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FLUID AND CRYSTALLIZED INTELLIGENCE: A FACTOR ANALYTIC STUDY OF THE STRUCTURE AMONG PRIMARY MENTAL ABILITIES

BY

JOHN LEONARD HORN
B.A., University of Denver, 1956
A.M., University of Illinois, 1961

THESIS

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY JOHN LEONARD HORN

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Abstract of Thesis Ph.D. 1965

Fluid and Crystallized Intelligence:
A Factor Analytic Study of the
Structure Among Primary Mental Abilities

by

John L. Horn

The purpose of this study is to determine whether or not it is feasible to suppose that abilities are organized at a general level in a way to suggest that there are two major kinds of intelligence, one (fluid intelligence) indicating ability to perceive relations, educe correlates, form abstractions, reason and thereby cope with quite novel complexities, where individual differences in past experience provide relatively little advantage to the persons with the greater experience and relatively little handicap for the persons with lesser experience, and the other (crystallized intelligence) indicating ability to likewise perceive relations, educe correlates, etc., but in situations where the adequacy with which a person copes with the complexities depends upon, and reflects, the breadth of past intellectual experience and the extent to which the person has become familiar with, and able to use, the concepts and generalized

solution instruments which constitute the more abstruse elements of the collective intelligence of a culture.

Following a survey of the kinds of studies which seem to have provoked the theory, an outline of the theory itself, a review of evidence on the problem and a discussion of some major issues relating to measurement methods and the sampling of subjects, 23 so-called primary mental abilities and 8 non-intellectual factors of personality are singled out as representing various important and distinguishing facets of the supposed fluid and crystallized attributes, and as markers for general visualization and speed functions which, as suggested by previous research, need also to be identified and distinguished from the fluid and crystallized abilities.

Measurements on 59 ability and personality tests are obtained from 297 subjects, 215 of which are males, ranging in age from 14 to 61 years. Balanced and broadly valid measurement on the more crucial of the 31 primary personality attributes is then obtained by unweighted linear combination of marker tests.

The intercorrelations of the 31 factor measurements are obtained and studied. These reveal a positive manifold among all of the abilities measured, except that Intellectual Speed, as measured by Furneaux's procedures, and Carefulness, as measured by the complement of the "wrongs" score, show a small but significant negative correlation. A cluster of non-intellectual personality factors indicating favorable or socially-desirable self-evaluation also tend to fall into the positive manifold of ability measures.

The number of common factors needed to account for the intercorrelations is estimated by the root-one criterion; 25 iterations of the principal axis procedure are carried out to stabilize reduced communality estimates for the nine second-order factors thus estimated; the factors are rotated orthogonally in accordance with the Varimax criterion and then obliquely through 13 repetitions of 36 shifts made on the basis of visual inspection of bi-variate plots of factor loadings. The correlations between the nine second-order factors are likewise factored, this yielding four third-order factors; two fourth-order factors are then extracted from the correlations between third-order factors. In the final analysis all factors are transformed into the second-order by the Schmid-Leiman procedure.

Support for the principal hypotheses of the study is provided in all three rotated solutions, but most clearly in the visually-rotated solutions, and Schmid-Leiman results. Two factors having the measurement properties specified for fluid and crystallized intelligence are revealed at the second-order and there distinguished from general visualization, speed, fluency and non-intellectual personality factors.

Results from the higher-order analyses are very cautiously interpreted as perhaps adumbrating a fluid intelligence-visualization-speediness-fluency function and a dimension of crystallized intelligence, self-sentiment development and personality integration.

PREFACE

The completion of this study is a result of the efforts of many people. I take this opportunity to acknowledge my debt of gratitude and to express my deep appreciation to the many who helped me, both those mentioned by name below and those more numerous individuals who must be referred to merely by category labels.

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J. L. H.

Denver, Colorado

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PART I -- PERSPECTIVE ON THE PROBLEM

A. General Purpose and Orientation

"Intelligence is knowledge." (Overheard in a course in philosophy).

"Intelligence appears to be that which enables a man to get along without education. Education appears to be that which enables a man to get along without the use of his intelligence." (Overheard in the halls of a university).

"Lawsy, Chile, when yo haint got no fetchin up, yo jus gotta use yo haid!" (Overheard outside a university).

It is recognized in what might be called the "folk science of the man on the street" that there is a real distinction between intelligence in the sense knowledgeable judgment and intelligence in the sense of a kind of judgment which does not greatly depend upon one's being knowledgeable. The "man on the street" notes that there are persons who "rupture the King's English", who are unaware of many things one might think an intelligent person should be aware of, and yet who in other rather subtle ways give indications of being very intelligent indeed. And he notes, too, that there are persons who are very knowledgeable, who make precise and elegant use of of language, who solve quite abstruse and seemingly complex problems and yet who sometimes seem to fail to grasp the essential idea in a situation as readily as might be expected or , in other subtle ways, give indications of being less intelligent in some sense than persons with less impressive credentials.

Now this idea has, of course, found numerous expressions in psychology. It is expressed, for example, in the notion that there is a "true" intelligence which is "there" but can never be measured (e.g., Hebb's Concept of Intelligence A), and a measured intelligence, which, however, is a biased, distorted caricature of the "true" attribute because there are such wide individual differences in educational opportunities and the like (i.e., Hebb's Concept of Ability B). It is expressed, also, in the distinction often drawn between intelligence and achievement tests; between so-called "performance" or "culture-fair" and verbal tests; between "hold" and "no-hold" measures, etc. And it is expressed in many other ways in the researches and writings of psychologists.

Cattell has tried to bring together from many sources the essential implications of this idea and to express them in terms of an integrated set of experimental and measurement operations. The result of this attempt is what Cattell calls the theory of fluid and crystallized intelligence.

Now, then, the purpose of the present study is to put this theory in better perspective, both as concerns its relation to reliable research results already extant in the field and as relates to the results from a specific experiment here undertaken to extend the knowledge in this area.

B. Conditions Leading to the Statement of the Theory

The theory of fluid and crystallized intelligence was first presented in 1941 (Cattell, 1941) to help integrate evidence then converging from five principal kinds of studies of intellectual performance, viz., those dealing with 1) the effects of early and late brain damage, 2) changes accompanying aging, 3) the relationship between test scores and opportunities to acquire the "collective intelligence" of the culture, 4) the factor structure among putative tests of intelligence, and 5) attempts to construct culture free (or culture fair) tests.

1. The Effects of Early and Late Brain Damage

In the late 1920s and through the 1930s researches (Bianchi, 1922; Feuchtwanger, 1923; Kubitschek, 1928; Dandy, 1933; Weinsenberg and McBride, 1935; Rowe, 1937; Rylander, 1939 and others, summarized in Hebb, 1942; 1949) were accumulating to show that in some cases surgery or pathology in the adult human brain (and the focus of most studies was on the prefrontal lobes) might produce very little, if any, change in traditional IQ, as measured by Binet-type tests, even when substantial intellectual loss could be detected by use of various reasoning tests. It appeared that if intelligence were defined primarily in terms of the kind of prudent judgment, sound inference, and clear expression which depend largely upon knowledge and verbal facility, then there might be relatively little permanent change in intelligence following brain injury as severe as hemidecortication (Rowe, 1937). Such intelligent behavior seemingly did not require a fully intact brain. But if intelligence were defined primarily in terms of tasks which demanded that the subject quickly perceive novel, complex relations and draw purely logical consequences, then there was evident loss of intelligence with brain injury, even when this occurred in areas other than the prefrontal lobes (Kubitschek, 1928). These different patterns of test performance appeared to result only, or primarily, when brain injury was sustained in adulthood, or late childhood--after a store of knowledge could have been accumulated. If brain damage occurred at a young age, then all intellectual functions were generally found to be impaired, seemingly about equally so (Doll, 1933; Doll, Phelps and Melcher, 1932; Werner and Strauss, 1939).

2. Changes Accompanying Aging.

Physiological research on aging in the second and third decade of this century was just beginning to suggest that after bodily growth stopped, irreversible injuries to the central nervous system began to accumulate (Lashley, 1929; Apel & Appel, 1942). It seemed that after about age 22 neural tissue began to decrease, nerve cells began to die off and be replaced by non-nerve cells and brain weight steadily decreased. It was as if anabolism began to lose ground to catabolism and the aging of the brain in adulthood could be likened to brain injury.

If this latter proposition were sound, the behavioral concommitants of aging could be expected to be similar to those disclosed for brain injury. And, indeed, the literature was replete with evidence suggesting just this interpretation (e.g. Beeson, 1920; Yerkes, 1921; Willoughby, 1927; Thorndike, et al, 1928; Jones, Conrad and Horn, 1928; Babcock, 1930; Miles & Miles, 1932; Jones and Conrad, 1933; Miles, 1934; Christian and Peterson, 1936; Wechsler, 1941; Heston & Connell, 1941). Taken together the studies suggested that although older adults frequently did not score as high as younger adults on measures of "general intelligence", this was not always the case and, more particularly, older adults did about as well as younger adults, or better, on tests which measured wisdom based on knowledge and experience--i.e. tests such as vocabulary, absurdities and practical judgments, the kinds of tests which showed little change in brain damage studies. But the older adults almost always showed up more poorly on tasks which required "pure" logical reasoning, particularly when the relations which had to be discovered were not such that they would have been frequently met and dealt with in the course of normal daily activities.

It was pointed out that many of the tests on which older persons performed least well were speeded tests and Lorge (1936) argued strongly that the decrements which accompanied aging were mainly a function of a speed factor in the tests and the fact that older persons were usually more concerned with accuracy than were younger persons. But Lorge's arguments were not altogether convincing, even when taken at full face value (why should older persons be more concerned with accuracy?) and the data did not fully support this position: older subjects were usually somewhat less adept than younger adults even on power tests if these tests contained a substantial reasoning component

(Miles, 1934; 1942). Thus, although the vote was by no means unanimous, a consensus of results prior to 1941 tended to favor the position that adult aging was accompanied by changes similar to those which seemingly resulted from brain damage.

3. The Relationship Between Test Scores and Opportunities to Acquire the "Collective Intelligence" of the Culture.

The influence felt through research in this area, although direct enough in its way, was perhaps a bit more subtle. We have to think not only of what the results seemed to be saying, as it were, but also what they were saying relative to what they were expected to say.

It will be recalled that at the turn of the century the concept of intelligence was rather generally understood to refer to innate capacity. Test construction projects concerned with the measurement of this attribute aimed, as did the Binet-Simon project, at developing scales which would indicate "intellectual level alone...disregarding the degree of instruction and the acquired information of the subject" (Binet & Simon, 1905). But the test which "caught on" as <u>the</u> test of intelligence was not one which obviously fulfilled these aims but instead one which rather obviously did measure "acquired information" and "degree of instruction"--viz., the Binet-Simon test. And the major popular intelligence scales from that time on were modeled on the Binet device. In the minds of many the very concept of intelligence itself came to be virtually equated with the measurement that could be achieved with this type test.

