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STABILITY AND CONSTRUCT VALIDITY OF SECOND-STRATUM FACTORS OF ABILITY

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STABILITY AND CONSTRUCT VALIDITY OF SECOND-STRATUM FACTORS OF ABILITY

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of the Ohio State University

By
Keith Franklin Widaman, B.A., M.A.

* * * * *

The Ohio State University
1982

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INTRODUCTION

The history of research on human abilities is long and varied. For convenience, one may date the advent of modern ability testing to Galton's attempt to measure a set of sensory abilities on a sample of people attending the International Exposition of 1884 (Anastasi, 1976). The course of the last 80 years of research on human abilities was strongly influenced by a relatively small number of early failures to find strong relationships between tests of human abilities and other measures with which the tests were hypothesized to correlate. In addition to Galton's research in which low correlations were reported between rather simple sensory tests and other measures of ability, later studies by Sharp (1898-99) and Wissler (1901), despite obvious and serious shortcomings, were often interpreted as demonstrating the lack of relationships between mental tests and laboratory measures of ability. Because of these failures, and because of the early success of Binet and his associates (Binet & Simon, 1905) in devising a test of rather complex mental processes that correlated highly with teachers' estimates of children's intelligence, ability testing soon became the study of individual differences in performance on mental tests, with little regard for the factorial manipulation of conditions that is important to the experimental tradition.
Subsequent individual differences research on mental abilities has had two related foci, one focus more applied and the other more basic in orientation. The more applied orientation encompasses the study of the relations among individual differences in test scores and individual differences on various measures of real-world performance. Examples of this type of study are researches on placement of Army recruits during both World Wars, and those on the relations between tested abilities and job performance which provide the basis for work on selection and placement by industrial and organizational psychologists.

The second focus of research on mental abilities, more basic in orientation, involves research on the most appropriate structural representation of human abilities. The principal exemplars of the basic work on human abilities are studies dealing with factor analytic theories of ability structure. The present investigation, by providing evidence regarding the second-stratum structure of mental abilities, is of this latter type.

Before considering the existing theories of mental abilities, the aim of the present investigation may come into clearer focus through careful consideration of the meaning of the terms stability, construct validity, and second-stratum abilities.

**Stability.** The stability of a factor analytic solution refers to the replicability of the solution across different samples of subjects. Typically, when assessing stability, or reliability, in psychology, one obtains on the same sample of subjects more than one measure of a given construct, e.g., one might use parallel forms of the same measure, or might administer the same instrument at two different times. Then,
after obtaining scores for the individual subjects based on the
different forms or times of measurement, correlation coefficients are
computed across subjects among the various measures. The correlation,
or reliability, coefficient is a standard, and highly communicative,
representation of the degree of stability of individuals' scores on the
measures. Of course, a high reliability coefficient indicates that the
relative standing of persons on the measures correlated is highly stable
or well preserved.

When assessing the stability of a factor solution, the above data
collection design is turned somewhat on its head. That is, one obtains
scores on the same set of measures from more than one sample of
subjects. Correlations among the set of measures are then computed for
each sample of subjects, and a factor analysis based on the correlations
is conducted for each sample. The stability of the solution is
typically assessed by comparing each factor from one sample with each
factor from the other sample. A high degree of stability is attained
for a factor from one sample if there is a factor from the other sample
that has the same pattern of high and low loadings. A high degree of
stability is obtained for the factor solutions as a whole if there is a
one-to-one correspondence between factors from the two samples, that is,
if each factor from one sample may be matched with a factor from the
other sample. Thus, the assessment of factorial stability involves the
determination of similarity of relative standing, or loading, of
variables on factors, rather than relative standing of persons on
variables.

In terms of the discussion below, factorial stability is most
similar to the use of the term "external validity" by Cook and Campbell (1979), since stability refers to the generalizability of factorial results across samples of subjects. The term "stability" will be used throughout the present study, however, due to its history of use in discussions of replicability of factor analytic results.

**Construct validity.** The distinctions among internal validity, external validity, and construct validity, first made by Campbell (1957) and discussed in more detail by Campbell and Stanley (1966) and Cook and Campbell (1979), refer to the confidence one may place on results from experiments. Internal validity concerns the assessment of the change brought about by an experimental manipulation. Campbell and Stanley (1966) listed eight types of threat to internal validity, each of which would be a viable alternative explanation of an observed difference between experimental groups. That is, each of the eight types of threat could cause a difference between experimental groups, and, to the extent that one may rule out the effect of each of the eight types of threat, the validity of the significance test of difference between experimental groups as reflecting the experimental manipulation is enhanced.

External validity refers to the representativeness or generalizability of the results from an experiment. Although an experiment may demonstrate that a particular manipulation reliably produces a given effect, there are at least four types of threat (Campbell & Stanley, 1966) to the inference that the manipulated variable would have a similar effect in some other situation than the experimental one. Once again, any of the four types of threat to external validity may explain differences between groups in situations
other than the experimental, and one's faith in the relationship between
the manipulated variable and behavioral change is strengthened if the
four threats to external validity may be discounted.

Construct validity involves the determination of the validity with
which generalizations may be made from observed, or operational,
variables to higher-order constructs. Construct validity actually has
two major variants: one variant concerns the degree to which the
conceptual definitions and the operational variables are well matched,
and the other variant involves the fit between predicted and observed
patterns of relationships among variables.

One may apply the notions represented by the three types of
validity to situations that involve no manipulated variables, such as
studies of ability structure, but the meaning of the terms may need to
be somewhat altered. Internal validity may be used to refer to the
relations among the tests in a battery, which serve as the basis of the
first-order factor structure of the battery, although Cook and Campbell
(1979) might term such results an aspect of construct validity. Again,
it would be possible to consider the relationships that any number of
outside, criterion variables have with tests in a standard battery to be
an aspect of construct validity; the term 'construct validity' may now
encompass the relations among a set of tests and the relations the set
of tests has with certain outside variables. All of the preceding could
be considered aspects of construct validity, since one is interested in
the relations exhibited by a given battery of measures, and the fit
between these relations and the predicted pattern of results.

But, the definition of construct validity must also include the
assessment of the generality of the patterns of relationships from one battery to other batteries of psychological measures. That is, one battery of measures may show interpretable patterns of intercorrelation and certain relationships with certain criterion variables, e.g., sex of subject; by the above redefinitions, such information would apply to construct validity. However, if the interrelations with the battery and relations with outside variables were found to generalize to a second battery of measures designed to parallel the first, the validity of the relationships among variables would have been demonstrated outside the context of the first battery, exhibiting another aspect of the determination of construct validity.

As noted above, the term "external validity" refers to the generalizability of results across samples of persons, settings, and times. As such, external validity and factorial stability share the notion of assessing the replicability of results; stability will be used in the present study to refer to the similarity of factors from the present study with those from previous studies of ability structure.

Second-stratum-factors of ability. Cattell (1971) provided a useful distinction between the order and the stratum at which a given factor falls. The order of a factor refers to the analytic level at which a factor appears, and necessarily relates to the particular context of the study in which the factor emerges. It is common to refer to the correlations among observed or measured variables as zero-order correlations. The factors extracted to represent the zero-order correlations may be regarded as somehow more basic than the measured variables, since the factors are used to explain the relationships among
the measured variables. The factors representing the measured variables thus have a higher status than do the measured variables and are typically labeled first-order factors. Upon rotation, first-order ability factors are often found to be correlated substantially. Extending to the correlations among the first-order factors the same reasoning that led to extraction of factors from the zero-order correlations, one may extract factors, labeled second-order factors, to represent or explain the correlations among the first-order factors. If the second-order factors are correlated, third-order factors could be extracted to represent the latter correlations. This sequence would be continued until one arrived at an order containing only uncorrelated factors or a single factor. In ability research, it is uncommon to proceed beyond determination of third-order factors, since the third order often reveals only a single factor.

The stratum at which a factor falls refers to the conceptual level of the construct embodied by the factor, rather than to the level of data analysis. First-stratum factors of ability are the narrowest, most particular type of factor that would be of use in a scientific theory of human mental abilities. Such first-stratum factors would most likely correspond to the factors Thurstone (1938a) labeled Primary Mental Abilities, such as Verbal Comprehension, Numerical Facility, and Word Fluency. Each first-stratum factor represents the tendency for a set of tests to correlate highly; for example, the Numerical Facility factor represents the tendency for tests of addition, subtraction, and multiplication to correlate more highly among themselves than with other tests. Although Cattell (1971) admitted that one could probably
determine separate Addition, Subtraction, and Multiplication factors if one included three or more tests of each type in an analysis, the resulting first-order factors would be very highly correlated and too particularistic in nature to be of use in scientific theorizing, since one then have to allow a "primary" ability for each different sort of task a subject may be asked to perform.

The factors that reside at the second stratum in the ability domain are not as easily determined, resting on the particular theory one is considering. For example, Cattell (1963, 1971), in a theory to be discussed below in more detail, found in a number of studies two factors that he labeled Fluid and Crystallized Intelligence. These two factors were extracted from the intercorrelations among first-stratum abilities and reflect different developmental histories. In a number of studies, Cattell found an additional number of factors, such as General Speed and General Retrieval, that were derived from the correlations among first-stratum abilities. Cattell then determined third-stratum factors from the intercorrelations among the second-stratum abilities, and continued until arriving at a single, general intellectual factor, labeled Historical Fluid Intelligence. The set of factors at different strata that derives from the work of Cattell is not the only set of higher strata abilities to be proposed; the following discussion of factor analytic theories of abilities will cover competing theories. The main item of note at this point is that, while there is general agreement concerning the abilities residing at the first stratum, the exact nature and stability of second- and higher-stratum abilities is a topic of some debate.
Factor Analytic Theories of Ability Structure

In the following pages, the six major factor analytic theories of ability structure will be discussed. Of necessity, the discussion of the theories will be rather narrowly focused, providing a brief outline of each theory as well as the position of the theory regarding second-stratum factors.

Spearman

Theory. The first theory to be covered is that of Spearman (1904, 1923, 1927). Spearman (1927) entertained and then rejected a number of conceptions of intelligence then current. These included the following: the monarchic theory that held that intelligence was a single power for goodness of response, the oligarchic view that the domain of intelligence was based on a small number of powers or abilities, and the anarchic position that all abilities are uncorrelated and that a measure of general ability was merely an average level or sample of the underlying independent abilities.

In contrast to the above theories, Spearman formulated what he called an 'eclectic doctrine,' the theory of two factors. The theory of two factors is a theory of two classes or types of factors, one class having a single member and the other class having as many members as there are tests in an analysis. The single member in the former class is $g$, the entity common to all tests of ability. Spearman carefully avoided identifying $g$ with any of the current notions of intelligence, holding that $g$ represented an individual's relative level of mental energy. Since one's mental energy would be expended on any particular ability task, one's relative standing on a test of ability would reflect
directly the relative amount of energy available and the extent to which $g$ influenced performance on the test.

The second class of factor contains as many factors as there are tests of ability, at least for the tests included in any particular analysis. In typical factor analytic terminology, the set of factors comprising the second class of factor represents the set of unique factors, one factor unique to each variable or test. Mathematically, each unique factor reflects test variance that is not shared with other tests as well as unreliable variance. Spearman, concentrating on the specific variance, claimed that the unique factors represented "engines" that $g$, or mental energy, could activate to solve a given type of problem. Presumably, the "engines," which represent the particular ways in which persons attempt to solve problems, are built up over a period of time as a person is confronted with problems of a certain type. Again presumably, one could assess individual differences in the engines. However, Spearman expressed no interest in such individual differences, which he viewed as differences in achievement, rather than ability. The basis of differences among persons in ability resided, according to Spearman, in differences in level of $g$, and this must be assessed independently of the specific engines.

The goal of the work of Spearman (1923, 1927) was the specification of the laws that govern cognition. Toward this end, Spearman formulated three qualitative and five quantitative laws of cognition that he believed would explain trends in the cognitive domain. The first qualitative law was the apprehension of experience, that one has the power to observe and be aware of what goes on in one's mind. Spearman
felt that there must be individual differences in apprehension of experience, but that such differences were not tapped by any of the tests presently used in ability research. The second qualitative law was the eduction of relations; the eduction of relations specifies that when one has in mind two or more ideas one has more or less power to bring to mind any relations that hold between the ideas. These relations would generally involve such qualities as resemblance, size, etc. The third qualitative law concerned the eduction of correlates, which holds that when one has in mind an idea together with a relation one has more or less power to bring to mind the correlate idea that satisfies the relation. The three qualitative laws of cognition were thought by Spearman to "make up absolutely all the cognition (other than purely reproductive) of which the human mind is ever in any circumstances capable" (1927, p. 167).

The forms of cognition that may be represented with the three qualitative laws are legion. Spearman (1923) devoted a great deal of space to discussion of analogical reasoning of the form A:B::C:D, or A is to B as C is to D. With this form, if one were given A:B::C:_, the generation of an answer D would reflect the eduction of a correlate, but this would take place only after the eduction of the relationship between A and B and the mapping of the relationship onto C. This form of reasoning still has a great currency--Sternberg (1977) used Spearman's ideas as a point of departure in developing very sophisticated information processing models of the manner in which persons solve analogical reasoning tasks. It is interesting that Spearman's conception, though less well specified than Sternberg's,
retains a generality that Sternberg's does not, at least on the surface. For example, Spearman could describe the task of adding two numbers as the eduction of a correlate—that is, if one had the idea of the quantity "two" and the relation "three higher," this would tend to bring to mind the quantity "five." Thus, although Spearman could explain addition as a special case of application of one of the three qualitative laws of cognition, it is not clear that Sternberg could easily incorporate addition into his rather specific, though quite elegant, model for analogical reasoning.

As noted above, Spearman (1923, 1927) also formulated five quantitative laws of cognition. These are briefly: 1) the law of mental energy, that every mind "tends to keep its total simultaneous cognitive output constant in quantity, however varying in quality" (1923, p. 131); 2) the law of retentivity, that any cognitive event simply by its occurrence produces a tendency for its recurrence; 3) the law of fatigue, that any cognitive event, by occurring, produces an inhibitory potential opposed to its recurrence; 4) the law of conative control, that "the intensity of cognition can be controlled by conation" (1923, p. 135); and 5) the law of effect of primordial potencies, that each of the preceding four quantitative principles are superimposed upon given primordial potencies that differ from person to person, and thus perturb the influence of the above principles. In addition to these five quantitative principles, Spearman (1923, 1927) also considered the influence of other person variables, such as age, sex, and heredity.

Empirical support. Although the theory proposed by Spearman appears to be rather well specified, the empirical evidence on which the
theory rested was and is rather suspect. In the major chapter in which empirical data were presented, Spearman (1927, Chapter 10) demonstrated that the tetrad difference criterion, which could be used to test whether a single factor adequately represented the correlations among a set of measures, indicated that more than one factor was needed to explain the correlations among three different sets of nonmental traits. Spearman then showed that the same criterion indicated that a single factor could represent the relations among five sets of mental traits or measures. On the surface, this would seem to be impressive evidence that only one factor was common to the mental tests and that the criterion used was not so insensitive that it would ensure the determination of a single factor in any given set of data.

The empirical data and Spearman's selection and analysis of the data may be criticized on a number of grounds. First, Spearman analyzed only a rather small number of variables in any one analysis. The five matrices analyzed in Chapter 10 (Spearman, 1927) contained 5, 7, 8, 9, and 14 variables. Since the smaller the number of variables the smaller the number of factors that may be determined from a given matrix, the rather small number of variables in the matrices analyzed by Spearman were rather biased toward determination of a single factor.

The small number of subjects and the very stringent criterion for retention of more than one factor were additional conditions that militated against multiple factors. In the abovementioned five matrices of correlations among mental traits, three of the matrices had sample sizes of 37, 50, and 66 subjects, which are quite small when performing factor analyses, while the remaining two matrices had more adequate
sample sizes of 149 and 757 subjects. But, since significance of the deviation of the distribution of tetrad differences from that expected from a single factor is highly dependent on sample size, Spearman was engaged in analyses of very low power with small sample sizes—there may very well have been additional factors present in the data but the sample size was so small that the additional factors were not statistically significant. Spearman also used a very stringent criterion that any additional factors must be determined by tetrad differences (which are akin to partial correlations) that were at least five times their standard error, whereas in current scientific practice differences of approximately two times the standard error, i.e., t values of 2.00, or greater are considered significant. The combination of use of small sample sizes and an unreasonably conservative criterion for additional factors almost certainly assured that Spearman would only find a single factor in the matrices analyzed.

A final general criticism of Spearman’s methods concerns the rather circular reasoning that was often used when, in very unusual circumstances, more than a single factor was indicated by the distribution of tetrad differences. In these situations, Spearman contended that the tests had too much overlap, e.g., one test of addition and another of subtraction. Spearman claimed that tests included in a single analysis must be rather different from one another, but appeared to invoke this condition only when more than one factor was suggested by the data. For example, the seven-variable matrix of mental tests based on a sample of 149 subjects in Chapter 10 contained only verbal tests, which appeared to have considerable overlap. Since only a
single factor emerged from Spearman's analysis of the matrix, nothing was written concerning the similarities among the measures. But, recalling the distinction between order and stratum, it appears that the single factor extracted from the seven-variable matrix was a verbal comprehension first-stratum factor, and not $g$ as Spearman supposed, even though the factor was the only one in evidence and it appeared at the order at which Spearman typically encountered $g$.

