MMI)	.44
21.	Memory for Word Relations (MMR)	.42
32.	Recalled Analogies (MMR)	.39
22.	Outcomes (MMS)	.39

DMC (divergent production of semantic classes)

47.	Utility Tests (shifts) (DMC)	.52
1.	Alternate Uses (DMC)	.49

DMI (divergent production of semantic implications)

30.	Possible Jobs (DMI)	.57
27.	Planning Elaboration II (DMI)	.44
14.	Ideational Fluency (DMU)	.35

APPENDIX C
DATASET 22 DESCRIPTION OF TESTS

3. Associational Fluency I, Form A, 1957. Write words similar in meaning to a given word. Score is the number of acceptable similar words produced.

Sample item: HARD

Answers: difficult, solid, tough, severe

Parts, 2. Items per part, 2. Working time, 4 minutes. H, Ib, DMR.

5. Attribute Listing II - HS01A. List attributes of an object that would serve a given function. Score is the number of relevant attributes listed.

Sample item: You wish to drive a long nail into a wooden post. You have none of the tools usually used for this purpose. List the attributes that a usable object or device would have.

Answers: Hold in hand, harder than the nail, flat striking surface, won't hurt hand

Parts, 1. Items per part, 1. Working time, 2 minutes. H, Va.

6. Brick Uses (shifts) - CF04A. List different uses for a brick. Score is the number of times the examinee shifts from one kind of use to another.

Parts, 1. Items per part, 1. Working time, 10 minutes. H, IVb, DMC.

16. Logical Reasoning, Form A, 1955. Choose a statement logically consistent with the given statements. Score is the number of correct choices, adjusted for chance success.

Sample item: No birds are insects.
All swallows are birds.

A. No swallows are insects.
B. Some birds are not swallows.
C. All birds are swallows.
D. No insects are birds.

Answer: A.

Parts, 2. Items per part, 20. Working time, 20 minutes. H, EMR.

17. Missing Links - HZ01A. Produce three words to complete a chain of associations between two given words. Score is the sum of weights for degree of completeness.

Sample item (with answers):

red sunset weather cold beer

Parts, 2. Items per part, 6. Working time, 6 minutes. H, CP.

DATASET 22 DESCRIPTION OF TESTS CONT'D

19. Object Naming (shifts) - CSX04A. List names of objects in a given class. Score is the number of times the examinee shifts from one sub-class of objects to another.

Parts, 1. Items per part, 1. Working time, 2 minutes. H, IVb, DMC.

20. Object Synthesis III - HX02A. List as many as five things that could be made using both of two given objects. Score is the number of acceptable responses.

Sample item (with answers):

nail and cane — spear

hook

Parts, 2. Items per part, 2. Working time, 4 minutes. H, IVa.

24. Predicaments - HZ02B. Describe two ways in which given objects could be used to solve a specified problem. Score is the number of times given objects were incorporated as essential parts of an adequate solution.

Sample item: You are on a picnic with some friends. Instead of bringing sandwiches already prepared, you have stopped at a store and bought the "makings." You discover that instead of sliced cheese you picked up a solid piece. How would you divide the cheese so that each person can make a sandwich, using only the objects given?

harmonica matches thermos bottle ukelele

Answer: A. take string from ukelele, hold taut, press through cheese

Parts, 2. Items per part, 3. Working time, 10 minutes. H, CP.

25-26. Seeing Problems - CS06A. Write as many as five problems arising from the presence of a given object. Score is the number of appropriate problems listed.

Parts, 2. Items per part, 6. Working time, 8 minutes. Note: Variable 25 is Part I; variable 26 is Part II. H, Vb, EMI.

DATASET 22 DESCRIPTION OF TESTS CONT'D

27. Sentence Pairs - HC01A.[4] Choose two sentences that express the same kind of idea. Score is the number correct, adjusted for chance success.