At the same time as the Binet type test was becoming implanted as the measure of intelligence it was also becoming more and more apparent to many that, as usually applied, substantial portions of the variance in measures achieved with this kind of device were due to factors that were largely independent of innate capacity. Studies with groups of children and adults who had been isolated from the mainstream of the culture--such as "mountain folk", "canal boat children", rural and small town dwellers, and itinerants--showed clearly that much of the variance on such tests could represent the extent of exposure to the dominant culture, or, more narrowly, the extent of cultural similarity between test constructors and test takers (cf. Anderson & Ells, 1935; Alexander, 1922; Asher, 1935; Baldwin, et. al., 1930; Duff, 1923; Edwards & Jones, 1938; Gordon, 1923; Hirsch, 1928; Jones, et. al., 1932; Klineberg, 1938; Neff, 1938; Sherman & Key, 1932; Shimberg, 1929; Thorndike and Woodyard, 1942; Wheeler, 1932;

Yerkes, 1921). Similarily the high correlation such tests showed with years of education (Yerkes, 1921), educational advantages (Newman, Freeman & Holzinger, 1937; Stoddard & Wellman, 1940) and social class of parents (Dubnoff, 1938; Loevinger, 1940; McDonald, 1925; Muller, 1933; Neff, 1938; Sirkin, 1929) strongly suggested that some of the test variance was due to educational opportunity and interests. More detailed analyses of test performance indicated that the mean, scatter and intercorrelation of Binet type subtests could be readily affected by practice and special training (Adkins, 1937; Anastasi, 1934; P. Cattell, 1931; E. Thorndike, 1922; Woodrow, 1938).

These two developments--the increasing tendency to identify Binet type measurements with intelligence and the simultaneous accumulation of evidence showing that such measurements reflected many influences besides physiologically-based capacity--worked to change the connotative meaning of the concept of intelligence itself. More and more writers hedged away from earlier definitions specifying innateness and emphasizing that intelligence was an inferred capacity rather than a manifested ability; the concept came more and more to be equated with the operations whereby it was represented: "Intelligence", many said, "is nothing more than what <u>this</u> particular test measures." And since <u>this</u> test was frequently either the Binet, like the Binet or thought to be like the Binet and since performance on the Binet type test was seen to be a function of both innate capacities and influences which might collectively be dubbed "educational" ("education" being very broadly conceived), the concept of intelligence itself came more and more to refer to a resultant of these two influences.

4. The Factor Structure Among Putative Tests of Intelligence.

From the time when Spearman (1904) first opened the door to development of mathematically-based methods for objectively analyzing test performances into components, termed factors, there was a steady increase in the number of elementary or "primary" factorial concepts used to explain and represent the phenomena of ability-test behavior. Although British psychologists were generally less inclined to accelerate this increase than were their American counterparts, the major impetus for this movement was set in motion in England. Burt's (1909 and subsequently) incisive criticisms of the two-factor theory and the evidence which had then been presented to support it got the ball rolling, so to speak. His own early-gathered evidence (Burt, 1909; 1911) showed numerical (N)[1] and verbal (V) group factors in addition to a general dimension. Burt's criticisms and results were repeated in several investigations reported between 1910 and 1920. By 1924 he was able to report substantial support for a memory span (Ms), a "manual" and a "scholastic" group-factor as well as for V, N and the general factor. To this list was added, even before Thurstone's influence began to be felt, a spatial factor (S or Vz), one involving perceptual or mental speed (P), a mechanical reasoning or visualization dimension (Mk or Vz) and several less clearly defined group factors (see Alexander, 1935; Brown, 1932; Brown and Stephenson, 1932-33; Brigham, 1932; Corter, 1928; Cox, 1928; El Koussy, 1935; Kelley, 1928; Patterson & Elliot, 1930). Although Spearman argued persuasively that many, if not all, of these factors could represent failures in a study design which should have carefully eliminated "specific overlap", this view did not find general favor and even he yielded to Burt's position to the extent of allowing group factors if they could be established by extension of the tetrad difference criterion.

Positive manifold among ability-test intercorrelations was discovered and repeatedly confirmed in the period before 1941, although the finding was so infrequently emphasized that one is inclined to surmise that investigators of that period were not so much impressed with it as a finding as they were inclined to take it for granted. This is suggested by their universal practice (prior to 1935 when Thurstone's influence began to be felt) of routinely extracting and discussing a general factor before even considering the possibility of group factors. According to Burt's (1949) recollections, there emerged "during the first two decades of the present century...a growing conviction (among psychologists using factor analytic methods)...that the mind, like the nervous system,[2] was organized into a hierarchy of levels...." with a single general factor at the top and factors of varying degrees of generality further down, "...the more general factors including the more specialized, as countries include counties..." Burt, 1949).

It will be recalled that Spearman's theory (developed partly from notions presented earlier by Spencer and Stern) postulated a general capacity, termed G--a kind of "neural energy"--from which all cognitive processes are differentiated and upon which all ultimately depend for their operation. Assuming individual differences in endowment of this capacity, positive manifold among intercorrelations of cognitive tasks could be expected and, assuming independence in development and operation of various specific cognitive processes, hierarchical[3] order could be predicted. (This was thus a hierarchical development theory.) As it became evident that, in most samplings of ability tests, specific factors were not truly specific or independent, the unit rank model gave way to the hierarchical model of which Burt speaks above. Probably most psychologists working with factor analytic procedures in the 1920's and early 1930's implicitly, or otherwise, accepted a theory much like this Spearman-Burt hierarchical conception.

The essential feature of Thurstone's (1931, 1935) multiple factor theory was that it proposed an alternative to this conception. As British investigators are prone to point out, Garnett had stated a multiple factor theory in 1919 and Burt had invented the equivalent of the centroid method for computing factor loadings in 1917, both some years before Thurstone outlined his theory and mathematical procedures. But it is largely incidental that Thurstone proposed multiple factors and suggested that the first step in factor analysis could proceed by calculation of centroid factors.[4] More important is the fact that the model he developed, and particularly the principle of simple structure which this contained, provided for a different conception of cognitive processes and a different system for classification of ability factors.

It might be argued that in fact Thurstone was anticipated in this development by several other workers. In a sense this is no doubt true: Galton's conception of intellect was in some respects "oligarchical", to use the characterization Spearman (1927) made famous in this respect, and Pearson had proposed to interpret intercorrelations in somewhat the same way as was implied by Thurstone's model. Garnett's multiple-factor notion was certainly reminiscent of Thurstone's. But for the most part these were rather vague theories, not mathematical models with explicit features indicating the way data should be structured if the model were adequate. Although many would contend that Thurstone's simple structure concept is likewise vague, still there is no question but that it represented a large step toward making the oligarchical alternative to the hierarchical-monarchical theory more explicit.

It might also be argued that in some respects the theories of Thomson (1916) and Kelley (1928) anticipated Thurstone's developments. Thomson, it will be remembered, argued that the evidence Spearman presented for his theory was equally compatible with a theory that postulated a large number of independent abilities, overlapping groups of which are sampled by mental tests. But Thomson never presented convincing arguments as to why investigators (including himself) did not create cognitive tests which correlated zero or negatively with each other, as could be expected if the underlying abilities sampled in such tests were truly independent and investigators exercised diligence to construct independent test-samples. In fact, Thomson's theory did not really involve an assumption that elementary abilities were independent except in the sense that a test constructor might choose his test samples of such abilities at random. Instead the theory argued, in effect, that a unitary process of inheritance--what Thompson sometimes referred to as "Mother Nature"--worked to account for the presence of a single general factor. In other words he interpreted a general factor as showing that abilities were <u>not</u> sampled independently within individuals. Likewise, Kelley's (1928) position was that a general factor was necessary, although he referred to this as an artifact due to differences in age, maturational level, social class, race, and sex, etc. Boiled down to its essentials his position was that because individuals differ on these variables (age, sex, etc.), they will tend to differ in a unitary manner in measured abilities. A collection of "artifactual" influences was thus assumed to constitute a unitary process.

Thus, while in retrospect it can be seen that in many ways the theories of Kelley and Thomson (and also the popular neurological theory of E. L. Thorndike, 1914) could be more compatible with a simple structure model than they were with a hierarchical model, it remains true that, as stated, these theories did not so much challenge the Spearman-Burt hierarchical conception as they did accommodate it. By contrast, Thurstone's simple structure model, at least as it was originally presented, offered a distinct alternative to Spearman's conception. Rather than predicting the operation of a single unitary influence or a unitary-acting collection of influences, the simple structure model argued that there would be several separate, largely independent and almost equally potent influences at work to determine the intercorrelations among tests. Thurstone's position was thus clearly in opposition to the "growing convictions" of influential factorists of his day.

Thurstone introduced his model with an analysis of non-ability data (Thurstone, 1931). It appears that he first applied it with ability tests in 1935, when he re-analyzed Brigham's (1932) data. In this study he located V and N as well as a visual imagery factor, "G" being conspicious by its absence. In his famous "Primary Mental Abilities" study (Thurstone, 1938) word fluency (Fw or W), inductive reasoning (I), general reasoning (R), and deductive reasoning (Rs or D) were added to the list of "discovered" factors, V, N, S, M, and P, being also located in this study. In 1940 he presented a second study showing substantially the same results. In each of these investigations "G" was noticably absent.

It can be argued that if Thurstone required that all ability factors be positively correlated,[5] then he, in effect, accepted the need for a general factor. But it appears that he was initially open to persuasion on this point. In 1935, he wrote, "even if the intercorrelations are positive or zero, it does not follow that the trait configuration can be inscribed in a positive manifold." In other words the question seemingly being asked was: "Does a positive manifold among test intercorrelations necessarily imply a positive manifold among underlying traits?" or, worded another way, "Is a hierarchy with a single factor at the top always a possible solution when a positive manifold exists among test intercorrelations?" To our knowledge Thurstone never provided answers for these questions.