**Burt-Thomson-Vernon Theory.** The major contemporary alternative to the Theory of Two Factors proposed by Spearman was the multi-factor conception propounded by a number of British researchers, labeled the British hierarchical theorists. This group of researchers are best exemplified by Burt, Thomson, and Vernon, although others made important contributions. The structure of mental abilities according to the hierarchical theorists included a general intellectual factor, but also included more particular, subgeneral factors, and below these even more particular factors similar to first-stratum abilities.

The theory developed by Spearman, discussed above, was presented first as it provides an interesting contrast, and polar orientation, to other theories of ability structure. Spearman's theory is often presented first on the ground that it was temporally prior to other conceptualizations of ability structure, but this is largely untrue. As early as 1909, Burt presented evidence of the existence of group factors for verbal and numerical ability in a set of tests. The major difference between the theories of Spearman and the British hierarchical theorists lies in the conceptually-driven versus data-driven nature of
the theories. As Burt (1949a) noted, Spearman was heavily influenced by the British philosophers of the 19th century, most notably Bain. Bain claimed that the mind was a unity, that the unitary power of the mind was that of discrimination. Spearman translated the notion of a single power of the mind into his theory that there was a single factor common to all tests of ability, whether the test involved mental or sensory discrimination. The series of debates in the literature from 1900 until approximately 1930 on the relative merits of the two-factor and hierarchical theories was fueled largely by Spearman's attempt to protect the integrity of his conceptually based system against the encroachments of the data-driven theorizing of the British hierarchical theorists.

The "theory" underlying the research of the hierarchical theorists is rather meager and somewhat post hoc in nature. This is not necessarily a negative assessment since, as will be noted below when covering Thurstone, it is the belief of many practitioners of factor analysis that factor analysis is a hypothesis-generating, as opposed to hypothesis-testing, method of analysis. Nonetheless, the theory underlying the hierarchical conception grew through accretion as studies of practical problems in the prediction of success in school yielded information applicable to the structure of abilities.

In 1949, Burt (1949a) provided his most comprehensive summary of factor analytic evidence on the structure of abilities. Burt hypothesized that factors appear at a total of five strata. The lowest, most particular stratum contains simple sensory processes, such as sight, hearing, smell, and touch. At the next higher level fall
perceptual abilities, which include general sense perception, with auditory and visual group factors, and motor capacity, with strength, steadiness, quickness, and skill subfactors.

It was at the third, associative level that Burt first introduced factors that others would consider intellectual in nature. Burt claimed that associative level factors would include both factors for which the form of mental operation was the basis of the factors, as well as factors for which content was the defining attribute. Formal factors include memory and productive association, and content factors include imagery, verbal abilities for dealing with words and language, arithmetical ability, and practical ability, which breaks down into spatial and mechanical subfactors.

At the fourth level appear higher relational factors; these factors subdivide into those of thought processes, with subfactors for apprehension of relations and combination of relations, and aesthetic processes, or aesthetic cognition. At the fifth and final level, Burt identified a single factor, general intelligence. In addition to the foregoing sets of factors at different levels, Burt mentioned two factors that appeared to influence mental processes at each level; these factors represent mental speed and attention.

As far as the basis for the factors at the various levels is concerned, Burt (1949a) was rather vague. Beside stating that each factor represented an ability that owed its appearance to the interaction of heredity and environment, little more was said. In other publications, Burt (e.g., 1955) held that 'intelligence' referred to an innate, general, cognitive ability, but here it is clear that he was
directing his interest to general intelligence, rather than to lower-stratum factors. One might conjecture, however, that Burt would have taken a rather strong hereditarian position with respect to lower-stratum factors that was similar to his position regarding general intelligence.

Turning to the other two hierarchical theorists, Thomson (1951) is notable primarily for his views of what it is that factors reflect. The position of Spearman (1904, 1927) and Thurstone (e.g., 1938) was that it was probable that any given factor represented one or a rather small number of underlying processes. Thomson's view was strongly opposed to such a position. Thomson began with the assumption that the mind is made up of a virtually infinite number of independent bonds. Any given task will require the sampling of a number, perhaps a rather large number, of the bonds making up the mind. The more similar the tasks, the greater the overlap of the sampling of bonds. For example, an addition test and a subtraction test both involve the execution of rather simple operations on numbers. Since both use numerical stimuli and the long-term storage of information about numbers would reside in the functioning of a large number of bonds, addition and subtraction, by sharing a large number of bonds relative to the total number of bonds used to perform each task alone, would then be highly correlated. It was in thus providing a radically different characterization of the underlying nature of factors that Thomson made his greatest contribution to the factorial study of mental abilities.

Vernon (1962) accepted Thomson's view of the nature of ability factors, and then proceeded to theorize about the ways in which
experience, primarily in the form of such cultural institutions as schools, might so structure the learning of ways of dealing with classes of stimuli that certain group factors might emerge. Since the particular form of the cultural institutions and their patterns of social reinforcement might differ across cultures, Vernon later (e.g., 1965) hypothesized that factor pattern for groups of subjects might be different, reflecting the influence of the institutions operating within their culture. Although Vernon did find differences across cultures in the factorial structure of a common set of tests and interpreted this as supporting his theory about the influence of cultural institutions on ability structure, the level of Vernon's theorizing remained at a rather abstract, or highly conceptual, level, failing to come down to the level of specifying the exact aspects of cultural institutions that might impact on ability structure and the precise mode of operation of such aspects.

Although the basis of Vernon's theorizing, largely environmental in nature, is opposed to the emphasis that Burt would give, the pattern of tests loading on factors that Vernon presented was very similar to that of Burt. Burt typically (e.g., 1955) concentrated on general intelligence when writing on the subject of abilities, but when he summarized evidence on ability structure Burt (1949a) started from the bottom, or lowest stratum, and worked his way up in the factor hierarchy. For Vernon (1962, 1965), there was no such wavering in presentation of the hierarchy of mental abilities—Vernon seemed always to start with general intelligence and proceed downward in the hierarchy. Vernon stressed the amount of variance explained by factors,
and general intelligence and the verbal:educational (v:ed) and spatial:mechanical:practical (k:m) subgeneral factors always accounted for nontrivial proportions of variance. Below the level of the two subgeneral factors lay a set of more primary-level factors that, while they might be reliable, tended to explain small, practically insignificant proportions of variance.

**Empirical support.** The empirical support for the hierarchical theory of abilities, while fairly extensive, may be faulted on a number of grounds. Burt (1949a) cited a large number of studies dating back to the early years of this century; Vernon (1962) also referenced a large number of studies. But, the majority of studies cited by both Burt and Vernon contained analyses based on rather small numbers of variables and, therefore, factors. The building of a consistent hierarchical theory from the spate of narrowly focused studies in the literature required a large amount of integrative work, but does not necessarily increase one's confidence that the whole hierarchy of ability factors may be shown in a single study.

As an example, Burt (1949a), when discussing the sensory factors that lay at the lowest stratum, cited a study in which a researcher had demonstrated sensory ability factors for each of three sense modalities. Burt considered this study support for the existence of certain factors in his proposed hierarchy, yet the relations of the sensory factors to any other factors at any other strata of the hierarchy is impossible to determine due to the small number of variables in the study. That such sensory factors belong rather far from more mental human abilities is clear; but, precisely where such sensory factors belong within a
hierarchy, indeed whether a single hierarchy of factors could encompass both sensory and mental abilities, was a question not clearly faced by Burt.

The hierarchy of ability factors as used by Burt (1949a) was, thus, a logical hierarchy. Abilities at lower strata in the hierarchy referred to simpler, more basic phenomena that may serve as a basis for the expression of other factors at higher strata, but with which there may be no direct empirical tie of an individual differences nature. For example, visual perception may be a logical prerequisite for a subject to show a meaningful level of performance on a spatial visualization test; Burt placed perceptual factors at the second stratum of his hierarchy, and such abilities as spatial visualization at the third stratum. This does not mean that one could put a set of tests into a factor analysis, arrive at perceptual factors, including visual perception, at a given order of factoring, and then define a spatial factor from the intercorrelations of the perceptual factors. To repeat, the hierarchy as presented by Burt is a logical hierarchy, containing five strata at which one may rationally place factors based on their interpretation.

Vernon (1962, 1965), on the other hand, presented factor matrices that contained factors at different hierarchical strata, but the latter strata were defined by the breadth of the loadings of a single set of variables on ability factors. Thus, Vernon tended to consider only the three highest strata outlined by Burt, which contained general intelligence, a small number of subgeneral factors, and factors similar to primary mental abilities. In addition, Vernon's use of the hierarchy
was as a more empirically based arrangement of factors, all of which could be in evidence in a single analysis based on a single set of variables.

A second criticism of the hierarchical theorists is the methods of analysis that were typically used. The hierarchical theorists tended to view factor analysis as a method of analysis only useful for classifying tests, for defining clusters of tests. As a result, since the clusters of tests could be identified by noting similarities in the pattern of loading across a set of factors, factor analyses were often presented without rotation to an interpretable simple structure. This led to a lack of clear relationship of the factor analytic results and the particular factors placed at different strata in the hierarchy.

Although one may criticize the methods of the hierarchical theorists, the set of factors at which they arrived are not radically different from those in other theories, most notably Cattell's to be discussed below.

**Thurstone**

**Theory.** The theory of mental abilities held by Thurstone will be rather briefly described, since the theory is rather sparse. Perhaps more important to consider is Thurstone's approach to the use of factor analysis. Thurstone (e.g., 1938a, 1948) claimed that the most appropriate use of factor analysis was at the boundaries of science, at the edge of explorations of new domains of behavior. One may use factor analysis to reduce the wide array of phenomena in a domain by expressing the observed measures of behavior as a function of a set of latent traits underlying the phenomena. Once one adequately replicated the
major dimensions of individual difference in any domain, Thurstone thought one should proceed to the laboratory, to conduct experiments that would contribute to our understanding of the factors that cause or determine human behavior. Thus, Thurstone never produced an elaborate theory of human abilities; he advocated factor analysis of large numbers of tests spanning a domain of interest, simply to determine the major dimensions in the domain. A more adequate theory of abilities would have to await much careful experimental work, for which factor analysis would be an inappropriate method.

Across a number of studies, Thurstone (1938a, 1939b, 1940; Thurstone & Thurstone, 1941) consistently found a small number of factors that he termed primary mental abilities. These primary abilities consisted of such factors as Verbal Comprehension, Word Fluency, Numerical Facility, Spatial Ability, Perceptual Speed, Memory, and Reasoning. Thurstone and Thurstone (1941) presented one of the first second-order factor analyses, determining a single second-order factor that adequately represented the correlations among the seven obliquely rotated primary mental abilities. Thurstone and Thurstone then claimed that the use of higher-order analyses appeared to have brought about agreement among the disparate claims of the Spearman, hierarchical, and primary ability theories—oblique rotation to simple structure led to determination of a set of primary abilities, and more general factors up to and including Spearman's \( g \) could be identified from analyses of the intercorrelations among the primary factors.

**Empirical support.** The empirical support for Thurstone's system of primary abilities appears to be more solid than the empirical evidence
underlying any other factor analytic theory of abilities. A very large number of tests were entered into each analysis, the sample sizes most often numbered in the many hundreds, and the analytical methods used were superb.

If there is one flaw in the writings of Thurstone, it may have to do with his constant claim that factor analysis should be used only for exploratory work, not for confirmatory. Thurstone apparently believed that he had settled the problems regarding the structural representation of abilities by determining a general factor as a second-order factor, satisfying the theorists who postulated a general factor common to all ability tests, while retaining primary factors that had simple, unique interpretations. As will be discussed below, subsequent work in the ability domain has revealed a number of rather subtle differences between the hypotheses of competing theories, differences with respect to the manner in which variables load on factors, thus different predictions that factor analysis could confirm or disconfirm. Aside from this aspect of Thurstone's work, the set of primary mental abilities determined in the studies cited above were so well replicated across studies that few researchers today doubt the place of the primary mental abilities in theories of ability structure.

Guilford

Theory. The Structure-of-Intellect theory developed by Guilford represents a radical departure from the theories covered so far. After a careful review of the experimental literature of the time, Guilford (1959, 1967, 1972b; Guilford & Hoepfner, 1971) postulated five ways in which the mind processes information; these five ways of processing are
the five operations of cognition, memory, divergent production, convergent production, and evaluation. Guilford noted that the mind operates on four types of content, figural, symbolic, semantic, and behavioral. Finally, six types of product are possible: units, classes, relations, systems, transformations, and implications. The nature of any ability factor may be defined by a particular combination of content, operation, and product, and Guilford hypothesized that there was one factor for each unique combination of content, operation, and product, a total of 120 ability factors.

The position Guilford took with respect to correlations among ability factors and the implied higher-order factors of ability is at greater variance with the other theories of ability structure than his postulation of a larger number of factors, 120, than most researchers have tests. In a number of places, Guilford (1961, 1964, 1967, 1972a, 1974) argued for the use of orthogonal rotations of ability factors, which would preclude the exploration for higher-order factors of ability. Although he often criticized other researchers for their hierarchical theorizing, Guilford (1981) recently significantly, and rather surprisingly, reversed his stand on this issue.

Empirical support. Beginning in the early 1950's, Guilford and his associates undertook a large number of studies designed to investigate systematically the factors hypothesized by Structure-of-Intellect theory. By 1971, Guilford and Hoepfner reported that 98 of the 120 abilities had been confirmed, each having appeared in at least one study. On the surface, this appears to offer substantial support for the Structure-of-Intellect theory.
Despite its apparent empirical support, a wide variety of criticisms have been made of Guilford's theory. Probably the most telling criticism was made by Horn and Knapp (1974a, 1974b) following their reanalyses of the matrices of correlations among tests from three studies by Guilford and his associates. Horn and Knapp reported three types of analysis of the matrices. The first type of analysis was a replication of the analyses the original authors reported having used for the original report. The original analysis typically involved extraction of the number of factors dictated by Structure-of-Intellect theory and orthogonal Procrustean rotation to the theoretical target. The second type of analysis was similar to the first, except that Horn and Knapp used random hypotheses to construct a target matrix for the orthogonal Procrustean rotation, as opposed to Structure-of-Intellect hypotheses. The third type of analysis started by extracting a number of factors suggested by tests for the number of factors followed by oblique analytic rotation to simple structure. Horn and Knapp found that random targets achieved hit rates, i.e., achieved high loadings where high loadings were targeted, similar to Structure-of-Intellect hypotheses, an 84% hit rate. But, when the factors were rotated to oblique simple structure, the hit rates for Thurstonian hypotheses was rather higher, 95%.

A second criticism, presented by Undheim and Cattell (1977) and rather important for the present study, concerned the lack of replication of factors. Although Guilford claimed that quite a number of factors had been replicated across studies, Undheim and Horn stated that there often were changes in variables from one study to another,
and this led to an inability to identify a primary factor as identical across studies.

In spite of the large number of additional criticisms directed toward Structure-of-Intellect theory, attention will be turned to the next theory of ability structure since Structure-of-Intellect theory has no clear or obvious position regarding the theoretical and empirical identity of second- and higher-stratum factors of ability (but, see Guilford, 1981).

Cattell Theory. Cattell (1963, 1971) proposed a theory to explain the observed patterns of correlation among primary factors. Cattell started with the notions of Fluid and Crystallized Intelligence as second-stratum factors of ability. Fluid Intelligence represents a power of dealing with complex relations in areas in which previous experience would not give some persons advantage over others. Befitting its title, one may direct one's Fluid Intelligence toward any type of task. When one first confronts a new type of task, the exercise of Fluid Intelligence is the most effective and efficient way of arriving at a solution to the problem. Later, however, after having dealt with a given type of problem for some time, it may be more efficient to call up a "program" that will speedily process the data and produce an answer. The program that is invoked in such situations is a crystallized aid specific to a certain type of problem. Cattell believed that there were individual differences in the largely innate Fluid Intelligence, and that it was only over time that crystallized aids were formed through the investment of Fluid Intelligence. Because individual differences in
Fluid Intelligence would influence the efficiency of one's programs or crystallized aids of whatever sort, persons with higher levels of Fluid Intelligence would tend to formulate more efficient aids or strategies for dealing with various types of stimuli or problems. This, in turn, would lead to a higher correlation among primary abilities reflecting crystallized solution strategies, and this higher correlation would provide a basis for a second-stratum factor labeled Crystallized Intelligence.

Assessment of Fluid and Crystallized Intelligence requires a carefully selected battery of measures. Tests that are clearest indicators of Fluid Intelligence are those that use stimuli equally novel or equally overlearned by all subjects. If the task posed is rather complex, use of very novel or overlearned stimuli will result in individual differences on the task that are a function of individual differences in amount of Fluid Intelligence. Tests that are markers for Crystallized Intelligence, on the other hand, utilize stimuli or types of problems that are culturally loaded.

It is interesting to note that Cattell essentially accepted the primary mental abilities that were prominent aspects of previously considered theories of ability structure, and developed the notion of Fluid and Crystallized Intelligence to account for the variety of factors that emerged from analyses of correlations among primary factors. Additional second-stratum factors that often emerge with Fluid and Crystallized Intelligence include General Visualization, General Speed, and General Retrieval Capacity.