Sample item:
1. He walked home every night.
2. Some animals make good pets.
3. Artists are sometimes well paid.
4. The train gathered speed as it left.

A. Cats are real companions.
B. Deer are excellent game.
C. Exercise promotes good health.
D. The storm approached rapidly.
E. The picture sold for twice its true value.

Answers: 1-C; 2-A; 3-E; 4-D.

Parts, 3. Items per part, 4. Working time, 6 minutes. H, IIa.

28. Sequential Association - HR02A. Arrange four given words in sequence so that the first is associated with the second, the second with the third, and the third with the fourth. Score is the number of correct sequences achieved.

Sample item (with answers):

Indicate the best order for the following words:

pen	pig	read	write
2	1	4	3

Parts, 2. Items per part, 5. Working time, 3 minutes. H, IIIa.

30. Similarities - RCS01A. Write six ways in which objects of a pair are alike. Score is the number of acceptable similarities given.

Sample item: Apple and orange are alike:

Answers:
A. sweet
B. have seeds
C. grow on trees

Parts, 1. Items per part, 6. Working time, 5 minutes. H, Ia.

31. Transitions (coherence) - HZ03A. Write a coherent account logically connecting the given initial and final situations of a short story. Score is the rating of response on a five-point scale for coherence of discourse.

Sample item: Jonas was not a hard man, at least in his own opinion. He spent his money wisely, and did nothing more than require his daughter to do the same. Take the matter of the car. ____________________

____________________ Jonas heard her rapid steps across the porch, the slam of the door, and the crunch of gears. He watched from the window as the dust blew across the road, then turned slowly toward the kitchen. It was almost dark enough to light the lamp.

Parts, 2. Items per part, 1. Working time, 10 minutes. H, CP.

DATASET 22 DESCRIPTION OF TESTS CONT'D

32. Transitions (logical aspects) - HZ03A. Same task as variable 31. Score is the number of aspects inherent in given material which examinee accounted for in his response.

Parts, 2. Items per part, 1. Working time, 10 minutes. H, CP.

33-34. Verbal Analogies I - RCR01C. Select the word to complete an analogy; finding the relation in the first pair is difficult. Score is the number correct, adjusted for chance success.

Sample item: cloth : dye :: house : ?

A. shade
B. paint
C. brush
D. door
E. wood

Answer: B.

Parts, 2. Items per part, 15. Working time, 12 minutes. Note: Variable 33 is Part I; variable 34 is Part II. H, IIIb, CMR.

35-36. Verbal Classification - EL16A. Assign given words to one or neither of two classes, each class defined by four other words. Score is the number of correct assignments. (Adapted by permission from a test by L. L. Thurstone.)

Sample item:

COW	___	desk	X	TABLE
HORSE	X	sheep	___	CHAIR
GOAT	___	rocker	X	BOOKCASE
DOG	___	tree	___	LAMP
	X	cat	___	
	___	nose	___	

Parts, 2. Items per part, 40. Working time, 8 minutes. Note: Variable 35 is Part I; variable 36 is Part II. H, IIb, CMC.

37. Verbal Comprehension, Guilford-Zimmerman Aptitude Survey, Part I, 1947. Select the word that is similar in meaning to a given word. Score is the number correct, adjusted for chance success.

Parts, 1. Items per part, 40. Working time, 12 minutes. H, CMU.

38-39. Vocabulary Completion - REC06A. Produce a word that fits a given definition and begins with a given letter. Score is the number correct.

Sample item (with answer): A contest of speed . . . . (r) race

Parts, 2. Items per part, 40. Working time, 6 minutes. Note: Variable 38 is Part I; variable 39 is Part II. H, IIIb, NMR.

DATASET 33 DESRCRIPTION OF TESTS

2. **Best Letter Set** - ESS03A. Choose one of three alternative letter sets that is most like the given set.