No doubt the repeated findings of positive manifold among ability test intercorrelations provided a persistent, if not always explicitly acknowledged, argument against acceptance of Thurstone's position and in favor of return to an hierarchical conception. Shortly after Thurstone's 1938 study appeared Eysenck (1939), Spearman (1939) and

Holzinger & Harman (1938), re-analyzed his data to show that the correlations permitted a general factor in addition to some of the primaries he had reported. Alexander (1935), although he used the centroid procedure developed by Thurstone, kept "G" throughout his analyses and Blakey (1940) acknowledged the presence of a "G" factor when he used Thurstone's methods to re-work the Brown-Stephenson (1932-33) to show V, S and P. Then, in a crucial experiment of this period, Thurstone & Thurstone (1941), after carefully rotating V, N, S, Fw, Ma, and I, into oblique, positive manifold simple structure, reasoned that "if these six primary mental abilities are correlated because of some general intellective factor, then the rank of the correlation matrix (for the primaries) should be 1." And they went on to report that "...upon further examination, this actually proves to be the case...our findings...support Spearman's claim for a general intellective factor."

Thus, after only a brief glimpse at another organizational scheme, those who were using factor analysis to help produce a better understanding of human abilities seemingly returned to full acceptance of a hierarchical organizational model.

But this was not quite the whole story. The G-hierarchy notion did not escape unscathed from its encounter with Thurstone's single-strata theory. The suggestion lingered that perhaps more than one factor would be needed at the second order. Kelley's argument that "G" was, in a sense, an artifact also continued to exert some influence. It was frequently noted that the general factor involved non-intellectual (artifact) variables (motivation and temperament measures as well as social class indicants) if such variables were included in analyses. Also, although those who adhered to the hierarchical organization conception usually regarded "G" as necessary at the top, it appeared that the group factors below this level were not all of the same order of generality; some were a good deal more specific. Indeed, some of the general group factors appeared to be almost as worthy of the title "intelligence" as "G" itself. Alexander's second factor, for example, involving noteworthy loadings on the Otis and Thorndike tests of general intelligence, as well as on verbal-numerical tests and achievement measures, certainly appeared to be a kind of intelligence, particularly so because another factor, labeled X and involving school attainments almost exclusively, appeared to pull off much of the variance which might be attributed to interest and other non-intellectual personality influences. Although this broad factor was interpreted as a verbal ability, it appeared to encompass a considerably wider spectrum of intellect than was implied by the notion of

V alone. Likewise, Alexander's third major factor, defined by his own Passalong Test, Kohs Blocks, Cube Construction, Porteus' Mazes and other non-verbal tests, was interpreted as a kind of "concrete" (as opposed to "abstract") intelligence. This, too, was a broad factor. It seemed to involve, for example, some of the characteristics of the narrower spatial visualization dimension which El Koussy (1935) labeled k.

There was the suggestion, then, of a "G" conglomerate dimension at the top of a hierarchy, perhaps verbal "abstract" and non-verbal "concrete" general abilities at the next level and, below these, various group factors of about the order of generality of Thurstone's primaries. A theory along these lines was not explicitly stated until somewhat later (Vernon, 1947), but the results were there and this kind of interpretation was certainly adumbrated in Alexander's and El Koussy's work prior to 1941.

5. Attempts to Construct Culture-Fair Tests

Language is, of course, the vehicle by which most of what is termed culture is transmitted and it is frequently one of the principal characters by which cultures are distinguished. Within a society wherein, ostensibly, a single language is spoken, there are usually several dialects or, if not clearly this, then there are various social class, racial, etc. groupings of people who use, primarily, somewhat different parts of the language system of the society as a whole. Hence, if one were to construct a "culture-fair" test probably one of the first considerations would be to reduce the test's dependence on language to a minimum.

Many of the early test construction projects premised on this dictate produced tests which, although they avoided extended use of vocabulary and were, therefore, non-language tests, were nevertheless about as culturally "loaded" as straightforward information tests. The picture completion test of Healy (1911), for example, or the comic strip re-arrangement tasks (Pintner and Patterson, 1915; Yerkes, 1921) and the picture absurdities tasks (Pressey, 1920), were seen to be very much immersed in cultural content and quite subject to the influences associated with cultural sophistication (cf. Shimberg, 1929). Other efforts along this line resulted in devices which were largely culture-fair, to be sure, but which were also largely free of measure of intelligence. Many of the so-called "performance" tasks, such as found in the Grace Arthur, Pintner-Patterson and Army Beta batteries, fell into this category. The major variance of such tests was shown to be involved with measure of manipulative-speed factors, not measure of intelligence (Cattell and Bristol, 1933; Cox, 1928; Cattell, 1940; Cattell, Reingold & Sarason, 1939).

However, not all tests which required manipulative skills were found to be devoid of intellectual variance. In Alexander's study, for example, the Passalong, Kohs Blocks, Cube Construction and Porteus' Maze Tests were found to show substantial correlations with general intelligence measures and to have noteworthy loadings on the "G" factor (although, as previously noted, they also loaded on Alexander's "F"). Likewise, El Koussy's Form Relations (Paper Form Board), Figural Equations and Fitting Shapes Tests, although they all loaded on k, had high loadings on the general factor. Such findings suggested that if the variance on manipulative and spatial visulaization components could be substantially reduced, tests of these various forms might provide the desired "culture-fair" measures.

One of the basic features of these tests was that they required the subject to perceive relations among test elements--what Spearman (1927) called fundaments--which could reasonably te supposed to be about equally familiar or equally unfamiliar to all who would take the test. Blocks, for example, and basic shapes like rectangles, ovals, and the like were such common elements in most European and American societies that it was certainly not unreasonable to suppose that all children above the age of ten or so would have had ample opportunity to become familiar with them. Yet tasks involving quite complex relations and requiring a high level of abstraction could be constructed from such materials. By putting these features into paper-and-pencil tests, the manipulative component could be almost entirely eliminated, and by casting the relations in a form that did not require subjects to imagine the movements of objects in space, much of the spatial visualization variance could be removed.

Spearman and his co-workers, particularly, but several others in Britain and a few workers in America worked at developing tests based on these principles. Spearman (1925) for example, produced an analogies test involving only shades of grey. Another test developed by Spearman (1933) and called figure analogies involved rows of geometric figures arranged so that by perceiving a common feature of one row, one could deduce what was missing in a second row. With slight modification this became known as the Relational Matrices Task (Cattell, 1940; Raven and Foulds, 1938), one of the best known of the "culture-fair" tasks for measuring intelligence. The Letter Series task, Figure classifications, Overlapping Shapes (similar to Topology, Cattell, 1940) Form Relations and many other tests that are now rather common came out of the ~~work of~~ this period. (Cf. Abelson, 1911; Arsenian, 1937; Davey, 1926;

El Koussy, 1935; Fortes, 1931; Line, 1931; Stephenson, 1931 and others).

In El Koussy's study many such tests were found to have low loadings on the k-spatial-visualization factor and to have high loadings on the factor interpreted as "G". Cattell (1940) using these findings and those of Stephenson (1931), Davey (1926) and others, brought together several tests of this type, selected those which simultaneously showed high loadings on "G" and low loadings on other factors, and put these together in test which he published under the name "A Culture-Free Test of Intelligence."

The principal feature of this test was that it claimed to yield a measure of intelligence that was largely uncontaminated by school and social achievement, per se. On the surface, at least, there was certainly good reason to regard this claim as partially justified: the test items were not of a kind which would ordinarily be found in achievement tests; the tasks required of the subject were not obviously those which were taught in schools, homes or other educational agencies of the culture; intuitively it was apparent that the tasks required intellectual "work"; the test did not correlate as highly with Binet type tests as did most devices which claimed to measure intelligence; and, perhaps most interestingly, the test nevertheless correlated only slightly less with school performance than did the Binet type tests (roughly .4 as compared with .5); thus the suggestion was that the Culture-Free test did indeed measure intelligence, but a somewhat different aspect of this than was assessed by traditional tests.

C. Early Statement of the Theory.

Roughly sketched, then, these would appear to be the principal antecedents setting the stage for the presentation which Cattell made in 1941. Taken overall, the evidence thus suggested that if the intercorrelations among ability tests, and the factors which could be derived from such correlations, were indicants of the kinds of influences which affected ability-test performances--and this, judging by their work, is what most factorists assumed--then at a general level there should be found at least two major factors, one associated primarily with physiologically-based influences and the one associated with educational-experimental influences, broadly-conceived.[6] If these two influences were not fully independent (as seemed indicated), then a positive manifold among ability measures would be expected, but this would not be indicative of a single factor at the second order, as reported by Thurstone and Thurstone, or of a single "g" factor directly above the group factors in a simple two-level hierarchy, as suggested by the

the solutions offered by most British factorists. Rather, positive manifold would reflect a social fact of correlation between the two major kinds of influences just mentioned.

More specifically, Cattell argued that the observed variation among individuals in their scores on any intelligence can be regarded as depending on:

G: variations in the innate gene endowment.

dG: variations in environmentally-produced development of general ability.

C: variations in the closeness of the individual's cultural training and experience to the cultural medium in which tests are expressed.

t: variations in familiarity with tests and test situations generally.

f: fluctuations in the underlying capacity.

fr: fluctuations in the effective expression or application of the ability through varying strength and direction of volition.

s: specific abilities.

e: chance errors of measurement.

(Slightly modified from Cattell, 1941), whence he expressed these notions in the specification equation form for which he is so noted.

In describing the G-term in this expression he had reference to a culture-fair concept of intelligence:

> Each individual is considered to have a particular capacity in perceiving complexity of relations, which exists independently of the particular field of skill or knowledge in which the individual comes most fully to exercise this ability. It is something which can be conceived in abstraction from the field in which it is measured and as potential to another field as energy can be conceived and calculated apart from the particular physical, chemical, or electrical system in which it happens to be resident. Only on this assumption is it possible to speak of an engineer and a lawyer as having equal intelligence...or of an Englishman and a Frenchman having the same amount of general ability..." (Cattell, 1941).

Whereas in describing the dG and C terms he introduced the notion of a distinct "crystallized" concept of intelligence:

> If this (the above) detachment of the power from its manifestations is possible..., then it is correct to ask how far the power, as such, can be impaired or augmented by environmental influences. This emphasizes that the environmentally produced change in intelligence, dG, is in the subject himself...

He then noted that the potency of the influences represented by dG and C would be:

> ...a function both of the time of exercise and the amount of culture encountered. If the information and skills were acquired very quickly, the effect on intelligence might not be so great as if they were exercised for a long time. Again, if they were acquired in early years when they seemed difficult they would offer more exercise than to a mature intelligence. Finally if they are acquired after the age at which mental capacity reaches biological maturity, their effect should be very small. (Cattell, 1941).

And he went on to state that the theoretical distinction between dG and C would probably not be a measurement distinction:

> ...having had the mental exercise of learning a culture and being well versed and informed in it almost invariably go together. The former is the cause of the supposed dG; the latter is C, the familiarity with cultural content." (Cattell, 1941)

This being the case, a combination of dG and C would constitute a manifest general ability, crystallized intelligence, which might, if there was any validity to the notion of culture-fair tests, be distinguished from G, fluid intelligence.