Empirical support. The theory proposed by Cattell has led to a
great number of empirical studies directed at demonstrating the existence of second-stratum factors of ability. Beside the Cattell (1963) study, studies by Cattell (1967; Cattell & Horn, 1978), Horn and his associates (1972, 1980, Horn & Bramble, 1967; Horn & Cattell, 1967a, 1967b; Horn, Donaldson, & Engstrom, 1981), Hakstian and Cattell (1974, 1978), Rossman and Horn (1972), Stankov (1978; Stankov & Horn, 1980; Stankov, Horn, & Roy, 1980), and Undheim (1976, 1978) have reported finding Fluid and Crystallized Intelligence factors along with a variety of other second-stratum factors. This apparently high degree of empirical support must be tempered by the observation that rarely have the batteries of measures remained the same across studies. It also appears that the loading pattern of factors may differ considerably across studies, but the interpretations given to factors remains rather constant.

The problem of lack of strict replication of factors across studies due to changes in the battery of tests was raised by Undheim and Horn (1978) when criticizing Guilford's theory. But, much the same criticism could be leveled at the Cattell-Horn theory of Fluid and Crystallized Intelligence. There are wide variations in the batteries used in different studies by the same authors, and variations in the loadings of tests on factors across studies are often overlooked. To take one or two examples, when considering five representative studies (Cattell, 1963; Horn & Cattell, 1967; Horn & Bramble, 1967; Undheim, 1976; and Hakstian & Cattell, 1978), Numerical Ability had loadings on Crystallized Intelligence ranging from -.05 to .59 and loadings on Fluid Intelligence ranging from -.11 to .45. For Spatial Ability, its
loadings on Fluid Intelligence ranged from \(-0.03\) to \(0.68\). Perceptual Speed loadings on Fluid Intelligence ranged from \(0.10\) to \(0.40\) and its loadings on General Visualization ranged from \(-0.05\) to \(0.59\). Thus, it appears that there are some major variations in the loading patterns across studies, but differences in the test batteries make the variations in loadings difficult to interpret.

To fill an obvious void, Hakstian and Cattell (1976) recently developed the Comprehensive Ability Battery, the first standardized battery of the type of tests that are used as a basis for second-stratum factors such as Fluid and Crystallized Intelligence. In the only published factor analysis of the Comprehensive Ability Battery, Hakstian and Cattell (1978) claimed to have found second-stratum factors similar to those from previous studies of Fluid and Crystallized Intelligence. With a standard battery available for future research on second-stratum factors of ability, perhaps variations across studies in the loading pattern of tests on factors will become more scarce. If not, the use of a standard battery will force investigators to face more directly the lack of stability of their results.

In addition to the variability of Fluid and Crystallized Intelligence loading patterns across studies, there have been other criticisms of the Cattell-Horn theory. For example, although he criticized the factor analytic methods used by Cattell (1963), Humphreys (1967) found that the pattern of results and the conclusions one would reach were rather stable. In a recent critique, Guilford (1980) emphasized that the tendency for Cattell and Horn to use samples quite heterogeneous in age might bias their results toward arriving at the
Fluid and Crystallized Intelligence patterns because of commonality of age trends for certain variables. But, other studies, e.g., Undheim (1976, 1978), Hakstian and Cattell (1978), that used age-homogeneous sample still arrived at a similar pattern of loading on tests, so Guilford's criticism loses its force.

In sum, the Cattell-Horn theory of Fluid and Crystallized Intelligence is currently the most heavily researched of the individual difference theories of intelligence, and appears to hold promise of explaining observed trends of various types, for example, age trends on different abilities.

Das

Theory and empirical support. One final theory will be discussed briefly, the theory of simultaneous and successive processing proposed by Das and his associates (1973; Das, Kirby, & Jarman, 1975, 1979). Basing their theory on Luria's brain research, Das et al. hypothesized that the simultaneous and successive coding processes Luria described may emerge from individual difference tests of ability. Simultaneous processing refers to processing in which one may approach an object from one of many directions until extracting sufficient information from the object. An example of this sort of processing would be the visual image of a concrete object that one may "turn over and turn around" in one's mind. Successive processing, on the other hand, refers to stimuli that must be processed in a linear fashion in order for the information to be understandable. The most obvious example of this type of stimulus is language.

On the basis of Luria's neurological studies and his conjectures
about the two types of coding processes, Das et al. have designed small batteries of tests and administered the batteries to rather small groups of subjects. Upon factor analyzing the batteries, Das et al. typically find a factor identifiable as simultaneous processing, a second that may be labeled successive processing, and occasionally a speed factor.

The reason for giving the Das et al. (1975, 1979) theory so little consideration here is that Das et al. have failed to compare systematically the conceptual definition of their factors with factors from all other theories, especially with respect to the tests used to identify the factors. Thus, the tests used to assess the successive processing factor bear a strong resemblance to tests for verbal and memory tests; Das et al. have not clearly explained why it is that the factor emerging from their analyses is a successive processing factor as opposed to a verbal or memory factor.

Nevertheless, there is one finding reported by Das et al. (1975) that is rather unique. In a study by Cummins (reported in Das et al., 1975), two paired associates tasks were prepared, one using concrete words and the other abstract words. Two free recall tasks were also prepared, with one task using concrete words and the other abstract words. When these tasks were factor analyzed with other measures of simultaneous and successive processing, the concrete paired associate task loaded most highly on the simultaneous processing factor as hypothesized, while the abstract paired associates task and the two free recall tasks loaded on the successive processing factor. Since the paired associates tasks were administered at a rather slow rate, subjects apparently could utilize the simultaneous code to remember the
association between stimulus and response for the concrete words, while the successive code was the only one available for the abstract words. On the free recall tasks, the words were read at such a fast rate, subjects apparently were not able to access the simultaneous code, using the successive code since it is the more practiced in dealing with quickly presented verbal material. Most factor theorists would have predicted that the two paired associates tasks would load on the same factor, since both involved fairly short-term recall of the pairing of response words with stimulus words. That the two paired associate tasks loaded on different factors in accord with the prediction based on the theory of simultaneous and successive processing lends support for claims of uniqueness of the latter theory.

Hypotheses

The hypotheses investigated in the present study may be grouped under the headings of the stability and construct validity of the relations shown by the CAB. As discussed above, the CAB is the first standardized battery of tests developed by Cattell and Horn and their collaborators to assess a considerable span of the ability domain. The theory of Fluid and Crystallized Intelligence would be strengthened if reliable relations could be demonstrated for the CAB, and if these pattern were similar to those observed by other batteries of similar measures.

Stability of Relations-Involving CAB Scales

Sex differences. It is hypothesized that the pattern of sex differences on the CAB obtained in the study by Hakstian and Cattell (1975) will be replicated on a sample of college freshmen. Hakstian and
Cattell (1975) used 11th and 12th graders as subjects, and, since college freshmen would tend to be only one or two years older than the subjects in the Hakstian and Cattell study, the pattern of sex differences on the CAB in the present study should be very similar to that reported in the previous study.

Second-stratum factors. A second, and the more important, stability hypothesis is that the second-stratum factors derived from the CAB in the present study will be highly similar to those from the Hakstian and Cattell (1978) study. As noted above for primary abilities, it appears that primary abilities may show a high degree of cross-sample stability. Prior to the construction of the CAB, there was no standard battery for assessing second-stratum factors of ability. As a result, the stability of loading pattern for second-stratum factors has yet to be demonstrated.

There are one or two reasons for concern regarding this hypothesis. First, Hakstian and Cattell (1978) labeled as Crystallized Intelligence a factor that had only 2 high loadings from the battery of 20 tests in the CAB. Although the two highly loaded tests were those usually used as markers of Crystallized Intelligence, Verbal Ability and Mechanical Knowledge, the factor did not appear to represent as strong and pervasive a factor as the theory of Fluid and Crystallized Intelligence would lead one to expect. If the failure of a large number of tests to load on the Hakstian and Cattell (1978) Crystallized Intelligence factor were due to sampling variability, one might expect that an attempt to replicate the factorial structure of the CAB would find a Crystallized Intelligence factor with more than two loadings. The result would be
that the Crystallized Intelligence factor from the replication study would more adequately reflect the underlying nature of the factor in question, but would appear to represent simply a variant pattern of loadings from those observed in the Hakstian and Cattell (1978) study.

Second, two additional factors from the Hakstian and Cattell (1978) study may not replicate well. The factor labeled General Perceptual Speed is a factor concerning whose interpretation Hakstian and Cattell disagreed, the General Perceptual Speed label representing a compromise between the different interpretations favored by Hakstian and Cattell. Since the General Perceptual Speed factor did not have a clean simple structure, an attempted replication of the General Perceptual Speed factor may result in a factor with better simple structure that would more strongly support one of the two proposed meanings of the factor, but in terms of stability of loading pattern the attempted replication may only lead to a conclusion that the loading pattern lacks reliability. The second additional factor is that identified as General Retrieval Capacity; in the Hakstian and Cattell (1978) study, this factor had only one rather high loading, and of the three lower loadings one was not consistent with the interpretation of the factor. Once again, a factor from an attempted replication that more closely fit with the loading pattern hypothesized for the factor may be perceived simply as an indication of the lack of stability of the factor rather than as a more accurate example of the second-stratum factor.

Construct Validity of CAB Relations

Sex differences. The first hypothesis regarding construct validity of the patterns of CAB relations concerns the existence of the pattern
of sex differences in an external battery designed to parallel the CAB. If the pattern of sex differences on an external battery of measures is similar to that observed for the CAB, one would have more confidence that the observed sex differences represented actual differences between males and females, rather than merely representing sex differences on the particular scales comprising the CAB.

**External relations of second-stratum factors from the CAB.** The additional battery of tests on which the above sex differences would be computed should be chosen to aid in the interpretation of factors from the CAB. To this end, the following hypotheses were made:

As noted above, although there is a rather large difference in the conceptual definitions of Fluid and Crystallized Intelligence and Simultaneous and Successive Processing, respectively, the tests used as markers of the factors do not seem to differ greatly. Das and his associates, however, would draw distinctions between the factors, claiming that one could solve a crystallized task using either simultaneous or successive processing, and likewise for fluid tasks. To test whether simultaneous processing may be equated with Fluid and successive processing with Crystallized Intelligence, four verbal tasks were created. Following the procedures used and results reported by Cummins (cited in Das et al., 1975), two paired associate tasks, one using concrete and the other abstract words, were hypothesized to load differently on Fluid (concrete) and Crystallized (abstract) Intelligence factors. Both concrete and abstract free recall tasks would be hypothesized to load on the Crystallized Intelligence factor due to the demands for successive processing.
Various types of reasoning tasks should load on both Fluid and Crystallized Intelligence factors. Based on the summaries presented by Horn (1968, 1978), Inductive Reasoning should load more heavily on Fluid Intelligence, Logical or Deductive Reasoning should load more heavily on Crystallized Intelligence, and a general reasoning test should load about equally on the two factors. Three tests, one for each of the above three types of reasoning, were selected from the Ekstrom et al. (1976) battery of measures to test the stated hypotheses.

If another test requiring verbal comprehension were included in the battery, the measure should load only on the Crystallized Intelligence factor, and broadening the meaning of the factor beyond that of the particular tests used in the CAB. The Quick Word Test, described below, was chosen for the above purposes.

Because of the crucial nature of the loading of CAB tests for Perceptual Speed and Spatial Ability on factors for the interpretation of the General Perceptual Speed, General Visualization, and Fluid Intelligence factors, one measure of Perceptual Speed and one measure of Spatial Ability from the Ekstrom et al. (1976) battery were included to provide converging indicators of the second-stratum factors of ability.
METHOD

Subjects

The sample consisted of 272 students (194 females) in Introductory Psychology, who participated in the study to satisfy a course requirement. Although all subjects were first-year students in college, a rather wide range of chronological age was represented in the sample. In the sample as a whole, the mean age was 18.57 years, with a standard deviation of 2.20 years and a range of 16 to 37 years. Among the 194 females, the mean age was 18.56 years (standard deviation of 2.42 years, range from 16 to 37 years); among the 78 males, the mean age was 18.59 years (standard deviation of 1.55 years, range from 17 to 29 years).

In terms of racial or ethnic status, the clear majority of the subjects were Anglo-American. With only eight Black and three Oriental subjects in the sample, analyses designed to determine racial or ethnic status differences were not feasible.

Instruments

Comprehensive Ability Battery

The majority of the measures used in the present study were those comprising the Comprehensive Ability Battery (CAB; Hakstian & Cattell, 1975). The CAB consists of 20 tests, one test for each of 20 primary abilities. A summary of the tests in the CAB is given in Table 1, which
lists the tests by name and gives the number of parts in the test, the total number of items, the total working time, and the median test reliability (summarized from the CAB manual; Hakstian & Cattell, 1975). Following is a description of the primary factor measured by each test, a comparison of the CAB test with other standard ways of measuring the factor (Thurstone, 1938; Thurstone & Thurstone, 1941; Ekstrom et al., 1976), and a sample item from each test.

Insert Table 1 about here

Verbal Ability (V). Verbal Ability represents the capability to understand or extract meaning from written language and to comprehend words and ideas; this ability is often labeled Verbal Comprehension. Typically, Verbal Ability is measured by tests requiring selection of the definition (e.g., synonyms, antonyms) of a word, answering questions based on a written passage, or supplying an appropriate word or words to complete a sentence. The CAB test consists of two separately timed parts. Part I is a multiple choice synonyms test, with items such as:

FAST: a. old b. rapid c. slow d. early e. late

The items on Part II require the choice from among five alternatives of the one saying that expresses the same meaning as a common proverb or saying; a sample item is:
STRIKE WHILE THE IRON IS HOT

a. take things as you find them
b. hot love is soon cold
c. make hay while the sun shines
d. first think and then speak
e. look before you leap

Numerical Ability (N). This factor represents the ability to perform in a fast and accurate manner simple operations on numbers, operations such as addition, subtraction, multiplication, and division. Numerical Ability, also called Number Facility, refers to a rather simple or lower-level computational ability that is distinct from mathematical reasoning or higher mathematical skills. Numerical Ability is most often measured with separate tests of addition, subtraction, multiplication, and division, each test being rather highly speeded and containing a large set of items relatively homogeneous in difficulty level. The CAB test, with a rather liberal time limit for the given number of problems, contains multiple-choice items graded in difficulty, beginning with addition of four two-place numbers and ending with multiplication and division of fractions (the latter items being more difficult than those usually used to measure Numerical Ability). Two example items are:

Add: \[ \frac{1}{2} + \frac{1}{4} = \]
\[
\begin{array}{ccccc}
\text{a. } & \frac{1}{8} & \text{b. } & \frac{3}{5} & \text{c. } & \frac{3}{4} & \text{d. } & \frac{1}{3} & \text{e. } & \frac{1}{2} \\
\end{array}
\]

Spatial Ability (S). Spatial Ability, also called Spatial Orientation, refers to the ability to rotate mentally an object in two- or three-dimensional space while maintaining the structural or
relational integrity of parts of the object. Spatial Ability has traditionally been assessed using tests that require the subject to determine whether one figure is a two-dimensional rotation of a standard or a three-dimensional rotation, thus requiring flipping as well as rotation to match the standard. The CAB test closely follows the preceding description, asking the subject to circle an $S$ (for "Same") if the comparison object is a two-dimensional rotation of the standard or a $D$ (for "Different") if the comparison is a three-dimensional rotation. A sample item follows:

```
X1. SD   X2. SD   X3. SD   X4. SD
```

**Speed of Closure** (**Cs**). Speed of Closure represents the ability to complete or construct a whole stimulus when parts of the stimulus are missing. Tests used to assess Speed of Closure include those with black-and-white pictures or words parts of which have been erased, or line-drawn figures that are almost completely obliterated by blizzard-like splatters. A similar factor in the Ekstrom et al. (1976) battery is Verbal Closure, one test for which requires the subject to rearrange a set of letters to form a common word. Each item on the CAB test for Speed of Closure presents a partially obliterated stimulus word that the subject must identify or recognize, and the subject must then select the one of five alternatives that contains the letters which, if rearranged, would spell the stimulus word. Thus, the CAB test for Cs
appears to involve components of both Speed of Closure and Verbal Closure in the terminology of Ekstrom et al. (1976). A sample item follows:

**Score**

a. ehrsu  b. rescu  c. osher  d. roesc  e. rtose

**Perceptual Speed and Accuracy (P).** This factor, usually labeled simply Perceptual Speed, represents the ability rapidly and accurately to scan figures or symbols and determine whether each of a set of comparison stimuli is the same as, or different from, a standard. Typical tasks include crossing out instances of a particular letter (e.g., the letter "a") on a page of letters or words, comparing multi-digit number strings to determine whether they are the same or different, and comparing simple drawings as the same as, or different from, a standard. The CAB test alternates pairs of multi-digit numbers and pairs of multi-letter strings, requiring a same-different judgment. Two examples follow:

```
TRSPUVGY  TRSPUVGY
10295364  10295364
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**Inductive Reasoning (I).** The Inductive Reasoning factor reflects the ability to reason from specific information to arrive at a general principle, forming and testing hypotheses that fit a set of stimuli. One marker test for Inductive Reasoning asks the subject to indicate which one of five four-letter strings fails to evidence a rule embodied in the other four; another typical test requests the subject to place an "x" on the fifth line of dashes and gaps such that the "x" on the
fifth line follows the rule implicit in the placing of an "x" on each of the first four rows. The CAB test is of the former type; a sample item is:

Which of the following sets of letters is different:

a. ABCD    b. GHIJ    c. LMNO    d. QSRT    e. VWXY

Flexibility of Closure (Cf). This factor represents the ability to concentrate on the critical or key aspects of a stimulus so that one may disembed the stimulus from irrelevant surrounding stimulus material. Flexibility of Closure is rather similar, if not identical, to Witkin's cognitive style labeled field independence. Tests that measure Flexibility of Closure may require the subject to choose which of five simple polygons may be found in a given complex display of lines, to determine whether or not a simple line drawing is present in a more complex drawing, or to reproduce by connecting the dots in a 5-by-5 matrix of dots a freely drawn figure consisting of a series of connected straight lines. The CAB test is of the former type, and a sample problem is the following:

The complex figure on the left contains which of the simple figures on the right:

```
  a b c d e

  a b c
d e
```

```
a  b  c
d  e
```


**Associative Memory (Ma).** Associative Memory, also known as Rote Memory, refers to the ability to recall one member of a paired set of otherwise unrelated stimuli when the other member of the pair is presented. Representative tests of Associative Memory, which are similar to tasks used in paired-associates learning, include the learning of the pairing of the pictures of common objects with particular two-digit numbers, of the pairing of object names with two-digit numbers, and the pairing of first and last names that have no obvious connections. The CAB test of Associative Memory is of the picture—number variety, except that the pictures consisted of abstract line drawings with which it would be difficult to associate verbal labels. An example is:

**Learning phase:**

![Diagram](image)

57

**Recall phase:**

![Diagram](image)

a. 16  b. 45  c. 57  d. 61  e. 75

**Mechanical Ability (Mk).** This factor depends on acquired knowledge and skill to a greater degree than the other factors in the CAB, since the test requires an understanding of basic mechanical principles and acquaintance with simple machines and tools. The Mechanical Ability factor, also called Mechanical Knowledge, was included in the ETS Kit of Reference Tests for Cognitive Factors (French et al., 1963) but dropped from the later version of the battery (Ekstrom et al., 1976) because the
factor appears to represent achieved skill rather than aptitude. But, the importance of this factor for differentiating between the Burt-Thomson-Vernon and the Cattell theories of higher-stratum abilities argues for the inclusion of the factor in the CAB and the present analyses. The CAB test, following traditional methods of assessing Mechanical Ability, requires identification of tools, determination of which direction or the speed with which a target axle will turn as the result of the action of motor gears or pulleys, and definitions of technical terms. An example of a verbal definition problem is:

Any material that electricity will pass through is called a(n)

a. insulator  
b. magnet  
c. transformer  
d. filament  
e. conductor

Memory Span (Ms). The Memory Span factor corresponds to the classical short-term memory ability well researched by cognitive psychologists. Typical tests involve either visual or auditory presentation of strings of numbers or letters which the subject is required to recall in order, or in reverse order, of presentation. The CAB test is composed of auditory presentation of a series of strings of 5 to 10 single-digit numbers, at the rate of one digit per second, with the subject to write down a given number string in order of presentation immediately after the string is presented. An example is:

(Auditorily presented): 8 1 9 5 7 2
Recall: ___ ___ ___ ___ ___ ___

Meaningful Memory (Mm). Meaningful Memory represents the ability to remember, over a relatively short period of time, material in which
recall is based on meaningful semantic relationships. This factor and its associated CAB test have no clear parallel in previous individual differences research on abilities. The CAB test requires subjects to study a list of 20 object-adjective pairs, in which the adjective was a reasonable (though not uniquely applicable) descriptor of the object with which it was associated. The Memory Span test is administered immediately following the period of study of the Meaningful Memory object-adjective pairs. After completion of the Memory Span test, the recall portion of the Meaningful Memory test is administered; during recall, the subject is given the object name and asked to select from five alternative adjectives the one that is closest in meaning to the adjective from the study list. An example follows:

Study: hammer excellent
Recall: hammer a. big b. rough c. good
d. small e. heavy

Spelling (Sp). The Spelling factor reflects the ability to recognize misspelled words, clearly a capability of rather limited scope. Although the ETS battery does not include any tests of this sort, Thurstone (1938; Thurstone & Thurstone, 1941) included tests similar to the present one in his early studies of ability structure. Spelling-type tests have been found to load highest on a variety of factors, e.g., Word Fluency primary factor (Thurstone, 1938), Perceptual Speed primary factor (Thurstone & Thurstone, 1941), Verbal Comprehension primary factor (Thurstone, 1940), and Hakstian and Cattell (1978) found the Spelling test to load on a second-stratum General Perceptual Speed factor. The Spelling factor, while not a "Primary Mental Ability" in
the Thurstonian sense, was included in the CAB because ease and accuracy of recognizing misspelled words is an ability that would be predictive of success in a wide variety of occupations. Each item on the CAB Spelling test presented four words to the subject; the subject was requested to identify which of the four words was misspelled or to choose a fifth alternative indicating that none of the four words was incorrectly spelled.

An example item from the CAB Spelling test is:

a. barely  b. question  c. secret  d. present  e. none wrong

Auditory Ability (AA). The Auditory Ability factor is another factor that has few parallels in previous work on mental abilities. The first part of the CAB Auditory Ability test required the subject to indicate whether the pitch of the second of a pair of tones was lower than, equal to, or higher than that of the first. In the second part of the test, subjects listen to a number of pairs of four- or five-tone sequences; after listening to a pair of sequences, the subject is to identify which of the four or five tones in the second sequence differed in pitch from that in the first sequence. The Auditory Ability test was included in the CAB because of its expected predictive utility; Hakstian and Cattell (1975) stated that pitch discrimination (Part I) and tonal memory (Part II) are two of the major components of musical ability. Because of the straightforward nature of the items on the Auditory Ability test and because the items require auditory presentation, no example item is provided for this test.

Esthetic Judgment (E). Esthetic Judgment represents the ability to discriminate whether or not principles of art or design are followed.
The CAB Esthetic Judgment test asks the subject to select from among two or three abstract designs the one that follows principles of good design, as determined by a panel of judges. The Esthetic Judgment factor was included in the CAB since it was expected to correlate with success in a wide variety of occupations dealing with art and design.

An example item from the CAB Esthetic Judgment test is:

![Design A](image_a.png) ![Design B](image_b.png)

**Spontaneous Flexibility (Fs).** Spontaneous Flexibility refers to the ability to recombine elements into nontraditional organizations. This factor is represented by one of the four tests for the Flexibility of Use factor in the ETS battery (Ekstrom et al., 1976); the latter, Flexibility of Use factor appears to have been too narrowly labeled—finding alternate uses for objects seems to be a subset of the tasks that require a person to break a typical set and think of a new organization. On the CAB test, the subject is given the names of seven objects, and is asked to form as many different groups of two or more of the objects as s/he can, listing both the similarity that unites the new group of objects and listing all objects that share the similarity relationship. An example follows:
Form new subgroups from the belowlisted objects and briefly describe the characteristic the objects in the group share.

a. chair  b. rug  c. table  d. lamp  
  e. radio  f. bed  g. stove

**Ideational Fluency (Fi).** Ideational Fluency involves facility in generating quickly ideas about a given topic or class of objects, a task on which quantity rather than quality is emphasized. The CAB Ideational Fluency test is similar to the tests for the identically named factor in the ETS battery (Ekstrom et al., 1976), tests which ask subjects to write ideas about a given topic, to write as much as possible about a given theme, and to enumerate objects that are alike in a given way. On the CAB test, the subject is required to produce as many single-word adjectives descriptive of a certain thing as they can within a given time limit. One example is:

List as many words (adjectives) as you can that might describe a MOUNTAIN STREAM.

**Word Fluency (W).** The Word Fluency factor concerns the ability to generate quickly words that satisfy structural restrictions that are irrelevant to the meanings of the words produced. This factor is usually assessed by tests that require production of words that start, end, or start and end with given letters. The CAB Word Fluency test is an anagrams task on which the subject is to produce as many words as possible from a set of five letters; an example is:
As quickly as you can, write as many words as you can using only the letters: E T N W I

Originality (O). Originality concerns the production of a novel and useful object by combining ordinary objects. The Originality test on the CAB is quite similar to one of the four tests for the Spontaneous Flexibility factor in the ETS battery (Ekstrom et al., 1976); the latter test presents the subject with a problem situation (e.g., cleaning the inside of a bottle) that the subject must solve using two everyday objects (e.g., a rag and a pencil). The CAB test reverses this task; the subject is given pairs of ordinary objects and is asked to produce the name of a new, useful object constructed from the given pair of objects.

One example item from the CAB Originality test is:

Old objects: ______ New object constructed

pole   tin can

Aiming (A). Aiming refers to the ability to execute fine motor movements, involving hand-eye coordination, under highly speeded conditions. Since the Aiming factor reflects a psychomotor ability, this factor is not represented in the ETS battery or in Thurstone's work on mental abilities. The Aiming factor was included in the CAB for its expected validity in predicting success in mechanical, drafting, and clerical jobs. The Aiming test on the CAB consists of a large number of identical stimuli; each stimulus is comprised of two squares, one drawn inside the other, with a dot placed in the center of the stimulus. The
subject is to draw two complete lines, one encircling the dot and the other between the two squares, such that the drawn lines do not touch any part of the printed stimulus display. One row of the stimulus problems follows:

1. [●]  2. [●]  3. [●]  4. [●]

Representational Drawing (RD). The Representational Drawing factor represents the ability to reproduce, under some time constraint, a standard figure. The subject is to draw the reproduction as accurately as possible, in terms of both size and shape, given the standard stimulus and a small number of clues to aid in establishing the proper scale for the reproduction. The Representational Drawing factor, which has no clear precedent in previous ability research, was included to provide predictive efficacy for the CAB in the areas of art and design, drafting, and cognate occupations. An example item is:

Standard

Draw here

Extension Set

A total of ten tests were selected to assess the construct validity
of the second-stratum factors of the CAB. A summary of the ten tests in the extension set is presented in Table 2, which lists the tests by name and gives the number of items, the total working time, and the reliability of the tests. Below, each test is briefly described, the source of the test is identified, and a sample item from each test is presented.

Insert Table 2 about here

Paired Associates—Abstract (PA-A). The Abstract Paired Associates task is the first of four tests designed to test how the theory of simultaneous and successive processes developed by Das et al. (1975, 1979) meshes with the Cattell-Horn theory of fluid and crystallized intelligence. As discussed above, it appears that the simultaneous processing factor reportedly found across a number of studies by Das and his associates is rather similar to that identified as Fluid Intelligence by Cattell and his associates; likewise, the successive processing factor is rather similar to the Crystallized Intelligence factor. In a study by Cummins (cited in Das et al., 1975), an abstract paired associates task defined a factor labeled Successive Processing. In the present study, the procedures used by Cummins were followed, except that 12 pairs of abstract words were used, rather than 9 pairs. The abstract words were chosen from the set of 925 words rated for meaningfulness, concreteness, and imagery in a study by Paivio et al. (1969). The 24 abstract words used in the paired associates task, listed in Table 3, had a mean value of 6.17 on meaningfulness, 2.84 on
concreteness, and 3.25 on imagery. The 12 pairs of abstract words were recorded on magnetic tape in the order presented in Table 3, with a 3-second silence between successive pairs, which were presented at a one word per second rate. The list was played three times to subjects; on the fourth time, only the stimulus word of a pair was presented, and subjects were given 15 seconds to write down the appropriate response word before the next stimulus word was presented.

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Insert Table 3 about here

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Paired Associates—Concrete—(PA-C). A task identical to that described above, with the exception that rather concrete words were used on the test, was found by Cummins to define a factor identified as Simultaneous Processing. Once again, 12 pairs of words were used, rather than 9 pairs. The 24 concrete words used in the paired associates task, listed in order of presentation in Table 3, had a mean of 5.94 on meaningfulness, a mean of 6.83 on concreteness, and a mean of 6.55 on imagery. Thus, the concrete words used in the paired associates task were well matched with their counterparts in the abstract paired associates task on meaningfulness, but differed greatly on concreteness and imagery value. The concrete paired associate items were recorded on magnetic tape using the same temporal pattern as used with the abstract items described above. A pretest of the Concrete Paired Associates test revealed that this task was rather easy, with 55 percent of the subjects attaining perfect scores of 12. In order to make the task more difficult, the number of presentation sequences was varied in a second
small pretest. Based on the second pretest, only a single presentation sequence was used in the present study, followed by the test sequence during which only the stimulus word was presented and subjects were given 15 seconds to write down the correct response. As will be discussed below, use of one presentation sequence successfully lowered the mean of the distribution of scores on this variable and eliminated the negative skewness of scores.

**Free Recall—Abstract (FR-A).** Two free recall tasks were used in the present study, tasks that were also modeled after tasks used by Cummins (cited in Das et al., 1975). The Abstract Free Recall consisted of a single list of 12 words, listed in order of presentation in Table 3. The 12 words had a mean of 6.15 on meaningfulness, 2.47 on concreteness, and 3.24 on imagery. The list of words was recorded on magnetic tape at a speed of one word per second. The list was played one time to subjects, who were instructed to write down as many words as they could in any order immediately following a tone signalling the end of the word list. Subjects were given two minutes to record their answers. Cummins found the Abstract Paired Associates task to load on the Successive Processing factor, due most likely to the use of abstract words and the rapid rate of presentation.

**Free Recall—Concrete (FR-C).** The Concrete Free Recall task also consisted of a single list of 12 words, listed in order of presentation in Table 3. The 12 concrete words had a mean of 7.24 on meaningfulness, 6.73 on concreteness, and 6.57 on imagery. As with the two paired associates tasks, the stimulus words for the concrete free recall task were matched for meaningfulness with the abstract words, although the
sets of free recall words differed greatly on concreteness and imagery; the attempt to match the abstract and concrete words on meaningfulness was not as successful with the free recall words as with those on the paired associates tasks, but the sets of abstract and concrete words on the free recall task certainly differed strikingly on concreteness and imagery, and differed less on meaningfulness. The manner of recording and presenting the concrete list was identical to that used for the preceding, Abstract Free Recall task. Subjects were once again given two minutes to record their answers. Even though rather concrete words were used and subjects typically use simultaneous processing strategies for concrete material, Cummins found the Concrete Free Recall task to load on the Successive Processing factor, due to the fast presentation rate that inhibited use of clustering strategies.

**Locations (ETS-I).** The Locations test is the second of three tests used by Ekstrom et al. (1976) to serve as marker variables for the Induction factor. The first marker of Induction is the Letter Sets test that is virtually identical to the Induction test on the CAB; the third marker requires subjects to classify comparison figures into one of two or three categories based on the rule implicit in the classification of the standard stimuli. On the Locations test, the subject is to place an "x" on a fifth line of dashes and spaces such that the placement of the "x" follows the rule implicit in the placing of an "x" on four preceding lines. The Locations test was chosen for the Extension Set to provide a second measure of Induction; the Locations test was selected to ensure a broader definition of Induction, which Hakstian and Cattell (1978) found to load on Fluid Intelligence. If the Letter Sets test from the
ETS battery had been chosen, then given its equivalence to the Induction test on the CAB, similarity between the Letter Sets test and the CAB Induction test in their loadings on the factors underlying the CAB would have been evidence only of reliability, rather than some measure of construct validity afforded by the use of the Locations test. A sample item from the Locations test is:

Card Rotations (ETS-S). The Card Rotations test is one of two from the ETS battery designed to serve as marker variables for the Spatial Orientation factor. The remaining test from the ETS battery that defines the Spatial Orientation factor is the Cube Comparisons test, on which the subject is to determine whether a pair of cubes could be the same or must be different based on the subject's viewing of a two-dimensional drawing showing three faces of the cubes. The test selected for the present study, Card Rotations, while more similar to the Spatial Ability test on the CAB, was chosen because of its wide use and because the Cube Comparisons test has less adequate reliability data. It may be noted that the stimuli used on the Card Rotations test differ substantially from those used on the Spatial Ability test from the CAB. Further, a search of the literature (e.g., French, 1951), especially the studies by Thurstone and his associates (e.g., Thurstone, 1938a, 1938b; Thurstone & Thurstone, 1941) in which the Spatial
Orientation factor was first firmly established, led to the conclusion that a wide variety of tasks was not available for this factor. The Card Rotations test was included in the study to parallel the Spatial Ability test, which was found to load on both the Fluid Intelligence and General Visualization second-stratum factors in the study by Hakstian and Cattell (1978). A sample item from the Spatial Orientation test is:

```
\[ \begin{array}{c}
\hline
B \\
\hline
\end{array} \begin{array}{c}
\hline
\end{array} \begin{array}{c}
\hline
\end{array} \begin{array}{c}
\hline
\end{array} \end{array} \]
```

**Nonsense Syllogisms (ETS-RL).** The Nonsense Syllogisms test is one of four tests that are markers of the Logical Reasoning factor from the ETS battery (Ekstrom et al., 1976). The remaining three tests for the Logical Reasoning factor are rather varied: the first requires selection of the one of five Venn diagrams that demonstrates the relationships among three classes of objects, the second involves the selection from among five alternatives of the conclusion that is consistent with a set of premises, and the third requires the decoding or deciphering of several artificial languages. The Nonsense Syllogisms test consists of a set of items each of which is in standard form, i.e., two premises and a conclusion; but, the premises and the conclusion all embody nonsensical propositions (see example below). Following the rules of logical inference, the subject is to determine whether or not the conclusion is implied by the premises, that is, regardless of the truth value of the three propositions, is the conclusion necessarily entailed by the premises. The Nonsense Syllogisms test was selected for
the present study to provide definition for the Crystallized Intelligence factor, which in the Hakstian and Cattell (1978) study had loadings from only 2 of the 20 CAB tests. Logical reasoning tests have previously been found to load on factor labeled Crystallized Intelligence (Horn & Cattell, 1967; Horn, 1968). A sample item from the Nonsense Syllogism test follows:

Indicate, by crossing out the correct letter, whether you think that each set of statements shows good reasoning (G) or poor reasoning (P).

All trees are fish. All fish are horses. Therefore all trees are horses. G P

Mathematics Aptitude Test (ETS-RG). The Mathematics Aptitude Test is one of three markers for the General Reasoning factor from the ETS battery (Ekstrom et al., 1976). The remaining two tests of General Reasoning consist of one test containing word problems that require use of simple arithmetic operations for solution, and a second test on which subjects are to determine the order of execution of simple arithmetic operations needed to solve a problem (without having to carry out the operations). The Mathematics Aptitude Test is comprised of a set of verbally-stated math problems that require the use of simple arithmetic or simple algebraic operations for solution. The Mathematics Aptitude Test was selected as the representative of General Reasoning due to its appropriate level of difficulty and high reliability. General Reasoning differs from Logical Reasoning in the following way: General Reasoning refers to the selection and organization of material that is relevant for the solution of a problem, while Logical Reasoning reflects the ability to produce or to evaluate the correctness of a conclusion given
a set of premises. Although General Reasoning and Logical Reasoning each load on both Fluid and Crystallized Intelligence second-stratum factors, Logical Reasoning is the more clearly affected by culture and thus loads rather more highly on Crystallized than Fluid Intelligence, while General Reasoning loads approximately equally on the two second-stratum factors. A sample problem from the Mathematics Aptitude Test follows:

How many candy mints can you buy for 50 cents at the rate of 2 for 5 cents?

A. 10  
B. 20  
C. 25  
D. 100  
E. 125

Finding A's (ETS-P). The Finding A's test is one of three marker variables for the Perceptual Speed factor in the ETS battery (Ekstrom et al., 1976). Of the remaining two Perceptual Speed tests in the ETS battery, one is very similar to the Perceptual Speed test in the CAB, requiring the subject to indicate whether pairs of multi-digit numbers are the same or different; on the other test, the subject is to mark the one of five alternative figures that is identical to the standard. On the Finding A's test, the subject must read words printed on a page, with five columns of 50 words apiece, and is instructed simply to put a slash through each of the five words per column containing an "a." The Finding A's test was included in the present study to provide a measure of construct validity for the Perceptual Speed and Accuracy test on the CAB. The latter test, although a General Perceptual Speed factor emerged from the analyses, loaded highest on the Fluid Intelligence factor. But, regardless of the loading pattern of the CAB Perceptual
Speed and Accuracy test, if the Finding A's test shows a similar pattern of factor loadings a measure of construct validity for the CAB will be demonstrated. A short sample of the stimuli for the Finding A's test follows:

Put a slash through any word containing an "a."

<table>
<thead>
<tr>
<th>cider</th>
<th>east</th>
<th>stripe</th>
<th>insert</th>
<th>defend</th>
</tr>
</thead>
<tbody>
<tr>
<td>bough</td>
<td>blind</td>
<td>coarse</td>
<td>court</td>
<td>settle</td>
</tr>
<tr>
<td>fudge</td>
<td>chord</td>
<td>govern</td>
<td>pearl</td>
<td>lodge</td>
</tr>
<tr>
<td>greet</td>
<td>solar</td>
<td>perfect</td>
<td>bridle</td>
<td>oaken</td>
</tr>
</tbody>
</table>

Quick Word Test (QWT). The Quick Word Test (Borgatta & Corsini, 1964) was developed to provide researchers with a quickly administered measure of General Intelligence. The Quick Word Test manual (Borgatta & Corsini, 1964) reports impressive correlations of .75 to .85 with the Wechsler Intelligence Scale for Children and other tests yielding single, overall estimates of intelligence. But, against the background of the hierarchical theory of abilities, it is clear that the Quick Word Test is a heavily verbal-loaded test and should thus provide a clear marker of the Crystallized Intelligence second-stratum factor. In the present study, Form A from Level II of the Quick Word Test was used, because of its appropriate level of difficulty in a college sample. The abovementioned form of the Quick Word Test is comprised of 100 synonym items, on each of which the subject is asked to select the one of four alternatives that means the same thing as a given word. The Quick Word Test was given without an explicit time limit; subjects were told that the test should take about 15 to 20 minutes to complete and that they should not take too much time considering any single item. The Quick Word Test is essentially a power test, as opposed to a speed test, and
retains its ability to discriminate along the dimension of General Intelligence by including items of differing difficulty levels and, on each item, including incorrect alternatives that are associated with, but do not mean the same thing as, the standard stimulus. Two examples follow:

Select the one word that means the same thing as the first word.

- crank
- auto tier line turn
- stuff lout hard cram junk

Procedure

The test battery of 30 measures, 20 from the CAB and 10 in the Extension Set, was administered in group-testing sessions to between 40 and 50 subjects at a time. Since the test battery took approximately four hours to administer, each subject participated in two two-hour testing sessions separated by 48 hours. That is, each subject participated in testing sessions from 7:00 p.m. until 9:00 p.m. on Monday and Wednesday or on Tuesday and Thursday of a given week. During the first testing session, the first 14 tests in the CAB were administered in the order listed in Table 1, beginning with the Verbal Ability test and ending with that for Esthetic Judgment. During the second testing session, the remaining six CAB tests were administered in the order given in Table 1, followed by the 10 tests in the Extension Set in the order given in Table 2.

Due to a mistake in scheduling testing rooms, administration of tests to the first group tested, consisting of 49 subjects, was set back about 45 minutes. As a result, the first group of subjects completed only the CAB. Thus, any analyses performed on the Extension Set were
based on a sample size of 223, down from the 272 subjects who completed the CAB.

Answers to items on the first 14 tests on the CAB were recorded on separate answer sheets; these tests were machine-scored at the Institute for Personality and Ability Testing, publishers of the CAB. The remaining six CAB tests and the 10 tests in the Extension Set contained specified areas on the test booklets in which answers were to be recorded. The latter tests could not be machine-scored, but were of the objective type, i.e., required little or no judgment on the part of the scorer to determine whether an answer was correct or incorrect; the author scored by hand all of these latter tests.

Analyses

The first set of analyses of the CAB concerned the stability of relations among scores on the CAB. One analysis indicative of stability of scale scores involves the sex differences revealed on the CAB scales. Hakstian and Cattell (1975) reported an analysis of sex differences on the CAB based on a sample of 12th grade students. If a parallel analysis revealed a similar pattern of differences on the present sample of college freshmen, one aspect of stability of the CAB would be supported.

The second type of analysis bearing on the stability of the CAB, and the more important for theory building with the hierarchical theory of abilities, involves the determination of the stability of the loading pattern of CAB tests on second-stratum factors. To determine the degree of factorial stability of the CAB second-stratum factors, the matrix of correlations among the 20 CAB scales was factor analyzed. Communalities
were estimated using the highest correlation of a given scale with the remaining 19 CAB scales. Three tests for the number of factors were used: the scree test, the likelihood ratio chi-square associated with maximum likelihood factor analysis, and the reliability coefficient for maximum likelihood factor analysis. The scree test (Cattell, 1966) involves inspection of successive latent roots of the correlation matrix, retaining factors that account for practically significant portions of variance and discarding factors accounting for insignificant portions of variance. The likelihood ratio test associated with maximum likelihood factor analysis provides a chi-square statistic that reflects the statistical significance of the residuals after a given number of factors is extracted; thus, one keeps extracting factors until there is nonsignificant residual variance to be explained. The reliability coefficient for maximum likelihood factor analysis was developed by Tucker and Lewis (1973) to aid interpretation of the likelihood ratio chi-square. Since the likelihood ratio statistic is dependent on sample size, even trivial residuals will lead to a statistically significant chi-square if sample size is large. The proposed reliability coefficient is independent of sample size and represents roughly a measure of off-diagonal variance explained (Tucker & Lewis, 1973). Tucker and Lewis suggested that, regardless of the significance level of the chi-square statistic, one should only accept factor solutions of adequate reliability, mentioning a reliability coefficient of .95 and above.

After the number of factors was determined, a variety of rotations was undertaken. Although varimax orthogonal and promax oblique
solutions were obtained, final resolution of the rotated factor pattern was performed using the orthoblique rotation (Harris & Kaiser, 1964) using a raw varimax prerotation. The orthoblique rotation was preferred since the general orthoblique formulation allows easy determination of a family of rotations varying in degree of obliquity of the rotated factors. By varying $\rho$, an exponent in the orthoblique formula, between .00 (for the independent cluster solution) and .50 (for the nonindependent cluster solution) by steps of .10, six solutions were determined from which the optimal solution was selected. The optimal solution was then compared in a number of ways with the solution obtained by Hakstian and Cattell (1978). Specifically, the defining loadings for apparently similar second-stratum factors in the two studies were compared, the consistency of the loading pattern of the factors with the theoretical interpretation of the factors was noted, and coefficients of congruence among the Hakstian-Cattell factors and those from the present study were computed. Finally, an oblique Procrustian rotation of the first six factors from the present study was performed, using the Hakstian and Cattell (1978) primary factor pattern matrix as the target. The latter analysis was undertaken to determine whether differences between the Hakstian and Cattell (1978) factors and those from the present study were due to small differences in procedures used in the present study. Since the oblique Procrustean rotation achieves an approximate least squares fit of the rotated to the target factor pattern matrix, if similar factor patterns underlie two identical batteries of tests the oblique Procrustean rotation should demonstrate that similarity.
The second focus of analyses of data from the present study was the construct validity of the patterns of relations involving the CAB. First, a discriminant analysis was performed to determine whether males and females scored significantly differently on tests in the Extension Set. Next, primary factor pattern and structure coefficients on the second-stratum factors underlying the CAB were estimated for the 10 tests in the Extension Set using Dwyer's extension (Gorsuch, 1974), which allows the estimation of factor loadings for variables not included in a factor analysis. The primary factor pattern coefficients are those that should reveal simple structure, while the primary factor structure coefficients represent correlations of the tests with the factors.
RESULTS

The goal of the present study was to investigate the stability and construct validity of the CAB. The presentation of results will be ordered to facilitate evaluation first of the stability of internal relationships based on CAB scores and second the construct validity, or generalizability, of the internal relations.

Stability of Relations Involving the CAB

Sex Differences

The topic of sex differences is a research area of considerable interest in developmental psychology. After an extensive review of studies of sex differences in mental abilities, Hakstian and Cattell (1975) reported the results of a discriminant analysis of the difference between males and females on the 20 CAB scales, based on a sample of 280 high school juniors and seniors.

The results of a similar discriminant analysis, based on the data from the 272 college freshmen in the present study, are presented in Table 4. The multivariate test of difference between males and females on the CAB scales was highly significant, F(20, 251) = 10.16, p<.0001.

The preceding multivariate test may be used in two ways: as a protection against Type I error (i.e., rejecting the null hypothesis when, in fact, it is true), and as the test of the linear combination of variables that maximally discriminates males and females. Information
for both of these uses is presented in Table 4, and the two types of result will be discussed in turn.

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Insert Table 4 about here

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Using the multivariate test as a protection against Type I error, the observed significance of the test suggests that the significance revealed by particular scales does not represent a set of chance findings, justifying inspection of the univariate results. The scale showing the greatest difference between males and females was the Mechanical Knowledge (Mk) test, with males scoring higher than females (p<.001). Females scored substantially above males on the Perceptual Speed (P) and Spelling (Sp) tests, both at the .001 level. On the remaining tests, males scored higher than females on the Spatial (S) test (p<.05), while females scored higher than males on the Word Fluency (W, p<.01), Spontaneous Flexibility (Fs, p<.05), and Aiming (A, p<.05) tests.

The above pattern of significant findings is very similar to that reported by Hakstian and Cattell (1975). Using the .01 level for all comparisons, Hakstian and Cattell found that males scored higher than females on the Spatial, Auditory Ability, and Mechanical Knowledge tests, and that females scored above males on the Perceptual Speed, Spelling, Word Fluency, and Aiming tests. Thus, the Hakstian and Cattell finding that males scored significantly higher than females on the Auditory Ability test was not replicated in the present study. Since Hakstian and Cattell had found little previous support in the
literature for a male superiority on auditory abilities, they considered the sex difference observed in their study to be of a tentative nature; since a significant difference was not found in the present study, a prudent position would be that sex differences on auditory abilities have yet to be established.

The other difference between the present study and that by Hakstian and Cattell is the significant difference favoring females on Spontaneous Flexibility in the present study. Females also scored higher than did males on Spontaneous Flexibility, though not significantly so, in the Hakstian and Cattell study. Because the difference, with females scoring higher than males, is consistent across studies, we may hypothesize that there is a reliable sex difference on Spontaneous Flexibility, though the size of the effect is likely to be rather small.

The second way one may utilize the multivariate test of significance of sex differences on CAB scales is as the test of the difference between the sexes on the linear combination of CAB scale scores that maximally discriminates males from females. That linear combination based on data from the present study is given in the last column of Table 4, which contains discriminant function weights. The tests weighted most heavily, whether having a positive or negative weight, are the tests that contribute most to the discrimination between the sexes. As can be seen in Table 4, the most highly weighted test is that for Mechanical Knowledge, which had shown the largest relative difference between males and females (based on size of F ratio). Of the seven tests with discriminant weights above .20, six had significant
univariate F ratios, and the seventh, Induction (I), represented a strong trend (p<.06). In addition, only one of the seven tests with significant univariate F ratios, Word Fluency (W), failed to attain a high discriminant weight.

The finding that the variables that were relatively heavily weighted to discriminate maximally males from females were those with larger univariate F ratios lends support to the stability of the weighting represented by the discriminant function, implying that the weights were not affected appreciably by capitalization on chance in the estimation procedure. The stability of the weighting function is also supported by the fact that, except for one very minor exception involving the Ideational Fluency (Fi) test, each test on which males scored higher was negatively weighted and each test on which females scored higher was positively weighted. A final indication of the stability of the discriminant function weights is the correlation between the vector of weights from the present study and that reported by Hakstian and Cattell (1975). The correlation between the two sets of discriminant function weights was very large and highly significant, \( r(18) = .872, p<.001. \)

**Stability of Second-Stratum Factors**

The stability of second-stratum factors based on the CAB scales is a topic of crucial importance to the Cattell-Horn theory of fluid and crystallized intelligence. As mentioned above, Undheim and Horn (1978) criticized Guilford for failing to replicate adequately factors that were predicted by his Structure-of-Intellect theory, but that had been demonstrated in only a single study. If an analysis of the CAB reveals
second-stratum factors similar to those reported by Hakstian and Cattell (1978), the CAB may be recommended as the first standard battery that researchers may use to obtain scores on the factors of fluid and crystallized intelligence.