Sample Item: EKN A. JFI B. PAQ C. YBT

Answer: C (begins with a vowel)

Score: Number right minus one-half number wrong. Parts: 2; items per part 15; working time: 10 minutes.

9. **Correct Spelling** - ESU04A. Judge whether or not given words are spelled correctly.

Sample Items: I. experience II. seperate

Answer: I correct; II incorrect.

Score: Number right minus number wrong. Parts: 2; items per part 60; working time: 6 minutes.

11. **Derivations** - ESU08A. Rapidly judge whether words can be derived from a given word by using some of its letters.

Sample Items: Given: PROCRASTINATE

I. trap
II. crust
III. percent

Answer: I can be derived; II and III cannot.

Score: Number right minus number wrong. Parts: 3; items per part 50; working time: 9 minutes.

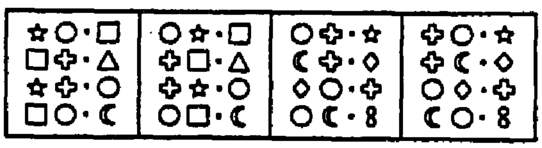
12. **Disemvowelled Words**[b] - CSU04B. Recognize familiar words with dashes in place of vowels; then complete the words by writing the vowels.

Sample Item: m_t_l_t_ Answer: mutilate

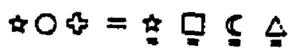
Score: Number of correctly completed words. Parts: 1; items: 25; working time: 5 minutes.

14. **Form Reasoning**[a] - NSI02C. From the table, find the form that is equal to the three given forms.

Table:



Sample Item:



Answer:

Score: Number right minus one-third number wrong. Parts: 1; items: 20; working time: 4 minutes.

19. **Letter "U"** - ESU06A. Check all the words in lists that contain the letter "u".

Sample Items:
( ) sense
( ) short
(X) juice
( ) special

Score: Number correctly placed X's minus number incorrectly placed X's. Parts: 2; items per part: 200; working time: 2 minutes.

20. **Marking Speed Test**. Make as many X's as you can in the rows of squares provided.

Sample Item:

Score: Number of complete X's made within squares. Parts: 1; items: 160 squares; working time: 1 minute.

DATASET 33 DESCRIPTION OF TESTS CONT'D

24. Numerical Operations[4] - MS101B. Part III of the Guilford-Zimmerman Aptitude Survey (adapted).

Rapidly add, subtract, or multiply simple numerical problems and select one of six alternatives as the answer.

Score: Number right minus one-fifth number wrong. Parts: 2; items per part: 36; working time: 4 minutes.

31. Sign Changes - NS101A. Solve simple arithmetic problems in which the operation sign is changed according to a set of rules.

Sample item: Rules: wherever you see: - replace it by x; + replace it by -

3 - 6 = 18
6 + 2 = 4
4 - 3 = 12

Score: Number right solutions. Parts: 1; items: 32; working time: 1 minute.

36. Symbol Identities - ESU07A. Judge whether both members of pairs of words and numbers are the same or are different.

Sample items:

2 1 6 3 __S__ 2 1 6 3
Hahn, Lorena __D__ Hahn, Lorina
Bob Ulm __D__ Rob Ulm

Score: Number right. Parts: 2; items per part: 50; working time: 4 minutes.

41. Way-Out Numbers - ESS07A. Choose the one alternative number from a list of four ordered numbers that is farther away from the other three.

Sample item:

A. 31
36
45
B. 47

Answer: A

Score: Number right minus number wrong. Parts: 2; items per part: 15; working time: 8 minutes.

44. Word Combinations - CSU06A. Produce a new word from the ending of one word and the beginning of another.

Sample items: Given:

1. bridge
2. beam
3. open

A. duress
B. zero
C. pledge
D. need
E. none of these

Answers: 1. D (gene) 2. C (ample) 3. A (endure)

Score: Number right minus one-fourth number wrong. Parts: 2; items per part: 15; working time: 8 minutes.