Later Cattell (1943, 1950) made these ideas more explicit. General ability, he said:

> is of two kinds, fluid ability, which manifests itself in relation perception, in speeded performances, and in new situations, and crystallized ability, which manifests itself only in relation perception in known material and unspeeded performances... (Cattell, 1943)

He argued that the two abilities should show different developmental patterns of change, that fluid ability:

> ..declines after about twenty-three, leaving crystallized ability like a dead coral formation, maintaining, except where brain injury occurs, the levels of the original fluid ability...
>
> The (age-difference) curves for intelligence... refer to basic powers: the cumulative result of learning by these powers reaches a plateau...consequently, where good performance is a matter of wide information, of wisdom and foresight born of experience, of shrewd tactics, and especially of truths of living less acquirable by explicit teaching than by trial-and-error

learning, the older person has the advantage... (Cattell, 1950).

Such, then, was the theory as developed in Cattell's early writings. Rather surprisingly, in view of the fact that the theory aimed at integrating evidence and concepts from several otherwise diverse areas in the psychology of abilities and in view of the clearness of some of the implications of Cattell's formulation, practically nothing was done with the idea until the present research was conceived. This is not to say that there have not been many developments which have affected more recent statements of the theory (Cattell, 1957, 1963), but it is to say that virtually no empirical work has been based upon a serious consideration of the theory, Cattell's (1963) study being, at best, only a minor exception to this generalization.

D. Some Facts and Feelings Which Probably Need to be Taken Into Account by the Theory

1. Issues Concerning the Inherited, Neurological and Learning Bases for Intelligence

Perhaps the principal theoretical difficulty encountered with the fluid-crystallized distinction is one of specifying the role of learning in the acquisition of the behaviors which essentially define the psychological measures of the two attributes. For it must be acknowledged that the measurement of both depends on observations of learned behaviors and yet a major distinction drawn between the two is that one (crystallized intelligence--hereafter Gc) represents goodness of "education" (broadly conceived) to a large extent, whereas the other (fluid intelligence--hereafter Gf) can be conceived of as largely independent of goodness of education.

The question of the extent to which ability test performances are dependent on, or independent of, learning is highly complex and debatable. Some role must probably be granted to unlearned reactivities, even in mature adult performances, and this role is possibly more important in some kinds of tests than in others; but the evidence surely indicates that many aspects of the behavior measured in <u>any</u> ability test are the result of a history of learning. Also, some role in the <u>development</u> of abilities must probably be granted to unlearned, instinct-like behavior patterns which function to get the organism going in the first place, so to speak, and perhaps provide rather global directional influences throughout development, but, again, the evidence surely indicates that learning is imposed, superimposed and superimposed, again and again, on such patterns, so much so that it is quite impossible to conceive of measuring these influences, as such, except at a very high level of abstraction. The answer must be, therefore, that abilities are both independent of, and dependent on learning, that the latter is probably the more crucial fact, but that the extent of either dependence or independence will be a function of the kind of ability considered and the stage in development where it is considered.

Thus, while it is certainly theoretically legitimate to regard fluid ability as "largely innately determined, except for physiological influences." (Cattell, 1957), it must, of course, be realized that the hypothesized innateness can be "seen", as it were, only after it has been refracted many times by passage through "prisms of learning." And the same may be said for Gc. Indeed, to continue with this analogy, the distinction between Gf and Gc cannot rest on the issue of innateness at all, but rather must be based on the nature of the "prisms of learning" through which basic potential passes to arrive at manifested abilities. The extension of the theory developed in this section argues that in both Gc and Gf this potential passes through some of the <u>same</u> "prisms" A through M, say, but that in the case of Gc it additionally passes through "prisms" N through P.

This is not to say that the instructions which are written into one's physiological structure by inheritance do not exert influence on the course of the learning through which Gf and Gc are developed. The exposure to opportunities to learn may very well take place within a context of maturational developments dictated by heredity. If so, exposure to opportunity would not indicate conditions for learning unless the maturational level were right. But this question is irrelevant as far as the present investigation is concerned. No serious effort can be made to distinguish maturational and learning influences, or their interactions. All that can be said is that both Gf and Gc must be understood as based in large part on learning and to be distinguishable, in part, in terms of different kinds of achievements resulting from this learning, regardless of whether maturation played a major part in transforming opportunity into "conditions for learning" or not.

Having put heredity in its place, so to speak, it may be worthwhile to pause here momentarily and do likewise with another reductionistic notion which must inevitably crop up in discussions of intelligence, viz., the notion that intelligence is something which might, in the millennium, be measured by counting neurons in the brain, or some such.

Even a superficial reading in the literature of comparative biology indicates that differences in the structure and function of nervous systems reflect in differences in the way various species adapt to their environments. As Lashley

(1949) points out, by no means all of these differences are in man's favor. But there surely is a sense in which man has shown himself better able to adapt than many animals and the one characteristic (among perhaps several) which appears to be most responsible for this is what may legitmately be called a "man-like intelligence."[7] It is also evident that this intelligence correlates with some index of cephalization, crudely but illustratively represented by a ratio of brain weight to body weight or perhaps somewhat more accurately by an A/S ratio (Hebb, 1949). From this it seems to follow that one might measure intelligence by, say, fitting calipers to the skull, as the anthropologist might do, or by using the instruments favored by pathologists, cytologists, neurologists, EEG specialists, etc. But in fact, while these approaches may be fair enough for those in the disciplines mentioned, they offer the psychologist no escape whatsoever from his job, which is to provide an adequate <u>behavioral</u> description of the phenomena which, in other fields as well as in psychology, may be referred to as "intelligence". No matter how accurate the counting of neurons or EEG blips may be, such procedures can never provide measures of intelligence which will serve a (behavioral) psychologist. His definitions must be based on behavior, as such, and this alone.

Incidentally, it is on this basis that a clear distinction can be drawn between the fluid-crystallized concept and Hebb's (1948) notion of an ability A and an ability B. The two notions are sometimes regarded as quite similar (cf. Clarke, 1962), but in fact they differ in the fundamental respect that ability A, as described by Hebb, is unmeasurable as a psychological (behavioral) attribute (as he acknowledges) because the concept refers to a neural state, per se, whereas Cattell's fluid ability is conceived of as a measurable trait. Hebb, although he observes that certain kinds of intelligent behaviors are more affected by brain damage than are certain other kinds, and thus implicitly acknowledges that different kinds of general abilities might be involved, apparently does not see this fact as an avenue which might lead to a measurement distinction between his A and B. (In fact, of course, Hebb has shown himself to be mainly concerned to provide qualitative description, rather than measurement tools).

But to say that intelligence cannot be measured by counting neurons is not to say that neurological, cytological, EEG, etc. findings are not relevant to the task here at hand. It is possible that a completely adequate description of intelligent behavior could be worked out without ever looking at data on neurology, brain structure and function, and the like. But to fail to look at such data is probably to fail to take the most efficient strategy for studying intelligent behavior. For it seems evident that whatever intelligence is, it surely reflects, and depends on, the integrity of neural tissues. Hence, changes or differences in neural tissues have at least a preliminary "right", so to speak, to be regarded as changes or differences in intelligence. Whether or not they are to be so regarded in the final analysis will depend upon many other considerations, paramount among which will be evidence indicating, or failing to indicate, a functional unity among the behaviors in question and other behaviors regarded as intellectual in nature.

2. Unity and Differentiation Among Abilities

There are two major facts which any theory of intelligence must recognize and make some effort to deal with. One is the quite obvious fact that by adulthood the human displays many more or less distinct abilities--abilities which vary somewhat independently between persons. The other is the fact that abilities are to some extent integrated--that there is a notable amount of dependence in their variation between persons.

In his latest summary French (1963) has reported on some 24 more or less distinct ability factors--patterns of performances which have shown up repeatedly in studies with samples of older children and adults and which have remained linearly independent in at least several replications.

Guilford (1959, 1960, 1961) has claimed that upwards from 52 ability factors have been established and has proposed that many more will be found as research continues. Humphreys (1962) has questioned the wisdom of work, such as Guilford's, aimed primarily at further proliferation of factors, as such, and has argued, in effect, that the correlational-factorial independence which is reported in many studies, and which therefore serves as the basis for distinguishing between supposedly independent abilities, is often small and, in any case, might often be better interpreted as reflecting somewhat different facets of the same ability, rather than independent abilities. According to this view (which, it will be noted, is rather similar to that taken by Spearman) the evidence indicates fewer basic or "primary" abilities than is suggested by Guilford's (and perhaps even French's) list, but that each of these can be measured by somewhat different methods (i.e., through somewhat different facets). Just how many "basic" abilities would need to be recognized in this system is not yet clear, but it would seem that the data require at least several, whether they be those presently listed as "primary" or not. Thus, the essential conclusion must be that if the criterion of independence (Horn, 1963a; Humphreys, 1952) is only loosely met in establishing ability dimensions, then very many "distinct" abilities must be recognized as existing in adult performances, whereas if this criterion is more rigorously met, then there are probably at least several (e.g., say, ten) basic and independent abilities.

It seems apparent to common sense that abilities are much less clearly differentiated in early childhood than at later ages. But it has proved difficult to demonstrate this "self-evident fact" with research data. Some investigators (e.g., Anastasi, 1936; 1958; Vernon, 1950) have seriously questioned the notion that differentiation of abilities is, indeed, a fact of development. Vernon cites the early work of Balinsky (1941, Clark (1944) and Garrett (1946) in support of the view that differentiation does take place, but then he goes on to review several studies (Doppelt, 1949; McNemar, 1942; Reichard, 1944; Swineford, 1947; Vernon and Parry, 1949 and Williams, 1948) which suggest that, at least in the period of adolescence, "there is no general tendency toward differentiation..., and that everything depends on the type of education and vocational training" (Vernon, 1950). However, Vernon does acknowledge that differentiation probably is a fact of development in the early years of life. Burt (1954), in the most recent, carefully conducted evaluation of the studies on this question, concluded that the evidence does generally support the differentiation hypothesis, insofar as it is testable.[8] For the purposes of the present study the conclusions of Burt and Garrett are accepted; the differentiation of abilities is viewed as in some sense a product of development.

It is not so obvious to common sense that all mental abilities are interrelated. Yet it is a rather amazing fact that of the hundreds (perhaps thousands) of mental ability tests which have been devised, practically none--if not in fact none--have been found to correlate consistently negatively with other mental ability tests. Related here is the fact--less well established--that even in re-tests over several years ability tests continue to inter-correlate positively.