Since considerable sex differences had been shown on the CAB scales, the effect of sex should be removed from the matrix of intercorrelations among CAB scales. If this were not done, the mean differences between the sexes would have an effect on the resulting factor analytic results, causing tests showing patterns of sex difference to correlate higher or lower than they otherwise would. Following the procedure used by Hakstian and Cattell (1978), the pooled covariance matrix was formed by summing covariance matrices weighted by sample size for males and females, and the pooled covariance matrix was then scaled into a correlation matrix. The resulting correlation matrix is presented in Table 5.

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Insert Table 5 about here

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Before pooling the covariance matrices, two checks on the similarity of the covariance matrices for males and females were computed, to ensure that the pooled covariance matrix would reflect rather similar patterns of covariation for males as for females. Accompanying the discriminant analysis reported above is a test of equality of covariance matrices; this test revealed a nonsignificant difference between the covariance matrices for males and females, \( X(210) = 242.309, .10 < p < .05 \). Because the preceding test is a rather
powerful one, the nonsignificant result, even though of borderline significance, indicates a fairly high degree of similarity between the two covariance matrices. To assess further the similarity of the covariance patterns among CAB scales for males and females, the 210 unique elements of the covariance matrix for males were correlated with the corresponding elements for females. (Note: If \( n \) equals the number of variables in a covariance matrix, the number of unique off-diagonal elements is equal to \( n(n-1)/2 \), and there are \( n \) unique values on the diagonal. For the CAB matrices, since \( n \) equals 20, there are 190 unique off-diagonal elements and 20 unique elements on the diagonal.) The correlation between males and females was very high and significant, \( r(208) = .945, p<.0001 \). Since the preceding correlation may have been unduly influenced by the 20 diagonal values, a second correlation was computed using only the 190 unique off-diagonal covariances. This correlation was lower, but was still substantial, \( r(188) = .722, p<.0001 \), and indicated a fairly high degree of similarity of the covariance patterns for males and females.

Turning to the correlation matrix in Table 5, a few observations may be made about the pattern of correlations among the CAB scales. First, the positive manifold typically found among ability tests, that ability tests tend to correlate positively or zero among themselves, is confirmed by the data, even in the present sample of college students which may represent a restricted sample. Only 8 of the 190 correlations were negative, and none of the negative correlations was significantly different from zero. Of the remaining 182 correlations, 33 were not significantly different from zero; thus, a total of 41 of the 190
correlations, or 21%, were not significantly different from zero, and the remaining majority (79%) of the correlations among CAB scales were significantly different from zero. Although the preceding implies that the positive manifold is shown by the data, the positive manifold is even more convincingly demonstrated by excluding one test. The Esthetic Judgment test is a rather unique test in the annals of mental ability testing, perhaps representing more a style variable than an ability variable. The Esthetic Judgment test contributed 7 of the 8 negative correlations and almost half (18) of the 41 nonsignificant correlations. Excluding for the moment the Esthetic Judgment test, only 1 of the remaining 171 correlations is negative, and 23 of 171, or only 13%, are nonsignificantly different from zero, leaving 87% of the correlations positive and significantly different from zero.

The correlation matrix in Table 5 was then factored by two methods, to provide information for making the decision on the number of factors. The resulting data are displayed in Table 6. The first test for the number of factors was the scree test (Gorsuch, 1974), which involves looking for a significant break in the eigenvalues of the correlation matrix. Factors were extracted from the matrix using the method of principal axes and using the highest \( r \) in the row as communality estimate. The resulting eigenvalues are given in the first column of Table 6. Starting with the eigenvalue from Factor 12 and proceeding upward, the first noticeable break in the curve is between 4 and 5 factors, indicating that the fourth factor, as the first to rise out of the scree, is the last significant factor.

The second test for the number of factors was the likelihood ratio
test from maximum likelihood factor analysis and the accompanying reliability coefficient developed by Tucker and Lewis (1973). As may be seen in Table 6, the chi-square test for each number of factors from one through four is significant, indicating that the respective models are not adequately representing the correlation matrix. The associated reliability coefficients also suggest inadequate representation of the data, nearing, but not exceeding, the .95 level suggested by Tucker and Lewis. The five factor model has a nonsignificant chi-square value of 108.33 with 100 degrees of freedom, $p = .268$, implying nonsignificant differences between the model and the data, and the Tucker-Lewis coefficient stands at a rather high level, .984. Thus, both the likelihood ratio chi-square test and the Tucker-Lewis reliability coefficient agree on five as the number of factors in the matrix.

The principal axis factors, with highest $r$ in the row as communality estimate, extracted for the scree test were the factors taken into the rotations. Because the number of factors in the matrix appeared to be either four or five, four- and five-factor solutions were rotated by a number of analytic procedures. The factor solutions were obtained using the varimax orthogonal rotation and the promax and Harris-Kaiser orthoblique oblique rotations. For the promax rotation, the value affecting obliquity of the rotated factors, $K$, was set equal to 3. For the Harris-Kaiser orthoblique, the exponent affecting obliquity of rotated axes, $e$, was varied between 0.0 and 0.5 using 0.1 increments, and raw varimax was used as the prerotation. The optimal solution, with five factors and resulting from the orthoblique rotation with $e = .20$, is presented in Table 7. The solution in Table 7 was
judged to be optimal on a number of grounds, specifically, that the factor intercorrelations should be moderate at most, that the simple structure factor pattern show a minimum of high negative loadings, and that, all other things being equal, the factor solution should be similar to the previous analysis of the CAB by Hakstian and Cattell (1978).

Factor I: Crystallized Intelligence. The first factor appears to represent the Crystallized Intelligence factor that has emerged from the studies by Cattell and Horn and their associates. The two loadings that are considered necessary to identify the factor are those for Verbal Ability and Mechanical Knowledge, both of which have substantial loadings on Factor I. In the Hakstian and Cattell (1978) study, only the two preceding tests had high loadings on the Crystallized Intelligence factor, but the present factor has interpretable loadings from three additional tests. The additional tests are those for Meaningful Memory, Induction, and Auditory Ability.

According to Cattell's (1971) theory, Crystallized Intelligence is the result of acculturational influences in a culture that mold, or crystallize, a person's given level of mental ability into rather set patterns, or strategies, for solving problems as well as into knowledge structures. Verbal Ability and especially Mechanical Knowledge have typically been considered exemplars of abilities that may be affected by differences in acculturation. The loading of Meaningful Memory is quite reasonable on the present factor, since the test requires a subject to remember, after an interposed task, the meaning of adjective descriptors of objects so that the one of five words most similar to the original
descriptor may be selected. While this task has a rather short-term nature, the advantages of having more extensive and elaborated verbal knowledge stores may have a strong impact on test performance, and these verbal knowledge stores would be the result of acculturational influences. The loading of Induction on this factor at a level higher than that of its loading on the second factor, to be described below, is not alarming. Although Induction has usually been found to load solely or more heavily on Fluid Intelligence, Horn (1978), in his summary of research on second-stratum factors of ability, estimated that Induction had an average loading about half as strong on Crystallized as on Fluid Intelligence. Since this estimate was based on a number of previous studies, it would be expected that Induction would load more highly on the Crystallized Intelligence factor occasionally due to sampling variability; that may be the case in the present study.

The loading of the Auditory Ability test on the first factor is more difficult to explain. Since the test was of such a simple nature, it is not clear precisely what learned mechanism or knowledge store would have contributed to performance on the test. Recent work by Stankov (1978; Stankov & Horn, 1980) showed that, if a number of tests of ability are presented in auditory mode, a General Auditory factor appeared in addition to the well-replicated General Visualization factor. It may be that the Auditory Ability test loaded on the first factor because auditory abilities were so underrepresented in the CAB that a separate General Auditory factor could not be determined. Further research, by administering the CAB and additional tests in auditory format similar to those developed by Stankov, could test the
above supposition; if it is true, Auditory Ability should switch its loading off of the Crystallized Intelligence factor onto a correlated General Auditory factor.

In summary, the loading pattern of tests on the first factor are consistent with previous research and the conception of Crystallized Intelligence, implying that application of that label to the present factor is appropriate. But, it must be noted that the present factor, with five relatively high loadings, is rather different from the factor identified by Hakstian and Cattell (1978) as Crystallized Intelligence, since the latter factor had high loadings from only two tests, Verbal Ability and Mechanical Knowledge.

**Factor II: Fluid Intelligence.** In Cattell's (1971) theory, Fluid Intelligence is assumed to be rather free of cultural influences, representing the level of a person's power of relation eduction in areas in which crystallized skills and knowledge would not aid performance. The best markers of Fluid Intelligence have been figural reasoning tests, but the CAB does not contain any such test. Another reliable marker of Fluid Intelligence is Induction, which may assist identification of this factor.

In the Hakstian and Cattell (1978) study, the Fluid Intelligence factor had a rather high loading from the Spatial Ability test and lower loadings, around .40, from Numerical Ability, Perceptual Speed, and Inductive Reasoning. The second factor from the present study has equal and high loadings from Spatial Ability and Perceptual Speed, lower loadings from Numerical Ability and Speed of Closure, and a rather low loading (.231) from Inductive Reasoning. Although there is some
variation between the loading pattern for the second factor from the present study and the corresponding factor from Hakstian and Cattell (1978), the similarity of the factors is stronger than their differences, and the present factor has been labeled Fluid Intelligence. Because of the rather low loading of the Inductive Reasoning test, the nature of this factor is not free from ambiguity, and future research with the CAB could help establish the meaning of the factor by determining whether tests of figural reasoning load on a factor similar to the present one.

**Factor III: General Closure.** The third factor from the present study has high loadings from five tests, which, in order of magnitude of loading, are Spelling, Speed of Closure, Word Fluency, Numerical Ability, and Verbal Ability. The corresponding factor from the Hakstian and Cattell (1978) study had high loadings from Speed of Closure, Spelling, and Word Fluency, with lower loadings from Perceptual Speed, Memory Span, and Numerical Ability. The loading pattern for the corresponding factors across studies is not identical, but provides a better level of cross-study similarity of loading pattern than either of the two preceding factors from the present study.

The factor from the Hakstian and Cattell (1978) study that matches the General Closure factor was one about which Hakstian and Cattell disagreed. Hakstian stressed the fact that a certain amount of closure was involved on each of the tests; Cattell countered that all of the tests loading on the factor were highly speeded, and that a General Cognitive Speed factor had been found in a large number of researches on mental abilities. The compromise at which Hakstian and Cattell arrived
was to label the factor General Perceptual Speed, combining aspects of the speeded nature of the tasks with the perceptual, closure aspects.

Closure refers to the power to attain a complete percept or concept in the face of inadequate information, or the the power to attain, or disembed, a complete percept or concept from overabundant information. The present factor, the third from the present study, was labeled General Closure for the following reasons. The necessity for exercise of closure on the Speed of Closure test is obvious, and the closure aspects of the Word Fluency seem clear, since the task is of the anagrams variety and subjects must select and rearrange from a pool of letters the ones that spell simple words (a task requiring disembedding of the letters from the pool of alternatives). The Spelling test requires some power to select from the alternatives the one words that is misspelled, and the decision of whether or not a word is misspelled requires a type of closure. The loading of Numerical Ability may be due to the need to attain closure on each item with respect to how one should proceed on the item. Unlike a typical Numerical Ability test that consists of a set of items homogeneous with respect to type of numerical operation required (e.g., addition), the Numerical Ability test on the CAB included items of addition, subtraction, multiplication, and division with both whole and fractional numbers. With this heterogeneous set of items, subjects who could decide more quickly how to proceed to solve a given problem would have an advantage, and their advantage might involve closure on operations each problem required. The Verbal Ability test may also have required a type of closure, in that, the subject must select from a number of meanings of a word the
one implied by the set of alternatives on the item. On the proverbs portion of the test, the ability to attain a proper sense of the standard proverb would aid in the selection of the correct alternative.

Thus, if the above considerations are correct, the present factor reflects a rather general type of closure that reaches beyond the bounds of the strictly perceptual. The one loading on the factor that is somewhat inconsistent with the General Closure interpretation is that for the Flexibility of Closure test, which loaded at a rather low level, yet contains obvious elements of closure. In defense of the interpretation, it may be noted that the Flexibility of Closure test had a rather low level of common variance and had a complex pattern of loading on factors. Perhaps, then, the closure aspect of the Flexibility of Closure test is not the major contributor to the common variance of the test, and the low level of common variance did not allow the expression of closure in the obtained factor pattern.

The only major argument against an interpretation of the present factor as General Cognitive Speed is that all tests on the CAB are timed, and are thus speeded to some extent. Since only five of the 20 CAB tests loaded on the present factor, the factor probably represents something common only to the five highly loaded tests. It may be more reasonable to locate the General Cognitive Speed at a rather higher order. Since all of the primary factors are positively intercorrelated, a higher-order factor extracted to represent the correlations among the first-order factors could as easily be identified as General Cognitive Speed than as Historical Fluid Intelligence, as Cattell (1971) would designate such a factor.
Factor IV: General Retrieval Capacity. The fourth factor from the present study has excellent simple structure and has three high loadings, from the Spontaneous Flexibility, Ideational Fluency, and Originality tests. The capacity these three tests appear to share is the power to retrieve quickly items or concepts from long-term memory. The Spontaneous Flexibility test requires the subject to access from memory category names that unite some, but not all, of a set of objects into a unique class, and on the Originality test subjects must combine two common objects to produce one useful object. The Ideational Fluency test asks subjects to produce as many descriptors as possible for a given object; while of a different form than the other two tests on the present factor, the Ideational Fluency test does involve speedy retrieval of items from long-term storage.

The matching factor from the Hakstian and Cattell (1978) study had a single high loading from the Ideational Fluency test and quite lower loadings (between .41 and .27) from the Originality, Esthetic Judgment, and Spontaneous Flexibility tests. The Esthetic Judgment test does not fit well the conception of the present factor; the absence of the Esthetic Judgment test from the General Retrieval factor in the present study thus results in a clearer General Retrieval factor than appeared in the Hakstian and Cattell study.

Factor V: General Carefulness. The fifth and final factor from the present study has only a moderate relationship with a factor from the Hakstian and Cattell (1978) study. The Hakstian and Cattell factor to which the present factor had the strongest similarity was labeled General Visualization, and had its strongest and approximately equal
loadings from Aiming (.44), Representational Drawing (.42), Spatial Ability (.37), and Mechanical Knowledge (.37). Hakstian and Cattell also interpreted the rather low, though consistent, loadings by the tests for Speed of Closure (.28), Perceptual Speed (.27), and Flexibility of Closure (.27), but failed to emphasize loadings of approximately equal size from tests inconsistent with the interpretation of the factor, namely, Auditory Ability (.24), Spontaneous Flexibility (.23), and Inductive Reasoning (.22). Thus, the Hakstian and Cattell General Visualization factor, although identified by them as reflecting the same general ability as found in earlier studies, is not a clean factor at all.

In contrast, the fifth factor from the present study has a much more clearly defined hyperplane, with only four major loadings. The tests that load highly are Aiming, Representational Drawing, Associative Memory, and Mechanical Knowledge. The element that these four tests appear to share is the attention to detail in visual displays. On the Aiming test, one must draw two complete lines, one around the circle in the middle of each figure and the other between the two squares, without having either line touch any part of the printed figure. Many persons completed a large number of Aiming items but received a low score on the test because they either allowed their drawn lines to touch a part of the printed figure or they did not adequately complete the lines. Subjects earned higher scores on the Representational Drawing test by sketching carefully a figure to the exact scale as a continuously presented standard. On approximately one-half of the items on the Mechanical Knowledge test, subjects had to attend to the speed and