47. Word Transformation - NST02B. Separate letters of words in a phrase with vertical lines to make a different set of words.

Sample item (answer marked): RING S|OF|T HE

Score: Number of vertical lines regrouping all the letters in the given phrase. Parts: 1; items: 15; working time: 4 minutes.

DATASET 37 DESCRIPTION OF TESTS

1. Alternate Uses - DMC03B SSC.[1] List as many as six different uses for each given common object. Uses refer to different properties or interpretations of the given object.

Sample: Given: A newspaper (used for reading). Uses: start a fire; wrap garbage in; swat flies

Score: Number of different uses given.
Parts: 2; items per part: 3; working time: 8 minutes.

4. Books And Authors - MMI01A. Supply (recall) probable occupations for given fictitious persons after studying a page of name-book title pairs.

Sample study items: Brooks - Pictures I Have Painted
Adams - Great Moments in Baseball

Sample test items: Adams - baseball player
Brooks - artist

Score: Number of occupations acceptably related to the given names; only one point is given for any one name.
Parts: 2; items per part: 15; working time: 8 minutes.

6. Classified Information - MMC01A. Identify (recognize) classes similar to those given on a previously studied page.

Sample study item:		Sample test items:			Answers:
	SILK		RAYON	SNOW	Yes, No.
	WOOL		COTTON	ICE	
	NYLON		FELT	SLEET	

Score: Number of correct responses minus the number of wrong responses.
Parts: 2; items per study page: 15; items per test page: 30; working time: 6 minutes.

10. Descriptions - MMI02A. Indicate (recognize) whether given adjectives are implied by noun pairs presented on a previously studied page.

Sample study items: RING - CIRCLE
HOUSE - TENT

Sample test items: 1. Livable
2. Tired
3. Round

Answers: 1. Yes; 2. No; 3. Yes.

Score: Number of correct responses minus the number of wrong responses.
Parts: 2; items per study page: 15; items per test page: 30; working time: 7 minutes.

14. Ideational Fluency - DMU01B SSC. List things that belong to a broadly defined class.

Sample: Name FLUIDS that will BURN.

gasoline
kerosene
hydrogen

Score: Number of different things listed that belong to the specific class.
Parts: 2; items per part: 1; working time: 6 minutes.

DATASET 37 DESCRIPTION OF TESTS CONT'D

18. Memory For Facts - MMS06A. Answer questions (recall) regarding information presented in previously studied sentences.

Sample study item: Abraham Lincoln was the sixteenth U. S. president.

Sample test item: Who was the sixteenth president of the United States? Abraham Lincoln

Score: Number of correct responses.
Parts: 2; items per part: 15 (some items require two answers); working time: 9 minutes.

21. Memory For Word Relations - MMR04A. Choose relations that have the same sense and direction as ones given on a previously studied page.

Sample study item: Alley - Highway

Sample test item: Highway

A. Lion - Kitten
B. Creek - River
C. Boat - River
D. Track - Train

Answer: B

Score: Number of correct responses minus one-third the number of wrong responses.
Parts: 2; items per part: 15; working time: 8 minutes.

22. Outcomes - MMS04A. Choose similar fact-inference conclusions after studying a list of fact-inference statements.

Sample study item: When a driver does not stop for a traffic signal, he usually gets a traffic citation.

Sample test item: Ted did not stop for that red light.

A. He probably didn't see the signal.
B. He must be in a hurry
C. He got involved in an accident.
D. He will probably get a ticket.

Answer: D
Score: Number of correct responses minus one-third the number of wrong responses.
Parts: 2; items per part: 15; working time: 7 minutes.

23. Paired Associates Recall - MMI03A. A word-word paired-associate learning task.

Sample study item: SUCCEED .... HEAVY   Sample test item: SUCCEED .... heavy

Score: Number of words correctly paired. Parts: 3; items per part: 12; working time: 6 minutes.