At least this latter statement is true of tests constructed for, and used with, people above the age of about five; if the reference is to samples of children below this age, the statement must be more guarded. There appears to be less consensus among psychologists about what mental ability is in very young children and whatever is measured as "intellect" below the age of five shows a rather low relationship with what is measured as intelligence at an older age. Hofstaetter, (1954), presenting results which mainly serve to clarify findings obtained in many previous investigations (cf. Anastasi, 1958), has demonstrated that the so-called intelligence measures (actually sensorimotor reactivity measures) taken before the age of about two have practically no value in predicting intelligence test scores obtained beyond the age of five, and that ability measures taken between ages two and five are only slightly better. It would seem, in other words, that although measures taken in the 2-5 year-old period fall within a positive manifold for the relationships among measures taken at older ages, the correlations are low, and that, moreover, many, if not all, of the tests used below the age of two may not even fall into the general positive manifold. Perhaps "positivity" of relationship among abilities is something that develops from integrative influences operating in the first few years of life or perhaps many tests that are used to measure abilities in young children and infants simply do not measure intellectual abilities. And there are other possible explanations for the observations. But the evidence is clear in indicating that ability measures taken at different ages between age five and adulthood, and measures of supposedly different abilities taken on a given occasion, tend to show generally positive intercorrelations. An adequate theory of intelligence must take some account of these facts.

3. The Transfer Phenomenon and Simplex Pattern in Development.

Some years back Anderson (1939, 1940) suggested that what is measured in intelligence tests (and the reference was to Binet type tests) might be thought of as an accumulation of elements acquired through learning. In the mathematical-statistical model he developed to more precisely express this idea it was assumed that each accretion to the expanding store of elements was independent of every other and of the base (e.g., the initial "intelligence"), and that no elements represented in early measurement were lost to later measurements. Rather surprisingly, in view of the restrictiveness of these assumptions, the model gave a fairly close fit to test-retest intercorrelations deriving from measures of intelligence that were obtained in successive years through childhood (Anderson, 1939; Roff, 1941).

Hoffstaetter and O'Connor (1956) modified Anderson's second assumption to allow for the possibility that some of the influences of an early period might drop out and not operate in later measurements. They found that the resulting model gave a somewhat better fit for intelligence retest intercorrelations and that it gave a very nice fit indeed for some intercorrelations among physical growth measures which had been obtained by Shuttleworth (1939).

Humphreys (1960) has shown that with the assumption that increments are independent, Anderson's model is equivalent to that which Guttman (1955) described as a simplex, but that in fact the simplex matrix can be derived with the somewhat less restrictive assumption that the intercorrelations and variances among sets of increments have equal means. To support the claim that the simplex model provides at least a rough description of test-retest correlations in a wide range of maturational and/or learning data, Humphreys presented matrices based on several rather diverse kind of observations including those obtained by Fleishman and Hempel (1954, 1955), on the learning of motor skills over fairly short time periods, and those obtained in studies of grades given over several years in university courses.[9]

It thus appears that the simplex model indicates something about the way traits in general, and abilities in particular, develop. This finding can be interpreted in terms which emphasize either maturational or learning influences. In either case the suggestion is that trait measurements are stable, but not rigidly so--that over time individuals are being gradually shuffled into different orders indicating their amount of possession of a trait. In behavioral terms this implies that the number of acquisitions of information and problem-solving techniques (as sampled in a Binet test, for example) at one point in development is a rough indication of the number of such possessions at a later point, but that some of these possessions are being lost and/or new ones are being acquired at different rates in different people.

Assuming that the simplex pattern among retest correlations between abilities is largely due to gradually changing patterns of emphases in learning, the high adjacent-year (or adjacent-session) relationships may be interpreted as suggesting that the learning upon which intelligent performances are based proceeds in a context of abilities learned immediately before. Ferguson (1954, 1956) and, more sketchily, Guttman (1955) have put forth theories which suggest that the simplex relationships do not so much reflect temporal proximity (as such) in measurement--and hence similarity in the sense of temporal contiguity--as they do reflect similarity in the broader, learning theory connotation of this term.

Specifically, Ferguson uses a concept of transfer to help explain boththe fact of positive interrelationship among abilities and the fact of their distinctiveness. He notes that learning in a given area tends to result in the development of an ability, such as might be measured with psychological tests. Learning tends to reach a "crude limit", he says, "beyond which no systematic improvement is likely to occur with repetition" (Ferguson, 1964). What is measured as intelligence and as "primary mental abilities (in the sense of factors such as French (1951, 1963) has listed) are, he argues, simply performances at this rather advanced stage in learning. Since learning at any stage tends to be facilitated by similar learning at a prior time and to be inhibited by dissimilar learning which has gone before, that which is learned initially in a given area will tend to encourage further learning in that area until the "crude limit" is reached, or, worded otherwise, the acquisition of one ability will tend to beget the acquisition of another similar ability. The "similarity" of abilities is defined in terms of those conditions which favor positive transfer and discourage negative transfer.[10] Thus Ferguson sees the positive interrelationships among abilities as representing a sort of facilitative network.

In line with this reasoning the simplex pattern in development data could be interpreted as representing, in part, the sociological-pedogogical fact that the child at one age is usually encouraged to learn material that could most readily promote transfer learning at an immediately adjacent age and could less readily promote transfer in learning at a more distant period. Also, of course, this fact itself may represent merely recognition of the psychological fact that the mental-faculty theory does not apply very well in practical education (Stroud, 1940) and that, instead, learning at any age is accomplished primarily only when the material to be learned can be understood in terms of the more or less immediate experiences of the learner. In other words, both the simplex pattern in test-retest ability correlations and the teaching practices of the culture reflect the importance of the principle of transfer in the development of abilities.

To explain the separateness of abilities, Ferguson argues that in the early stages of learning transfer from even rather remotely similar tasks is apt to operate but that as learning continues this becomes less the case and higher proportion of facilitation results from earlier learning on the same task. That is, learning initially involves transfer from rather dissimilar prior learning (the new is likened to the old), and some development which is entirely specific to the given task, but as learning continues, it is this latter which serves primarily to facilitate further learning in a given area. In this way an ability can become more and more specific and yet always be historically related, through transfer, to abilities that were developed earlier.

The general idea here would thus seem to be very close to the common sense notion that prerequisite courses set the conditions for learning in more advanced courses and in this sense the theory has ample support from practical pedagogy. More formally, there is the general support from studies of transfer of training and, rather tangentially, from the work of Anastasi (1936), Greene (1943), Woodrow (1938, 1939) and others showing that with practice in a given area of learning, the factor composition of tests of abilities in that area tends to change the abilities distinct from those measured by such tests tend to emerge. More directly, as Ferguson (1956) notes, the results of Fleishman and Hempel (1954, 1955) show clearly that established ability factors (from the French list) predict primarily only initial performance on motor tasks, not later performance, and that abilities which are more or less unique to the particular learning situation tend to develop at later stages in learning. It's of interest to note that these are the same results which Humphreys cited to illustrate an occurrence of the simplex pattern.

It is thus suggested that the so called "common elements" of which Anderson spoke in developing the overlap concept to help explain the stability of repeat measures of intelligence are elements which promote transfer learning, or in Ferguson's (1954) terms..."transfer components which are common to prior learning and the learning of a new task..." The lack of commonness which Hofstaetter and O'Connor emphasized in their modification of Anderson's model is represented in Ferguson's theory by the idea that with continued learning in a given area, abilities more or less specific to that area will be developed.

The pattern of development of an ability may thus be viewed as in some respects analogous to a genealogical tree. That is, the more advanced stage of ability development is "reproduced," as it were, out of a union of experience and more elementary abilities. Transfer of training is an integral part of this process. In the early stages of ability development, generalization in transfer is broad but not potent; learning is facilitated by previous learning that is even quite remotely similar, but the absolute amount of facilitation is small. This nevertheless provides a functional relationship between abilities. Thus all abilities measured at a given point in development are related, at least distantly, to all others, through common ancestors in the form of abilities that were learned at prior times. This "familial" relationship is manifested in positive manifold among the intercorrelations of measurements of different intellectual abilities taken on a single occasion and among measurements of ostensibly the same ability taken at different stages in development. These two kinds of positive manifold give credence to the assertion that there is one general intelligence, but this represents (according to the position taken here) a fact of moderate (but by no means perfect) correlation in the operation of two broad sets of influence, one set directly affecting the structure and physiology of the organism (i.e., the influences of heredity and physical injury) and another set affecting the structure and physiology only indirectly through the process of learning.

Thus learning tends to beget more learning and to build up a general ability. But as learning continues, facilitation at later stages results primarily from earlier learning in the same area. Facilitation is greatest when something new to be learned is highly similar to something which has already been learned. Elementary abilities thus beget the development of more advanced abilities of the same kind and somewhat distinct abilities come to be manifested at various levels of organization.

4. The Development of Abilities in Childhood

While the Anderson-Ferguson theory provides some useful <u>general</u> concepts for describing intelligence (or any ability) as both a predictor of future learning and as itself a product of learning, it gives little indication of the specific nature of the abilities which are in fact learned and which serve, therefore, to facilitate further learning.

Also, it gives little indication of the global environmental conditions under which this learning takes place. In order to develop a satisfactory rationale for a distinction between Gc and Gf, it is necessary to probe into these matters.

In organizing this discussion it will be convenient to think of the developmental period of childhood as broken into three principal sections. The cut-points defining these periods are largely arbitrary, being drawn primarily for organizational convenience, but it so happens that they correspond in a rough way to the cut-points suggested by Hofstaetter's (1958) factor analysis of the retest correlations for intelligence test scores obtained in the Berkeley Growth study reported by Bayley (1943).

a. The Development of Sensorimotor Alertness

Hofstaetter's first factor was characterized by measurements obtained between the ages of 2 months and approximately 2 years. The tests used in this period were The California First Year Mental Scale and the California Preschool Scale. At this level these scales are generally assumed to be measures of sensorimotor alertness (Bayley, 1943). Hence the period extending from conception to about age two might be characterized as one of sensorimotor development. This period corresponds closely with a sensorimotor period described by Piaget (1936, 1945, 1947) and Hunt (1961).