direction of movement of wheels and axles, which were connected by belts or pulleys, in order to arrive at the correct answer for a target wheel. Finally, the Associative Memory test involved the holding in mind of a relationship of each of 20 complex, novel figures with a unique two-place number. Performance on this task would also be enhanced by attention to the details in the figural stimuli, so that one might more easily discern one figure from another during the recall phase. Thus, carefulness to details in figural or visual displays appears to be an element, and perhaps the only element, common to the tests that load on the fifth factor.

Similarity of factors to those from Hakstian and Cattell (1978).

During the above consideration of each factor from the present study, comparisons of the present factors with those from the study by Hakstian and Cattell (1978) were made. Although three of the five present factors were similar enough to factors found by Hakstian and Cattell that identical names and interpretations were used, differences across studies in the loading patterns of the factors were noted. To gauge more precisely the degree of similarity of the loading patterns across studies, coefficients of congruence were computed between the present factors and those from Hakstian and Cattell (1978). As noted above, the coefficient of congruence is a type of correlation coefficient, with bounds of +1.00 to -1.00, and attains its maximal value when the relative pattern of loading of tests on two compared factors is identical. Also previously noted, there is some consensus that a coefficient of congruence must be above .90 for one to consider two factors identical.
The coefficients of congruence between present factors and those from the Hakstian and Cattell (1978) study are presented in Table 8. Factor I from the present study, Crystallized Intelligence, was more similar to the corresponding factor than to any other factor from the Hakstian and Cattell (1978) study; in turn, the Crystallized Intelligence factor from Hakstian and Cattell is more similar to the identically named factor than to any other factor from the present study. This pattern of similarity will be found for each factor from the present study, that each factor from the present study is most similar to the factor from the Hakstian and Cattell study that is, in turn, most similar to it. Returning to Factor I, the rather low coefficient of congruence (.679) with the matching factor from Hakstian and Cattell reinforces observations made above. Specifically, since Factor I had five high loadings and the Crystallized Intelligence factor from Hakstian and Cattell had only two, the obtained coefficient of congruence underscores the nonequivalence of the factors.

Insert Table 8 about here

The Fluid Intelligence factor, Factor II, attained a higher, moderate level of similarity with the corresponding factor from the Hakstian and Cattell study. The rather low loading for Inductive Reasoning and rather high loading for Perceptual Speed on Factor II relative to their loading on the Fluid Intelligence factor from Hakstian and Cattell probably contributed to the less than adequate congruence coefficient of .814.
The third factor from the present study, General Closure, had a higher still index of similarity, .850, with the General Perceptual Speed factor from Hakstian and Cattell. It may seem strange that the factor with one of the highest cross-study coefficients of congruence was one of the two factors from the present study that was given a different label, General Closure, than the factor in the Hakstian and Cattell (1978) study with which it was most similar, General Perceptual Speed. However, as mentioned above during discussion of the General Closure factor, the General Perceptual Speed factor from the Hakstian and Cattell study was far from clean in its loading pattern, and the General Closure factor had a zero loading from the Perceptual Speed test, a loading that would appear to be required in order to label the factor as General Perceptual Speed. For this reason, it appears most reasonable, recalling the dispute between Hakstian and Cattell in naming the similar factor in their study, to retain the General Closure label for Factor III from the present study and, given the fairly high coefficient of congruence of Factor III with General Perceptual Speed, suggest that the latter factor may indeed represent a general closure factor, rather than cognitive speed.

The fourth factor from the present study, General Retrieval Capacity, showed a rather high level of similarity with the corresponding factor from the Hakstian and Cattell study. It is interesting to note that, although the coefficient of congruence of Factor IV with the General Retrieval Capacity factor of Hakstian and Cattell was not high enough to deem the factors identical, Factor IV had a loading pattern more consistent with the theoretical interpretation of
the factor than did the Hakstian and Cattell factor.

Finally, Factor V from the present study was labeled General Carefulness, stressing attention to detail in visual displays. Factor V showed a higher degree of similarity with the General Visualization factor from Hakstian and Cattell than with any other factor, but the level of similarity is rather low, and the difference in interpretation between the two factors appears easily justified.

A second way of assessing the similarity of factors across studies is to use a Procrustean rotation of the factors from one study, using the factor pattern matrix from another study as the target matrix. Procrustean rotations allow an approximate least squares fitting of an obtained factor matrix to a target matrix. It may be argued that the rather low level of similarity of factors between the present study and that by Hakstian and Cattell (1978) may have resulted from the retention of six factors by Hakstian and Cattell and only five factors in the present study. To counter this argument, six factors were extracted from the matrix of CAB scale intercorrelations from the present study and were rotated, via oblique Procrustean transformation, toward the primary factor pattern reported by Hakstian and Cattell. The resulting correlations among rotated primary factors from the present study are given in Table 9.

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Insert Table 9 about here

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The Procrustean-rotated primary factor pattern matrix from the present study is not listed, since the correlations in Table 9 imply
that the Procrustean rotation failed to arrive at an acceptable representation of the data. In his study rotating random data factor matrices toward random target matrices, Horn (1967) found that the primary factor pattern matrices after Procrustean rotation often appeared reasonable. However, the correlations among the primary factors were often rather higher than one would expect from real data, as were the squared multiple correlations for predicting one factor from the remaining factors. The correlations among the obliquely rotated primary factors, presented in Table 9, range in absolute value from .862 to .994, with a median of .986; also, the signs of many of the correlations are negative. The above, coupled with the large squared multiple correlations of the factors which are also presented in Table 9, indicate that the factors from the present study cannot be rotated to match well the factors from the Hakstian and Cattell (1978) study.

Construct-Validity of Relations Among CAB Scales

Sex Differences

A discriminant analysis was performed on the variables in the Extension Set to determine whether variables in the Extension Set that were similar to certain variables in the CAB would show similar differences between the sexes. The multivariate test of significance between males and females was significant, $F(10,212) = 2.28, p < .05$. The results of the discriminant analysis are presented in Table 10.

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Insert Table 10 about here

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Only four variables in the Extension Set were quite similar to
tests in the CAB. The first of these variables was the Inductive Reasoning test, ETS-I. Although females scored higher than males on the CAB Inductive Reasoning test and on ETS-I, the level of significance for the two tests was somewhat different. The univariate test of significance for the CAB Inductive Reasoning test was almost significant ($p<.06$), but the parallel test for ETS-I was very nonsignificant ($p>.60$). The same failure to replicate findings for a CAB scale was found for the Perceptual Speed test, ETS-P. Once again, while females scored higher than did males on the CAB Perceptual Speed and Accuracy test and on ETS-P, the univariate test was highly significant for the CAB test ($p<.001$), but the corresponding test for ETS-P was very nonsignificant ($p>.65$).

The results for the two remaining tests in the Extension Set that were similar to tests in the CAB were more confirming of the findings reported for the CAB in Table 4 above. Both the Spatial test from the CAB and the Spatial test in the Extension Set, ETS-S, showed males scoring significantly higher than females, $01<p<.05$. Also, the Verbal Ability test in the CAB and the Quick Word Test in the Extension Set both revealed very small and nonsignificant differences between males and females.

In summary, the results of the multivariate test and of the univariate tests involving ETS-S and the Quick Word Test of the difference between males and females confirmed patterns of difference based on CAB scales. But, the results for the two remaining Extension Set variables similar to CAB scales, ETS-P and ETS-I, clearly failed to replicate differences found with the CAB scales.
Relations Among CAB Second-Stratum Factors and Extension Set Variables

The estimated primary factor pattern and primary factor structure coefficients on the five CAB factors for variables in the Extension Set are presented in Table 11. The estimated primary factor structure coefficients in the bottom half of Table 11 represent estimated correlations of the extension variables with the CAB factors and are presented for completeness. Interpretation of the relationships of the extension variables with the CAB factors will center on the estimated primary factor pattern coefficients in the upper half of Table 11, since the latter coefficients are the coefficients that should show simple structure and, thus, aid in the determination of the meanings of the CAB factors.

Insert Table 11 about here

Considering first the loadings of the four verbal measures constructed for the present study, the concrete paired associate task (PA-C) was expected to load on the Fluid Intelligence factor, while the abstract paired associate task (PA-A) and both the concrete and abstract free recall tasks (FR-C and FR-A, respectively) were hypothesized to load on the Crystallized Intelligence factor. The pattern of simple structure loadings of measures on factors was far from that hypothesized. The two paired associate tasks loaded only on the Crystallized Intelligence factor, and the free recall tasks failed to show strong relations with any of the CAB factors, aside from a rather low loading for FR-A on the third CAB factor. The findings for the free
recall tasks are disappointing, and perhaps stem from low reliability of the measures, which would keep the variables from loading highly on any of the CAB factors. Although procedures described by Das et al. (1975) were carefully followed, the present free recall tasks may not have been reliable enough for the rather high level, college freshman sample in the present study.

Turning next to the three reasoning tests, the inductive reasoning (ETS-I), logical reasoning (ETS-RL), and general reasoning (ETS-RG) tests were included to help define the Crystallized and Fluid Intelligence factors. The estimated factor loadings from these three variables are generally disappointing. Both the inductive reasoning and logical reasoning tests failed to load on any of the CAB factors. Instead of sharing its loading on the Crystallized and Fluid Intelligence factors, the general reasoning test split its high loadings on the Fluid Intelligence and General Closure factors. The latter finding is interesting; the general reasoning test was expected to load more heavily on Fluid than on Crystallized Intelligence, and, provided that the above speculations concerning closure are justified, the loading of the general reasoning test is consistent with the loading of other tests, most notably, the Numerical Ability test from the CAB. As with the Numerical Ability test, the general reasoning test consisted of a number of problems the strategies for solving which changed from problem to problem. The power to decide quickly on the operations required for a given problem involves a type of closure, hence the loading of the general reasoning test on Factor III.

The loading of the spatial test (ETS-S) on Crystallized and Fluid
Intelligence was not entirely expected. The Spatial Ability test from the CAB loaded on the Fluid Intelligence and General Visualization factors in the Hakstian and Cattell (1978) study; in the present study, the CAB Spatial Ability test loaded primarily on Fluid Intelligence and at a lower level on Crystallized Intelligence. Therefore, the loading of ETS-S on both Fluid and Crystallized Intelligence is consistent with the loading pattern of the CAB Spatial Ability test. In addition, the failure of either test of spatial ability to load on Factor V reinforces the interpretation offered above that, although Factor V was more similar in loading pattern to the General Visualization factor from Hakstian and Cattell (1978), Factor V does not represent General Visualization in the present study.

Unlike its counterpart in the CAB which loaded only on the Fluid Intelligence factor in the present study, the perceptual speed extension variable (ETS-P) loaded on both the Fluid Intelligence and General Closure factors. Since General Perceptual Speed was the label Hakstian and Cattell (1978) used for the factor most similar to Factor III, the present interpretation of Factor III as General Closure may seem suspect. However, the loading of ETS-P on Factor III is the only one of several loadings that should have appeared on the factor if the factor is indeed General Perceptual Speed; the interpretation of Factor III as General Closure thus seems safe.

The General Closure label for Factor III is reinforced by the loading pattern of the final extension variable, the Quick Word Test (QWT). The loading of QWT on Factor I, Crystallized Intelligence, is to be expected, since verbal comprehension is the major component of QWT
variance. But, the loading of QWT on Factor III argues against the General Perceptual Speed interpretation, since QWT was the only untimed test administered to subjects. The ability to select the appropriate sense of the standard word in the face of distractors highly associated with other senses of the standard word appears to require a type of closure similar to that of other tests loading on the factor. The loading pattern for QWT, thus, aids in the interpretation of Factor III, General Closure, in addition to providing a measure of construct validity for the Verbal Ability test in the CAB, since the two tests had quite similar patterns of loadings.
DISCUSSION

The results from the present study have implications for a number of topics relating to the study of mental abilities. Implications relating to the specific questions addressed in the present study will be covered in the same order as topics were discussed in the Results section. A final section will discuss some general substantive and methodological issues.

Stability of CAB Relations

Sex differences. Significant differences between males and females were found for seven CAB scales. Specifically, males scored higher than did females on two tests, Mechanical Knowledge and Spatial Ability, while females scored higher than males on five scales, Perceptual Speed, Spelling, Word Fluency, Aiming, and Spontaneous Flexibility. In the only previous study of sex differences on CAB scales, Hakstian and Cattell (1975) found a very similar pattern, failing only to find a significant difference on Spontaneous Flexibility and finding a significant difference on Auditory Ability favoring males. In addition to the univariate results, the linear function that maximally discriminated males from females showed a very high degree of stability across the two studies, the present study and that by Hakstian and Cattell (1975).

In an area of research such as sex differences, much effort is
directed toward establishing the reliability of findings and thence to determining the strength of the reliable effect in selected populations. The sex differences on the CAB in the present study so closely parallel the results reported by Hakstian and Cattell (1975) that, with an additional replication or two, the pattern of differences may soon be considered well-established. The CAB could then be used as a standard battery for investigating the pattern of sex differences in different populations; because of the reliability of the pattern of sex differences in unselected samples, one would feel assured that variations from the standard pattern of sex differences were real variations worthy of explanation, rather than the result of sampling variability. The CAB could also be used as a basis for the important work of investigating what it is about males and females, their genetic and experiential backgrounds, that leads to the observed, reliable differences on certain mental abilities and lack of difference on others.

Second-stratum factors. The second-stratum factors of ability derived from the CAB showed less than adequate levels of stability, certainly rather lower than the levels shown for first-stratum, or primary mental, abilities. Bechtoldt (1961) found that each of six first-stratum factors had cross-sample coefficients of congruence of .95 and above. In contrast, the second-stratum factor from the present study that showed the highest degree of stability had a congruence coefficient of only .867, and two of the factors had coefficients below .70. In general, the second-stratum factors from the present study demonstrated such low levels of cross-sample similarity the existence of
the second-stratum factors as useful empirical constructs is open to question.

Second-stratum factors within the theory of Fluid and Crystallized Intelligence have been used by Cattell (1971) and Horn (1978, 1980; Horn, Donaldson, & Engstrom, 1981) in their attempts to account for observed age trends on abilities. The second-stratum factors of Fluid and Crystallized Intelligence have been used as explanatory constructs, to explain the age trends shown by certain clusters of abilities. The major source of evidence for the existence and nature of the second-stratum factors has been factor analytic; if the present study is representative, then the reliance on second-stratum factors as explanatory constructs may be misplaced. Previous demonstrations of the various second-stratum factors of ability have been based on batteries of measures that differed from study to study, with little attention focused on attempting to replicate carefully the loading patterns of tests on second-stratum factors. The variability across studies in the factor loadings of selected variables was touched upon during discussion of the Cattell-Horn theory. If more similar batteries of measures had been used across studies, the lack of stability of factor loading patterns may have been more apparent. One thing appears clear: that the labels applied to factors show much higher levels of cross-sample stability than do the numerical results on which the labels rest. For example, note the factor from the present study that was given a label identical to that of a factor from a previous study, Crystallized Intelligence, even though the cross-sample coefficient of congruence was below .70.