26. Picture Memory - MMU04A. List (recall) names of common objects pictured on a previously studied page.

Score: Number of items correctly listed. Parts: 2; items per part: 20, 19; working time: 5 minutes.

27. Planning Elaboration II - DMI01B. Fill in as many details as are necessary to make a briefly outlined activity work.

Sample: Your club is presenting a play. There will be three performances — Friday and Saturday evening and Saturday matinee. The play is to be presented in the school auditorium. Rehearsals are now in progress. Profits will go to the club treasury. You have been chosen as manager for the production, which means you have to plan carefully to make the play a success. Write out the details you would include as parts of your plan.

Possible details: get tickets printed
arrange for ushers
advertise by billboard

Score: Number of specific relevant details listed.
Parts: 2; items per part: 1; working time: 8 minutes.

DATASET 37 DESCRIPTION OF TESTS CONT'D

30. Possible Jobs - DMI03B. Write as many as six different jobs or kinds of people that might be indicated by a pictured emblem.

Sample:

Possible jobs: electrical engineer
light bulb manufacturer
a bright student

Score: Number of different relevant jobs listed.
Parts: 2; items per part: 3; working time: 10 minutes.

32. Recalled Analogies - MMR05A. Supply (recall) missing elements for previously studied incomplete verbal analogies.

Sample study item: Native - Tourist : Resident - ___?___

Sample test item: Resident - visitor

Score: Number of acceptably completed analogies.
Parts: 2; items per part: 15; working time: 5 minutes.

33. Recalled Words - MMU05A. List (recall) words presented on a previously studied page.

Score: Number of correct words, or synonyms for the given words listed.
Parts: 2; items per part: 20; working time: 5 minutes.

34. Related Alternatives - MMI04A. Choose (recognize) items that are related to persons' jobs, based upon studying a page of name-job pairs.

Sample study item: SMITH - Bricklayer

Sample test item: SMITH
A. Piano
B. Microphone
C. Brick
D. Typewriter

Answer: C

Score: Number of correct responses minus one-third the number of wrong responses.
Parts: 2; items per part: 15; working time: 8 minutes.

35. Remembered Relations - MMR06A. Complete sentences from alternatives in a manner consistent with previously studied relations.

Sample study item: Diamonds are harder than coal.

Sample test item: Coal is ______________ than diamonds.
A. softer
B. blacker
C. less valuable
D. none of these

Answer: A
Score: Number of correct responses minus one-third the number of wrong responses.
Parts: 2; items per study page: 15; items per test page: 20; working time: 9 minutes.

43. Substitutions - MMT04A. Choose (recognize) an item that may be adapted for an unusual use in line with information given on a previously studied page.

Sample study items: A gummed label may be used as a bandage.
A cigarette filter may be used as a pin cushion.
A mop may be used as a wig.

Sample test items:
A. Cigarette filter
B. Gummed label
C. Mop
D. None of these

1. To dress for Halloween
2. To clean a floor
3. To help straighten a sewing box
4. To dress a wound

Answers: C, D, A, B.
Score: Number of correct responses.
Parts: 2; items per study page: 15; items per test page: 16; working time: 5 minutes.

44. Test Name Recall - MMU06A. List (recall) the names of the tests included in a booklet just completed.

Score: Number of test names listed. Names that are similar to the actual name are given full credit.
Parts: 3; items per part: 7, 6, 7; working time: 3 minutes.

DATASET 37 DESCRIPTION OF TESTS CONT'D

47. Utility Test (shifts) - DMC01B. List many different uses for a common object.

Score: Number of shifts in categories in a series of acceptable responses.
Parts: 2; items per part: 1; working time: 10 minutes.

50. Word Recognition MMU07A is a two-choice recognition tests in which Es are required to list words that are presented on the study page. The words are scattered irregularly about the page to minimize Es learning the aspect of order.

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