As Piaget, Hunt and others have described this period, it is one in which primitive instinct-like patterns get tied together in reticular networks and the "playing off" of these "circular reactions," as they have frequently been called (e.g. by Baldwin, 1906; Holt, 1931; Piaget, 1936), comes under the control of external stimulus patterns and/or inner activators. Transfer learning and even trial-and error learning would appear to be unimportant in these early changes. Rather, classical conditioning and frequent repetition would seem to be the principal factors. The stimulation resulting from exercise of one ready-made schemata (sucking reflex) becomes associated, thorough many trials, with stimulation (insertion of a nipple in the mouth) which produces another schemata (swallowing and the stimulation produced by swallowing). In this way, largely in the absence of anything resembling insightful learning or use of conscious long-term memory, the infant builds up increasingly more involved networks of responses and awarenesses: single, simple responses are built into more complex multiple-response patterns and "instantaneous" awarenesses are tied together into multiple-awareness patterns. At some stage it becomes possible to refer to the response patterns as simple skills and to the awareness patterns as simple perceptions. Thus, it can be said that the child gains skill in grasping objects and comes to perceive the "hardnesses", the spatial and temporal "separatenesses", the "movingnesses", the "noisynesses" of the systems of his immediate environment. Such skills and perceptions may be said to indicate sensorimotor alertness.

Lashley (1949) has very clearly argued that although intelligence might be defined as a capacity to profit by experience, it is not man's ability to learn, per se, which is the essential aspect of what is generally meant by intelligence. He points out that: "Learning involves both the ability for form associations and also the ability to solve problems, to discover the significant relations in the situation....under favorable conditions every animal, at least above the level of the worms, can form a simple association... In this sense the capacity to learn was perfected early and has changed little in the course of evaluation." It seems likely that the development of the simple skills and perceptions which are said to constitute sensorimotor alertness depends primarily on the kind of association learning Lashley has reference to in this passage. In this sense the mammals, generally, the birds, perhaps the reptiles and fishes, etc., may be said to gain a sensorimotor alertness which is no whit inferior to that of man.

The normative data gathered in studies like those directed by Bayley (1933, 1949, 1955) and Gessell (1940), as well as that found in the standardizations for various infant tests, indicates that most children reach a rather high level of such alertness by the end of the second year of life. But the evidence from many sources, including that from the studies cited above, indicates that the rate of development of such alertness is, at best, only very lowly related to the development of anything called intelligence at later ages. Indeed, the Berkeley growth data suggested that the sensorimotor alertness measures obtainable in the first five or six months of life actually correlate negatively with the ingelligence test scores obtainable at later ages, although the coefficients Bayley obtained were generally too low to be regarded as noteworthy.

Thus it would appear that the essential characteristic of human intelligence is not very closely related to sensorimotor alertness and may not be measurable in the earliest period of life (the first two years). Although the development of sensorimotor alertness precedes development of the abilities of which intelligence is comprised and this latter development is to a small extent dependent upon the former, the <u>rate</u> of development of sensorimotor alertness is probably not appreciably related to the <u>rate</u> of development of intellectual abilities, and may even be slightly negatively related. Also, the experiential factors which promote or inhibit development of sensorimotor alertness in the early period probably operate largely independently of the experiential factors which promote or inhibit the learning of the abilities of intelligence at later periods.

Somewhat in contrast to this position, Hunt (1961) has argued persuasively that lack of opportunity to exercise elementary sensorimotor schemata in this first period of development may have very crucial and far-reaching effects on all subsequent development of intelligence. Specifically he states that during this period..."The greater the variety of situations to which the child must accommodate his behavioral structures, the more differentiated and mobile they become, the more rapid is his rate of intellectual development, and the greater his range of interests in the novel and the new" (Hunt, 1961). The position taken here does not necessarily contradict this statement. It merely argues from the evidence that the rate of development in this period, as indexed by the tests that are presently used, is largely unrelated to what is called intellectual development in later periods. It must be granted that in certain rather unusual cases, as when children are raised in quite "unnatural" environments--such as (perhaps, though not necessarily) those described by Skeels and Dye (1939), Spitz (1945), Dennis and Najarian (1957) and Dennis (1960)--there may result a sensory deprivation analogous to that described by Cruze (1935) and Reisen (1947, 1948) and that this may have a deleterious effect on later intelligence test performance. But these cases surely cannot be said to be illustrative of commonly found child-rearing practices: such deprivation would be extremely rare. Most children would have ample opportunity for the kind of experiences which Piaget and others have described as necessary for the development of sensorimotor alertness.

Moreover, it does not follow from the data Hunt presents that even supposing severe visual deprivation, for example, the development of intelligence in humans is permanently hampered. Von Senden's cataract patients may have lacked the ability to visually discriminate between a triangle and a square, but it was not reported that they lacked in intelligence. It's interesting to contemplate whether these patients would have turned out to be more intelligent than they appeared to be had they not been blind from birth, but the inability to make discriminations in a sensory modality that has not been available to a person (or other animal, as in Reisen's studies) and a resulting inability to solve problems presented in that modality, is surely not sufficient evidence upon which to base a conclusion that intelligence itself has not fully developed: rather; this kind of situation points up the need for developing intelligence tests based on input through several sensory modalities, a need which Spearman (1927) recognized several years back.

Generally speaking, then, although sensorimotor alertness must be seen to underlie intelligent behavior, the evidence and common sense argue that the development of such alertness varies independently from the development of the kind of intelligence for which the human is noted.

b. The Acquisition of Concepts and Aids

An essential elementary feature of man-like intelligence would appear to be the process of perceiving relations as in the formation of concepts. This feature appears to emerge in the second period defined in Hofstaetter's analysis. This was characterized by measures taken between the ages of two and six, and the tests used in this period are exemplified by the subtests of the Stanford-Binet for these age levels. In very general terms these are measures of the extent to which the child has learned to categorize the common everyday systems[11] of his environment. At a most primitive level such categorizations can be referred to as cue representations; at a somewhat higher level they can be designated symbolic representations or simply symbols; at a later stage of development they can be defined as sign representations or signs. In another context such representations might be referred to as preconcepts, concepts, abstractions and the like. Here, rather arbitrarily, although perhaps somewhat in deference to Piaget, the period from age two until about age six is identified as one characterized by the attainment of concept representations. This corresponds to the first (preconceptual) phase of the second major period in the Piaget-Hunt scheme.

At first, as suggested above, concepts are represented idiosyncratically in terms of what might be called symbols--i.e., experiences which anticipate other experiences. In this context symbols are not the conventional referments for systems of the universe. These latter are what many writers refer to as "signs". It would appear that signs are themselves learned as symbols, somewhat independently of the symbols they later come to symbolize. That is, Brown (1959), Miller (1951) and others who have tried to describe the formation of language behavior, as such, as well as Piaget in his descriptions of the development of intelligence, have contended that the child learns to perceive and produce the sound patterns which are the elements of language just as he learns to perceive and produce representations for other environmental phenomena and these two learnings are at first only rather loosely related. The individual learns to "categorize speech itself", as Brown puts it, "so that he can identify equivalent and distinctive utterances... Finally, he...must form the referent categories (i.e., what are referred to above as symbols for systems). These part processes are not only analytically separable. They are actually separated in much of the child's earliest learning...the basic referent categories are formed with little assistance from language" (Brown, 1959). After having learned some symbols for the systems which are signs in a particular culture, and having also acquired some symbols for other systems of the environment, the child then learns to use the symbols which are signs to represent the idiosyncratic symbols which are his particular representations for the reality he knows.

The process by which this is accomplished is probably not basically different from that by which symbols, as such, are formed--i.e., the distinction between signs and symbols is one of <u>logic</u>, not one of process. The most primitive representation for a system involves a response to and a perception of a stimulus pattern which occurs close in time to that which is symbolized. For example, an automobile might be symbolized by a noise perception closely associated with the full sensation of seeing, hearing, riding in, etc., and auto--i.e., by a sound like that which an auto makes (and, of course, the symbol might also involve perception of a patch of color like that of a particular car). The behavior of children seems sometimes to suggest the metaphor by which they thus represent systems. For example, Piaget describes an instance in which a child opened and closed his mouth in an effort, seemingly, to represent the notion of the opening and closing of a match box; and, of course, in their spontaneous play and in their attempts to communicate children typically produce sounds reminescent of those made by the cars, animals, etc. for which they have representations. Thus, the symbol is often a part of the pattern which it symbolizes. But a sign, too, can often be seen to be a part of the pattern which it signifies; that is, the sounds which are word labels for systems are often almost as invariably associated with these systems as are the stimulus patterns which objectively define them: the sound of the word "car" is almost as invariably associated with an actual car as is the sound of the car's motor when it is running. This is particularly the case when the entire class of objects termed cars is considered; for although the colors and sounds and shapes, etc., of cars vary a great deal, the sound of the word car tends to be relatively invariantly related to all objects of the class.

It seems, then, that there are two principal factors contributing to the child's development of a concept representation like that for the class of objects termed "cars". First, there are some anticipations representing objective properties of cars which are invariably associated with all objects of this class and these constitute a symbol representation for these objects; second, the sound of the word "car" is in a probablistic sense quite uniformly associated with the objective stimulus patterns indicating actual cars, and it's not nearly so uniformly associated with any other stimulus pattern. Hence, it, too, tends to become part of the symbol representation for the class of objects termed cars. But rather unlike other parts of the symbol, the sound for the word car can be produced by the child and when it is so produced the response is rather apt to be rewarded by the behavior of others. Also, as Mowrer (1950) has suggested, the child may, to some extent, reward himself with this kind of response. In any case when the child produces an approximation to the sound of the word "car" which he can recognize as this and which others interpret (perhaps rather charitably at first) as this, then he can be said to use a sign as a symbol and to use this in a way that communicates to others. When he correctly produces this sound to represent several instances of what are generally regarded as cars in his society, then he can be said to have formed the concept of car.

With the advent of use of signs it becomes feasible to assess the individual's awareness of concepts and thus to measure the first glimmerings of his development of human-like intelligence. That is, it is a difficult practical matter to assess the child's concept awareness, and hence his ability to perceive relations, prior to the time that he has gained sign representations for the concepts he knows. It is evident, however, that he is aware of much more than he is able to express, or even understand, in terms of conventional sign systems.

For example, it is possible that a child who could not, or would not, correctly label a key, say, could nevertheless demonstrate his knowledge of a distinction between keys and other small objects, such as nails, hairpins, etc., by making a turning response to illustrate how a key is used to open doors; and it is possible that this response would be more indicative of knowledge about the concept "key" than would the appropriate labeling response of another child. In other words it must be granted that a concept may be known symbolically without its being known in terms of a particular conventional sign. It is necessary, therefore, to speak of symbol representation as being, perhaps, as advanced as sign representation, even though in general the latter would come at a later stage in development.

While perhaps some would take serious issue with the above account of how such learning takes place, few who have looked at the behavior of children would seriously question the assertion that the 2 to 6 year-old period in development is very largely occupied with gaining such abstract representations. It is also evident that this abstracting must depend upon the perception of relations of various kinds. Before the child can be said to have attained symbolic or sign representation for the category "car", he must have learned to discount various ways in which two or more cars can differ and to have become aware of some of the various ways in which they are similar. This means that he must be capable of relating cars in terms of the properties--such as color, noise, shape, hardness, etc.,--by which cars are defined.