On a more positive note, it may be that the results from the present study merely reflect the less than stable findings one should expect when moving into a new area of study. Studies of the stability of second-stratum factors of ability should be encouraged, studies based on a variety of batteries of tests including the CAB. By looking across a number of studies of second-stratum ability factors, it would be possible to note which findings appeared to represent the trend and which represent the workings of chance. From the vantage point of a recent attempt to replicate the second-stratum factors underlying the CAB and with little previous research of this sort on which to lean, the instability of the second-stratum factors appears to be more the rule than the exception.

Construct Validity of Relations with the CAB

Sex differences. The sex differences revealed on the Extension Set variables were mildly supportive of the sex differences observed on the CAB. Specifically, the significance of the sex difference on the multivariate test and on the spatial test and the lack of significant difference on the Quick Word Test confirmed patterns of sex difference on the CAB. There were two points of conflict, however. The failure to find large differences on the inductive reasoning and perceptual speed tests in the Extension Set, while such differences were in evidence on the CAB, represents a pattern of sex difference that does not generalize across tests of purportedly identical factors. Thus, although the pattern is generally supportive of a conclusion of similar patterns of sex difference on the CAB and Extension Set variables, there are noticeable deviations from the pattern.
On a topic as potentially volatile as that of sex differences, one should proceed with caution. It would be less than desirable to find that the observed differences between males and females depended on the particular battery of measures one used, that is, that different batteries of supposedly parallel measures revealed different patterns of difference between the sexes. The observed differences between the CAB and the Extension Set in the patterns of scores obtained by males and females should invite research to determine why one measure of, for example, perceptual speed should show a reliable sex difference while a second measure of the same ability would not. On the basis of the present study, one may conclude that certain sex differences appear to generalize across batteries of measures, but others do not so generalize.

**External Relations of Second-Stratum Factors of the CAB.** The final focus of the present investigation was the external relations of the second-stratum factors of ability from the CAB. As with the sex differences on Extension Set variables, the relations of CAB factors with variables in the Extension Set were only partly in line with predictions.

The two paired associate tasks, rather than loading on separate factors, both loaded on the Crystallized Intelligence factor. The implication of this finding is clear: that the simultaneous-successive processing theory is of a different sort than the Fluid-Crystallized Intelligence theory. Because the sets of tests Das et al. (1975, 1979) have used to define their simultaneous and successive processing factors have been rather similar to those used by Cattell and Horn and their
collaborators for marking Fluid and Crystallized Intelligence factors, respectively, it was hypothesized that the concrete paired associate task would load on the Fluid Intelligence factor, while the abstract paired associate task would load on the Crystallized Intelligence factor. If the preceding prediction had been borne out, a strong argument could have been made that Cattell and Horn were providing one general rationale for patterns of factor analytic results, and Das et al. were providing a rather different rationale for the same pattern of results. Since the two paired associate tasks loaded on the Crystallized Intelligence, one could argue that the two types of coding, simultaneous and successive, appear to reflect crystallized aids in processing information. Also, it appears that the Cattell-Horn and Das et al. theories are distinct, and a more complete characterization of human abilities would take account of both. While the two paired associate tasks revealed interesting patterns of loading, the two free recall tasks were disappointing, failing to load on any of the CAB factors.

The three reasoning tests in the Extension Set—ETS-I, ETS-RL, and ETS-RG—were chosen to help define the Fluid and Crystallized Intelligence factors, since ETS-I was hypothesized to load more heavily on Fluid, ETS-RL to load more heavily on Crystallized, and ETS-RG to load about evenly on Fluid and Crystallized. Only the latter test, ETS-RG, loaded highly on any of the factors, and ETS-RG loaded about equally on the Fluid Intelligence and General Closure factors, failing to load significantly on the Crystallized Intelligence factor.

The remaining three tests, ETS-S, ETS-P, and QWT, loaded on the CAB
factors in a fairly interpretable manner, with the exception perhaps of the rather large loading of ETS-S on the first factor. Since the CAB factors displayed a somewhat difficult to interpret pattern, it is not surprising that the estimated factor pattern loadings of the Extension Set variables were of a rather complex nature as well.

Overview and Outlook

At the time that the present study was designed and executed, the general form of the study was reasonable. To attempt to replicate the factors spanning a domain, for example, the factors underlying the CAB, and to then relate, using Dwyer's extension, the replicated factors to other variables outside the analysis appeared to offer a fairly elegant way of establishing the stability and external validity of a set of factors.

However, new methods of analysis are appearing in the literature in rapid succession, and some of the new methods offer rather sophisticated opportunities for fitting models to data. Thus, persons considering the collection of data similar to those in the present study should become acquainted with the more adequate methods of analysis presently available.

Rather than administering to subjects only a rather small subset of variables to enter into an extension analysis, it would have been possible to administer a set of measures from the ETS battery (Ekstrom et al., 1976) that paralleled in one-to-one fashion the tests in the CAB. If this had been done, recently developed, and rather simplified, methods for inter-battery factor analysis now available (e.g., see Widaman, 1981) could have been employed to represent the relations among
the sets of tests. If this approach were taken, it would be possible to estimate the correlations between batteries of the factors underlying each battery, rather than simply estimating the correlations of observed variables in one battery with factors in the other. One would then have what would amount to parallel forms reliabilities for the factors underlying each battery, and, if the correlations were quite low, one would have a good indication that the factors from the different batteries were rather different. In the present study, one must consider the pattern of loadings of, for example, the ETS-S test on the factors and its similarity to the CAB Spatial Ability test to arrive at an intuitive estimate of the agreement between the CAB and the ETS battery. It is to be hoped that, in the near future, the newer and better methods for representing data will become widespread; our knowledge of the relations involving the latent variables of interest in our scientific theories can only become more enriched.
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### Table 1
Summary of Tests in the Comprehensive Ability Battery

<table>
<thead>
<tr>
<th>Test</th>
<th>Number of Parts</th>
<th>Number of Items</th>
<th>Working Time (Sec)</th>
<th>Median Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Verbal Ability (V)</td>
<td>2</td>
<td>24</td>
<td>405</td>
<td>.75</td>
</tr>
<tr>
<td>2. Numerical Ability (N)</td>
<td>1</td>
<td>20</td>
<td>330</td>
<td>.79</td>
</tr>
<tr>
<td>3. Spatial Ability (S)</td>
<td>1</td>
<td>72</td>
<td>270</td>
<td>.92</td>
</tr>
<tr>
<td>4. Speed of Closure (Cs)</td>
<td>1</td>
<td>20</td>
<td>300</td>
<td>.71</td>
</tr>
<tr>
<td>5. Perceptual Speed (P)</td>
<td>1</td>
<td>72</td>
<td>270</td>
<td>.82</td>
</tr>
<tr>
<td>6. Induction (I)</td>
<td>1</td>
<td>12</td>
<td>360</td>
<td>.72</td>
</tr>
<tr>
<td>7. Closure Flexibility (Cf)</td>
<td>1</td>
<td>12</td>
<td>300</td>
<td>.81</td>
</tr>
<tr>
<td>8. Associative Memory (Ma)</td>
<td>2</td>
<td>14</td>
<td>360</td>
<td>.77</td>
</tr>
<tr>
<td>9. Mechanical Knowledge (Mk)</td>
<td>1</td>
<td>18</td>
<td>390</td>
<td>.65</td>
</tr>
<tr>
<td>10. Memory Span (Ms)</td>
<td>1</td>
<td>75</td>
<td>taped</td>
<td>.88</td>
</tr>
<tr>
<td>11. Meaningful Memory (Mm)</td>
<td>2</td>
<td>20</td>
<td>315</td>
<td>.81</td>
</tr>
<tr>
<td>12. Spelling (Sp)</td>
<td>1</td>
<td>20</td>
<td>300</td>
<td>.80</td>
</tr>
<tr>
<td>13. Auditory Ability (AA)</td>
<td>2</td>
<td>32</td>
<td>taped</td>
<td>.78</td>
</tr>
<tr>
<td>14. Esthetic Judgment (E)</td>
<td>1</td>
<td>26</td>
<td>360</td>
<td>.69</td>
</tr>
<tr>
<td>15. Spontaneous Flexibility (Fs)</td>
<td>2</td>
<td>NA</td>
<td>360</td>
<td>.74</td>
</tr>
<tr>
<td>16. Ideational Fluency (Fi)</td>
<td>3</td>
<td>NA</td>
<td>270</td>
<td>.78</td>
</tr>
<tr>
<td>17. Word Fluency (W)</td>
<td>3</td>
<td>NA</td>
<td>270</td>
<td>.77</td>
</tr>
<tr>
<td>18. Originality (O)</td>
<td>1</td>
<td>16</td>
<td>360</td>
<td>.74</td>
</tr>
<tr>
<td>19. Aiming (A)</td>
<td>2</td>
<td>70</td>
<td>300</td>
<td>.81</td>
</tr>
<tr>
<td>20. Representative Drawing (RD)</td>
<td>2</td>
<td>NA</td>
<td>360</td>
<td>.58</td>
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Table 2
Summary of Tests in the Extension Set

<table>
<thead>
<tr>
<th>Test</th>
<th>Number of Items</th>
<th>Working Time (Sec)</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Paired Assoc.—Abstract (PA-A)</td>
<td>12</td>
<td>taped</td>
<td>---</td>
</tr>
<tr>
<td>2. Paired Assoc.—Concrete (PA-C)</td>
<td>12</td>
<td>taped</td>
<td>---</td>
</tr>
<tr>
<td>3. Free Recall—Abstract (FR-A)</td>
<td>12</td>
<td>120</td>
<td>---</td>
</tr>
<tr>
<td>4. Free Recall—Concrete (FR-C)</td>
<td>12</td>
<td>120</td>
<td>---</td>
</tr>
<tr>
<td>5. Locations (ETS-I)</td>
<td>14</td>
<td>300</td>
<td>.75</td>
</tr>
<tr>
<td>6. Card Rotations (ETS-S)</td>
<td>114</td>
<td>240</td>
<td>.82</td>
</tr>
<tr>
<td>7. Nonsense Syllogisms (ETS-RL)</td>
<td>15</td>
<td>240</td>
<td>.64</td>
</tr>
<tr>
<td>8. Mathematical Aptitude (ETS-RG)</td>
<td>15</td>
<td>360</td>
<td>.81</td>
</tr>
<tr>
<td>9. Finding A's (ETS-P)</td>
<td>125</td>
<td>120</td>
<td>.82</td>
</tr>
<tr>
<td>10. Quick Word Test (QWT)</td>
<td>100</td>
<td>NA</td>
<td>.90</td>
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</table>
Table 3
Word Lists for Paired Associates and Free Recall Tests in the Extension Set

### Paired associates

<table>
<thead>
<tr>
<th>Number</th>
<th>Stimulus</th>
<th>Response</th>
<th>Free recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ability</td>
<td>gravity</td>
<td>advice</td>
</tr>
<tr>
<td>2</td>
<td>history</td>
<td>amount</td>
<td>menace</td>
</tr>
<tr>
<td>3</td>
<td>answer</td>
<td>justice</td>
<td>effort</td>
</tr>
<tr>
<td>4</td>
<td>knowledge</td>
<td>cost</td>
<td>session</td>
</tr>
<tr>
<td>5</td>
<td>development</td>
<td>law</td>
<td>chance</td>
</tr>
<tr>
<td>6</td>
<td>length</td>
<td>direction</td>
<td>nonsense</td>
</tr>
<tr>
<td>7</td>
<td>discipline</td>
<td>mind</td>
<td>fate</td>
</tr>
<tr>
<td>8</td>
<td>moral</td>
<td>economy</td>
<td>style</td>
</tr>
<tr>
<td>9</td>
<td>edition</td>
<td>pledge</td>
<td>crisis</td>
</tr>
<tr>
<td>10</td>
<td>position</td>
<td>evidence</td>
<td>origin</td>
</tr>
<tr>
<td>11</td>
<td>explanation</td>
<td>soul</td>
<td>impulse</td>
</tr>
<tr>
<td>12</td>
<td>welfare</td>
<td>freedom</td>
<td>vanity</td>
</tr>
</tbody>
</table>

### Concrete

<table>
<thead>
<tr>
<th>Number</th>
<th>Stimulus</th>
<th>Response</th>
<th>Free recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>bar</td>
<td>factory</td>
<td>arm</td>
</tr>
<tr>
<td>2</td>
<td>nail</td>
<td>body</td>
<td>house</td>
</tr>
<tr>
<td>3</td>
<td>girl</td>
<td>barrel</td>
<td>dawn</td>
</tr>
<tr>
<td>4</td>
<td>breast</td>
<td>rock</td>
<td>peach</td>
</tr>
<tr>
<td>5</td>
<td>mule</td>
<td>alcohol</td>
<td>blood</td>
</tr>
<tr>
<td>6</td>
<td>harp</td>
<td>elbow</td>
<td>king</td>
</tr>
<tr>
<td>7</td>
<td>automobile</td>
<td>village</td>
<td>flag</td>
</tr>
<tr>
<td>8</td>
<td>truck</td>
<td>piano</td>
<td>river</td>
</tr>
<tr>
<td>9</td>
<td>candy</td>
<td>pipe</td>
<td>chair</td>
</tr>
<tr>
<td>10</td>
<td>newspaper</td>
<td>cigar</td>
<td>ocean</td>
</tr>
<tr>
<td>11</td>
<td>chin</td>
<td>mother</td>
<td>geese</td>
</tr>
<tr>
<td>12</td>
<td>jelly</td>
<td>hotel</td>
<td>street</td>
</tr>
</tbody>
</table>
### Table 4

Results of Analysis of Sex Differences on CAB Scales

<table>
<thead>
<tr>
<th>Test</th>
<th>Males (N = 78)</th>
<th>Females (N = 194)</th>
<th>Univar. F test</th>
<th>Disc. Funct. Wts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>1. V</td>
<td>14.90</td>
<td>3.90</td>
<td>15.15</td>
<td>3.67</td>
</tr>
<tr>
<td>2. N</td>
<td>11.60</td>
<td>2.98</td>
<td>11.45</td>
<td>2.75</td>
</tr>
<tr>
<td>3. S</td>
<td>43.65</td>
<td>11.25</td>
<td>39.98</td>
<td>11.35</td>
</tr>
<tr>
<td>4. Cs</td>
<td>12.03</td>
<td>3.61</td>
<td>12.90</td>
<td>3.58</td>
</tr>
<tr>
<td>5. P</td>
<td>37.18</td>
<td>8.68</td>
<td>41.10</td>
<td>8.73</td>
</tr>
<tr>
<td>6. I</td>
<td>7.31</td>
<td>2.62</td>
<td>7.94</td>
<td>2.31</td>
</tr>
<tr>
<td>7. Cf</td>
<td>8.46</td>
<td>2.79</td>
<td>7.95</td>
<td>2.91</td>
</tr>
<tr>
<td>8. Ma</td>
<td>9.67</td>
<td>3.21</td>
<td>9.98</td>
<td>3.05</td>
</tr>
<tr>
<td>9. Mk</td>
<td>10.55</td>
<td>3.04</td>
<td>6.36</td>
<td>2.71</td>
</tr>
<tr>
<td>10. Ms</td>
<td>56.42</td>
<td>8.91</td>
<td>54.63</td>
<td>7.87</td>
</tr>
<tr>
<td>11. Mm</td>
<td>15.32</td>
<td>3.72</td>
<td>15.97</td>
<td>3.66</td>
</tr>
<tr>
<td>13. AA</td>
<td>21.13</td>
<td>4.27</td>
<td>20.36</td>
<td>4.25</td>
</tr>
<tr>
<td>14. E</td>
<td>13.71</td>
<td>3.26</td>
<td>13.69</td>
<td>3.30</td>
</tr>
<tr>
<td>15. Fs</td>
<td>10.92</td>
<td>3.14</td>
<td>11.84</td>
<td>2.71</td>
</tr>
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<td>16. Fi</td>
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<td>6.93</td>
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<td>17. W</td>
<td>32.39</td>
<td>8.35</td>
<td>35.30</td>
<td>7.42</td>
</tr>
<tr>
<td>18. O</td>
<td>8.95</td>
<td>2.36</td>
<td>8.46</td>
<td>2.62</td>
</tr>
<tr>
<td>19. A</td>
<td>28.51</td>
<td>9.91</td>
<td>32.00</td>
<td>10.21</td>
</tr>
<tr>
<td>20. RD</td>
<td>30.40</td>
<td>5.80</td>
<td>30.89</td>
<td>5.66</td>
</tr>
</tbody>
</table>

Note: The multivariate test of the difference between the sexes was highly significant, $F(20,251) = 10.16$, $p<.0001$. All univariate $F$ ratios had 1 and 270 degrees of freedom.

* $p<.05$

** $p<.01$

*** $p<.001$
Table 5
Correlations among CAB Scales and Extension Variables

<table>
<thead>
<tr>
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Extension Variable

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| PA-C   | .352 | .134 | .174 | .212 | .141 | .260 | .112 | .204 | .156 |
| FR-A   | .255 | .137 | .100 | .196 | .106 | .115 | .068 | .217 | .023 |
| FR-C   | .177 | .008 | -.010 | .105 | .168 | .080 | .024 | .256 | .064 |
| ETS-I  | .179 | .260 | .163 | .211 | .076 | .151 | .164 | .034 | .294 |
| ETS-S  | .227 | .248 | .618 | .282 | .272 | .317 | .232 | .196 | .315 |
| ETS-RL | .174 | .183 | .022 | .079 | .010 | .140 | .068 | .125 | .080 |
| ETS-RG | .241 | .445 | .299 | .230 | .244 | .243 | .097 | .096 | .161 |
| ETS-P  | .239 | .292 | .280 | .404 | .331 | .236 | .213 | .226 | .074 |
| QWT    | .627 | .156 | .131 | .370 | .046 | .250 | .264 | .199 | .316 |</p>
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**Extension Variable**

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Note. For correlations among CAB scales, N = 272, and correlations greater than .119 and .156 are significant at the .05 and .01 levels, respectively. For correlations involving variables in the Extension Set, N = 223, and correlations greater than .132 and .173 are significant at the .05 and .01 levels, respectively.
Table 6

**Summary of Tests for the Number of Factors Underlying the CAB**

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### Table 7
Primary Factor Pattern and Factor Intercorrelation Matrices

From Orthoblique Rotation of Five Factors from the CAB

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**Factor Intercorrelations**

| Factor I | 1.000 |
| Factor II| 1.000 |
| Factor III| .354 | 1.000 |
| Factor IV| .498 | .434 | 1.000 |
| Factor V | .331 | .243 | .273 | 1.000 |
| Factor V | .452 | .515 | .437 | .361 | 1.000 |
Table 8

Coefficients of Congruence Between CAB Factors from the Present Study
And CAB Factors from the Hakstian and Cattell (1978) Study

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Table 9

Correlations Among CAB Factors Following Procrustean Rotation
Using Hakstian and Cattell (1978) Factor Matrix as Target

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<td>.955</td>
<td>-.963</td>
<td>-.862</td>
<td>.975</td>
<td>.957</td>
</tr>
</tbody>
</table>

Note: The diagonal elements are squared multiple correlations for predicting a given factor from the remaining five.
Table 10

Results of Analysis of Sex Differences on Tests in Extension Set

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>1. PA-A</td>
<td>6.50</td>
<td>3.52</td>
<td>7.57</td>
</tr>
<tr>
<td>2. PA-C</td>
<td>9.24</td>
<td>1.88</td>
<td>9.60</td>
</tr>
<tr>
<td>3. FR-A</td>
<td>4.92</td>
<td>1.51</td>
<td>5.23</td>
</tr>
<tr>
<td>4. FR-C</td>
<td>7.29</td>
<td>1.61</td>
<td>7.66</td>
</tr>
<tr>
<td>5. ETS-I</td>
<td>4.24</td>
<td>3.20</td>
<td>4.49</td>
</tr>
<tr>
<td>6. ETS-S</td>
<td>82.89</td>
<td>22.29</td>
<td>75.30</td>
</tr>
<tr>
<td>7. ETS-RL</td>
<td>1.92</td>
<td>3.81</td>
<td>2.30</td>
</tr>
<tr>
<td>8. ETS-RG</td>
<td>3.35</td>
<td>2.31</td>
<td>2.61</td>
</tr>
<tr>
<td>9. ETS-P</td>
<td>29.23</td>
<td>7.45</td>
<td>29.82</td>
</tr>
<tr>
<td>10. QWT</td>
<td>39.02</td>
<td>10.51</td>
<td>38.41</td>
</tr>
</tbody>
</table>

Note: The multivariate test of mean difference between the sexes was significant, F(10,212) = 2.28, p<.05. All univariate F ratios had 1 and 221 degrees of freedom.

* p<.05
** p<.01
Table 11
Estimated Primary Factor Pattern and Structure Loadings
For Variables in the Extension Set

<table>
<thead>
<tr>
<th>Variable</th>
<th>Factor I</th>
<th>Factor II</th>
<th>Factor III</th>
<th>Factor IV</th>
<th>Factor V</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA-A</td>
<td>0.337</td>
<td>0.135</td>
<td>0.082</td>
<td>-0.159</td>
<td>0.831</td>
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<tr>
<td>PA-C</td>
<td>0.569</td>
<td>-0.017</td>
<td>-0.008</td>
<td>-0.085</td>
<td>0.700</td>
<td></td>
</tr>
<tr>
<td>FR-A</td>
<td>-0.010</td>
<td>0.308</td>
<td>0.125</td>
<td>0.075</td>
<td>0.866</td>
<td></td>
</tr>
<tr>
<td>FR-C</td>
<td>0.019</td>
<td>-0.088</td>
<td>0.111</td>
<td>0.135</td>
<td>0.923</td>
<td></td>
</tr>
<tr>
<td>ETS-I</td>
<td>0.146</td>
<td>0.075</td>
<td>-0.026</td>
<td>0.156</td>
<td>0.892</td>
<td></td>
</tr>
<tr>
<td>ETS-S</td>
<td>0.529</td>
<td>-0.296</td>
<td>0.013</td>
<td>-0.096</td>
<td>0.432</td>
<td></td>
</tr>
<tr>
<td>ETS-RL</td>
<td>0.119</td>
<td>0.311</td>
<td>0.105</td>
<td>-0.202</td>
<td>0.766</td>
<td></td>
</tr>
<tr>
<td>ETS-RG</td>
<td>0.048</td>
<td>0.285</td>
<td>0.092</td>
<td>-0.083</td>
<td>0.710</td>
<td></td>
</tr>
<tr>
<td>ETS-P</td>
<td>0.069</td>
<td>0.318</td>
<td>0.285</td>
<td>0.130</td>
<td>0.201</td>
<td></td>
</tr>
<tr>
<td>QWT</td>
<td>0.484</td>
<td>-0.368</td>
<td>0.326</td>
<td>0.201</td>
<td>0.410</td>
<td></td>
</tr>
</tbody>
</table>

Note. Since N = 223, primary factor structure coefficients above .132 and .173 are significant at the .05 and .01 levels, respectively.