Philosophers, for centuries, and psychologists, for as long as they have been around, have attempted to devise systems whereby relations can be exhaustively classified into a few sets that cover all instances of abstracting, but it cannot be said that there is yet any high degree of agreement in such classifications. It seems evident that some of the useful categories are those described under the heading of "essential relations" by Spearman (1927)--viz., the "ideal" relations of evidence, likeness and conjunction and the "real" relations[12] of space, time, identity, attribution, causation, constitution and psychological, but other writers (e.g. Ammett, 1959; Bruner, Goodnow and Austin, 1958; Sigil, 1962) pointedly omit use some of these and include other categories in their discussions of intelligence. Ammett claims that his study shows that children classify objects according to principles which are not recognized in formal logical systems, such as Spearman and Piaget have depended upon, and this may be the implication, too, of some of the work of Bruner and his co-workers. Also, although many writers have organized relations into hierarchical systems in which perception involving those at the top of the hierarchy might be said to be more characteristic of man-like intelligence than perception involving those at the bottom, it cannot yet be claimed that any such hierarchy has been established on the basis of behavioral observations. Spearman, in fact, was led by the data he studied to specifically reject this hypothesis. Bruner, et al, speak of the great difficulty which people of Western Cultures have with disjunctive concepts, but it does not follow from the data they present that disjunctive reasoning is any more, or less, characteristic of high intelligence than, say, conjunctive reasoning. Horn (1962) has shown in one analysis that disjunctive tasks show intermediate loadings on a general factor in a battery of tests carefully selected to yield only one common factor (viz. G). The difficulty of an intellectual problem seems to be compounded by many characteristics other than merely the formal kind of relation it mainly involves. Thus, in general, although the perception of relations must be seen to be an essential aspect of intelligent behavior, present-day <u>classifications</u> of different kinds of relations are, as classifications, of relatively little use in describing the nature of intelligence.

But intelligence must be seen to consist not only of concepts, but also of a number of techniques for inventing or discovering new concepts and for identifying exemplars of concepts already formed. The techniques here referred to would include what are described as <u>operations</u> in some theories (e.g. Piaget, 1936; Hunt, 1962; Guilford, 1959) and what are treated as strategies in other developments (e.g. Bruner, et al, 1958; Sigel, 1962). Here, following Cattell (1963), they will be referred to as "generalized solution instruments" or "aids"--i.e. skills "the acquisition of which becomes a key, opening the way to rapid advance in some general area of cognitive problem solving" (Cattell, 1963).

Like a concept, an aid may be viewed as an abstraction representing the fact of a class of phenomena having something in common. In this sense an aid is a kind of concept. However, whereas the term concept is here used to refer to phenomena of the universe which can be thought of as "things" (i.e. represented by nouns), an aid is thought of as referring to a series of behaviors or thinking operations which might lead to the formation or attainment of a concept. In other words, an aid does not so much represent a class of systems of the universe as it does a class of procedures whereby one comes to perceive the relations which lead to the formation of classifications of systems.

An aid can be thought of as existing at several levels of complexity much as concept representations can be thought of as existing at several levels of abstraction (viz., those extending from the simple cue to the complex sign). The so-called "learning sets" which Harlow (1949) described might be analogous in this sense to a simple cue. In the learning set the animal (at least one at, or above, the phylogenetic level of a monkey) seemingly discovers some way of forming hypotheses (representing anticipations for an entire class of possible outcomes), a way of evaluating a test of these and thus a way of eliminating whole blocks of trials-and-errors which he would otherwise take in solving a particular kind of problem. Once the "set" is acquired the animal makes more efficient use of its learning trials and thereby cuts the number of trials to a criterion of learning by a noteworthy amount. In human behavior the similar phenomena is described as "becoming aware of principles", "learning the tricks of learning", "learning for transfer", etc. The transfer learning of which Ferguson spoke in his account of the acquisition of intelligence must be based to a very great extent on acquisition of aids.

Many observers have remarked on the fact that the young child's problem-solving behavior indicates a concrete, rigid, centered, stimulus-bound, irreversible conception of the problem-situation. The child seems to perceive relations but not to internalize the procedures whereby he thus perceives. He seems to focus on observed events to the exclusion of any consideration of what might have gone before or might come after. For example, Piaget, in describing the way children come to understand the notion of conservation of quantity, notes that if--right before the child's eyes--a quantity of liquid is poured from one large glass into several smaller ones, the young child is apt to report that the amount of liquid has been increased! It is as if the child cannot realize that the pouring operation might be reversed, that the liquid in the small glasses might be poured back into the large one, and that if this were done the liquid would look much the same as it did before the pouring started. His perception is said to be "centered", as Piaget terms it, on the existing several quantities in the smaller glasses, and in this centering he fails to take cognizance of the operations which led to this event or which might revert the situation to what it was before. The phenomenologically "honest" impression is that there is more liquid in the several glasses than in the one and the young child reports this "honest" impression.

It seems, however, that as the child goes through several trials of seeing quantities of substances moved from one container to another, he internalizes sequences for these kinds of changes: in consequence his span of awareness seems to be enlarged, so that the stimulus pattern may be said to include many elements of past stimulation and to provoke anticipations of future stimulation. The child's behavior indicates that he shifts from preoccupation with the focal stimulus before him at a given moment to a consideration of the events which preceeded this stimulus and which might, as anticipated on the basis of previous occasions, follow it. At first this internalization of sequences is only partial and the child is not able to verbalize the notion; he then fluctuates between accepting the evidence of his senses, as it were--whence he gives his phenomenologically "honest" impression--and accepting the evidence suggested by consideration of a reversal, say, of the sequence leading to a given stimulus pattern. He may report that a quantity of liquid remains unchanged if it is poured from one large glass into just two smaller glasses, but that it is increased if the amounts in each of the smaller glasses are then poured into two further glasses. As he gains increasing experience with the procedures whereby quantities of various substances are moved from container to container, he learns to "prove" to himself that the quantities remain largely invariant with such change. At first he actually reverses the pouring operations. Later it is not necessary for him to carry out a reversing experiment as long as he can "see" that the sequence might be reversed. Once the notion of reversing a sequence is grasped, the child may thereafter apply it to make predictions in a wide range of situations, in many of which it will be found to work, in a few of which it may not (as in the event that a chemical reaction occurs in one container). The notion that a sequence of events can often be reversed in some sense becomes, in fact, a generalized solution instrument that is applied to solve a wide range of problems which people may encounter.

Besides reversibility, Piaget lists "transitivity", "associativity", and "nullifiability" as kinds of general operations which become internalized as a function of the child's experimentation with its environment. The principle of transitivity, for example, is viewed as an internalization of experiments in which the child finds that if A is perceived as larger than B and B is perceived as larger than C, then A is (usually) perceived as larger than C. Once this set of operations is internalized, it becomes an aid (and in some cases a hinderance) which can be applied to the solution of many problems.

c. Developmental Distinction Between Fluid and Crystallized Intelligence.

The third factor in Hofstaetter's solution overlapped rather a great deal with the second factor in the age range from four to six, and thus involved variance provided by some of the Stanford-Binet subtests used in this age range, but it was characterized chiefly by the Stanford-Binet and Terman-McNemar Group Test measures obtained at ages 9, 12, and 15. As is well known, the Stanford-Binet includes progressively more school-oriented verbal items at the age-level of its subtests increases. In the four-to-eight age range, for example, the tests requiring recall and verbal explanation--as in Comprehension, Verbal Analogies, Verbal Similarities and Differences, and the like--are allowed increasingly greater weight in determination of the IQ score as age-level increases, whereas the tasks requiring the immediate perception of spatial analogies, similarities and differences progressively contribute less variance to total scores. Likewise the Terman-McNemar subtests are greatly involved with school-type information and with relations that are specifically taught in this setting. Hence the third developmental period suggested by Hofstaetter's analysis might be characterized as one in which progressively more pressure is put on the child to express his abilities in terms of the kinds of performances that are encouraged in the school environment. In at least a rough way this kind of encouragement reflects the hierarchy of values of the society and, more generally, of the culture possessed by the society. The period extending from about six into adulthood may thus be characterized as one in which, principally, the resources of intelligence become more or less "harnessed", as it were, by the culture, for use in maintaining the culture and expanding it in accordance with its existing structure. Hence this is a period of intensive acculturation.

Now it is contended here that although the development from age six onward is, generally speaking, a period of intensive acculturation for all people, it is more so for some than for others; it is this fact which allows for a gradual dividing of intelligence into two intelligences, a fluid and a crystallized.

Culture is frequently defined in such a way that it includes((at least theoretically) just about everything men have ever invented, made, discovered or thought about. Typical of such a definition is one given by Kluckhohn and Kelly (1945). They refer to it (culture) as "...all those historically created designs for living, explicit and implicit, rational, irrational and nonrational, which exist at any time as potential guides for the behavior of man." Acculturation, then, is the processes whereby all of these things are imparted to the young of a particular social group said to possess a given culture.

These definitions cover too much territory for present purposes. Here the concern is with a subset of the elements of culture, viz., a set which might be said to be the <u>collective intelligence</u> of the culture. This is a mass of ideas, generalizations, rules, techniques and the like which men have developed to help rationalize and cope with the complexities presented by their environments. It is implied that different groups of people (perhaps, though not necessarily, living at different times) have different collective intelligences. Also, it is implied that a collective intelligence is expressed through the behaviors of particular individuals. It is, in fact a collection of the separate intelligences of individuals, insofar as these are communicated to other individuals. Thus, it is implied that within any society which may be said to possess a culture, there will be some who express more of the collective intelligence of that culture than do others. In particular, the mature individuals of any society will generally possess more of this than will the young. Indeed, a major function of many of the institutions of a society is to facilitate transmission of that society's collective intelligence from older to younger individuals.

In the last section a concept was described as a class of systems ("objects") having a noteworthy property (or noteworthy properties) in common. It was suggested that the objective fact of a concept is represented within individuals either in terms of conventional signs, systems of which are termed languages and which allow for communication of the concept from one person to another, or in terms of symbols, which either are not communicated at all or are communicated by means other than use of conventional languages. As soon as a concept is communicated, by whatever means, it becomes a part (at least temporarily) of a culture. According to this view, then, not all concepts need to be a part of any culture. In fact, logically they must always be the exclusive property of a particular individual before they get into a culture. They "get in" only when they become communicable. Only when an individual not only forms a concept, but also conceives of a way of expressing this idea to others--and does in fact express it and it is in fact understood by others--can a concept become a part of culture. Theoretically, the notion of a class of objects which might be tagged by the sign "tree", for example, might have occurred to many men--perhaps to many apes, some monkeys, a few dogs, etc.--without its ever being expressed by them in a form which could be understood by others. Before it was thus expressed, the concept was not a part of a culture.

Most of the concepts of a collective intelligence are imbedded in the spoken and written language of a given people. It is possible that a concept like a tree was not at first communicated by means of this kind of language: perhaps some pantomine demonstration was set up to illustrate the idea. But many concepts of a culture come to be "tagged" with some utterance or figure which can function as a conventional sign. As Zipf (1935) has demonstrated, the frequently used concepts often come to be tagged by the comparatively short utterances and small figures which are termed words (viz., nouns). To a considerable extent, then, the collective intelligence of a people is represented in their lexicon or some equivalent of this; and to a considerable extent, too, an individual's possession of the collective intelligence of his culture is represented by the number of words he can use correctly. A substantial portion of the variance of Binet type intelligence tests can, for example, be said to result from measurement of this component of intelligence.

To some extent the rate of development of awareness of concepts is independent of the rate of development of the use of signs; this would seem to be particularly the case when the child's models for the use of signs must be found almost exclusively in the home, rather than in the society at large. Hence, particularly before the leveling influence of mass education is felt, measures of intelligence may fail to validly assess concept awareness. The extent of this failure decreases as a function of the extent to which all persons are given opportunities and encouragements to develop use of the conventional sign systems. Mass formal education and, in societies like that of the U.S.A., the informal education which is provided to most people through the mass media of communication, tend to equalize opportunities and encouragements of this kind. Thus, as these influences are felt and the effects of individual differences in home models are partially cancelled out, the correlations between ability measurements taken in the pre-school period and those taken at progressively later developmental stages get smaller.

Many of what were described as aids in the last section are likewise parts of the collective intelligence of a culture. Knowledge of the structure of language (as opposed to awareness of "tags" for concepts) would be such an element, for example. As Whorf (1956), among others, has emphasized this in an extremely powerful aid, although, like most aids, one which is sometimes a hindrance, as when it suggests, for example, that a nonsensical concept (e.g. invisible green spiders) must be reliably related to phenomena because the language in which it is expressed "makes sense". Perhaps a better example here would be the calculus provided by Newton and Leibnitz. Once learned, this enables a person to solve many problems he might otherwise not be able to solve or be able to solve only by expending a great deal more time and effort than would be the case if the calculus were used. This example illustrates, also, that an individual might be able to acquire and use a cultural aid even though, for lack of ability or opportunity, he might not be able to invent it himself. As Hayes (1962) nicely puts it, culture may relieve the individual of much of the burden of creativity by "giving him access to the products of creative acts scattered thinly through the history of the species."[13] By virtue of his possession of aids which other people created, a person living in an advanced culture can, as Newton himself observed, "stand on the shoulders of intellectual giants" in his efforts to deal with the various problems he might encounter.

It is probable that in their "natural" environment the monkeys used in Harlow's (1948) study would never have acquired the particular "learning sets" he taught them. These monkeys were given an exceptional educational opportunity. In terms of Ferguson's transfer theory, the effects of this opportunity might have spread to the learning of concepts and other aids which otherwise would not have been acquired. As compared with monkeys who were not given this educational opportunity, Harlow's monkeys would have acquired a new--one might say a "cultural"--component of intelligence. If a number of monkey intelligence tests were given to a sample which included both Harlow's laboratory-educated monkeys and monkeys who had not had the "learning set" training, the intercorrelations and factors among the tests could reflect this sampling fact and the extent to which the tests measured abilities resulting from a "laboratory education." Tests which contained a high proportion of problems which could be solved readily by application of skills acquired as a result of this education would tend to form a factor on their own and be distinguished from tests which measured abilities that could be learned from the more usual environmental contacts which monkeys have. In simplified form this indicates the way in which crystallized abilities can come to be distinguished from measures of fluid abilities.

During the period from about age six onward the influences of acculturation accumulate by transfer and gradually draw individuals apart in their manifestations of intelligence: some persons are drawn more and more into the swirling eddies of the culture of a given society, while others drift into quieter waters along the edges of the dominant currents of this culture. To some extent the different courses which individuals follow are determined by factors which are initially quite independent of the person's characteristics, intellectual or otherwise; for example, except in a few cases where adoptive parents are chosen to have traits that are concordant in some sense with the characteristics of a child, a person's characteristics in no way determine the parents (or other) which he gets to raise and educate him. Likewise, many of the treatments to which he is exposed in school and in the community, broadly, are haphazard as concerns his traits, or are determined by factors which are no more characteristic of his personality than is his age. To some extent the different acculturation courses which people take are determined by their non-intellectual traits at particular stages in development. Possibly some potentially great scientists are "lost", so to speak, in kindergarden because they are too obstreperous to "fit in", come to grief with their teachers and peers and never go on to develop their intelligence along lines that are required of scientists. It is in this sense, too, that what Hayes (1962) has called "experience producing drives" may be quite important determinants of intelligence: in some cases curiosity might tend to draw one into the educational institutions of a society, while in other cases it might lure a person away from these. To a considerable extent, however, the degree of acculturation influence which comes to be imposed on an individual at any given time is a function of his intellectual development up to that time. As was emphasized in previous sections, what can be learned at one stage is in some measure a function of what has already been learned. The child who has been much exposed to, and has profited from, acculturation influences in early stages of development tends to be "ready" for further acculturation, whereas a child of perhaps equal potential who has not been thus exposed, or has not profited, is not "ready". According to the transfer theory, acculturation will tend to beget more acculturation.

Assuming, then, that the acquisition of the collective intelligence of a culture tends to come about in a more or less unitary manner, a gulf can gradually widen, in the period from age six onward, between individuals whose abilities come to be expressed in increasingly more abstruse concepts and aids of a culture--and in the idiosyncratic intellectualizations which can follow from possession of these--and individuals whose abilities come to be expressed primarily in the prosaic concepts and aids of the every-day culture--and in the idiosyncratic developments which can follow from possession of these.

d. Some Measurement Implications of the Foregoing.

Thus intelligence comes to be manifested in the attainment of concepts, indicating the relations one has been able to perceive among the elements of his environment, and in the aids used to educe new concepts. Tests may thus measure intelligence if they require the subject to demonstrate his awareness of concepts that would have been previously (e.e., before testing) attained or if they require him to use aids to find, probably for the first time in his life, the significant relations existing among the test stimuli. Actually, of course, most intelligence tests involve both requirements, but they differ in the emphasis that is placed on one of the other.

The environmental conditions which are needed to enable persons to acquire some kinds of concepts and aids exist quite generally--i.e., for most people. The physical environment is in some respects similar for virtually all people living anywhere at any time and this therefore provides some common conditions for development of concepts and aids. Likewise, although perhaps in lesser degree, the social environment is in some respects similar for virtually all people. When a study concerns only people of a given society, this is even more clearly the case. On the other hand, it is evident that opportunities to acquire some kinds of concepts and aids are offered to some and not to others in a given society. To some extent the offering of these opportunities is based upon consideration of the individual's ability, but to a considerable extent, too, it can be based on factors which are quite unrelated to the person's attributes--factors such as area of residency, interests of parents, economic status of parents, etc. In a sense, too, at least some of these opportunities come merely as a function of one's continuing to live in a given society, for they are provided in a number of ways, through a number of social institutions, etc., so that if a person misses out, so to speak, at one time, he may get another chance at a later time in life. Thus, although no perfectly clear line can be drawn between the two, one can identify relatively abstruse concepts, aids and signs in distinction from those which may be obtained from experiences that are available more generally and one can note that, in general, opportunity to acquire the more nearly abstruse cultural elements is in part a function of age.

Most of the problems posed in putative measures of some aspect or another of intelligence can be solved in two or more ways--that is, use of alternative mechanisms underlies the observed variance on most ability tests. This is merely another way of stating the fact, derived from factor analyses of ability tests, that few tests have been found to involve only one non-error factor. Here, more specifically, however, the position is that the alternative mechanisms used in some tests may be a reflection of a differential influence of acculturation. In some cases the aids and concepts that are used to reach solution to a problem may have been obtained from the human equivalent of the "laboratory education" Harlow's monkeys had (call it intensive acculturation or specialist training) whereas when this is lacking the problem must be solved, if solved at all, by means of abilities that are acquired without benefit of this education. Some problems simply cannot be solved, however, if certain concepts and aids have not been derived from specialist training. The variance of tests which contain a high percentage of problems of this sort will thus largely reflect differences in the amount of this training. On the other hand, such aids and concepts may be of little use in obtaining solutions to a high proportion of the problems of other tests, in which cases the variances of the tests will largely reflect differences in abilities that are taught and learned more universally.

Table 1 has been prepared to help illustrate the ways in which these assumptions are interpreted in the present study. The table shows the first (unrotated) factor loadings obtained for a select group of tests in several well known studies. This factor would generally be interpreted as highly representative of whatever it is we mean by general intelligence. By this interpretation all of the tests could be said to measure intelligence. But according to the theory outlined here, the relative sizes of the

TABLE 1

First Factor Loadings Obtained in Several Studies

	Botzum (1951)	Carter (1952)	Rimoldi (1951)	Thurstone (1938)	Thurstone & Thurstone (1941)
Vocabulary (multiple-choice)	46	64		77	68
Vocabulary (reproductive)	49	76	44		
Sentence Completion	65			71	
Verbal Opposites (reproductive)			50	69	59
Verbal Classification				79	
Verbal Analogies	66		62	77	
Arithmetic Reasoning	71		64	70	
Number Series	68		55		
Letter Series	71	63	62		60
Letter Grouping	70		52		55
Figure Classification	66	40	45		
Gottschaldt Figures	67	46			

loadings for a given test in the various analyses reflect the density of sampling of variables whose variances are due either to specialist training or to abilities which can develop independently of this. Since the tests are listed roughly in order of the assumed extent to which their variances would reflect intensive acculturation influences, the suggestion is that in Botzum's (1951) study a high proportion of the problems in the entire battery could be solved by use of aids and concepts which do <u>not</u> derive from such acculturation whereas in the Corter (1952) study a high proportion of the tests of the battery show variance which could largely reflect this influence. More particularly, however, as concerns the individual tests in question, there are two important things to note about the ways in which one could obtain a correct solution to the different kinds of test problems.

First, solutions to the problems of some of the tests must depend primarily on the <u>recall</u> of relations which almost certainly would have had to be perceived or educed prior to the testing: if they were not, the subject could not demonstrate his ability to comprehend the relations in question. Thus, in vocabulary, for example, one would either have learned that there is a relation between what is tagged as "turgid", say, and what is tagged as "bloated", or else he would not, and if he had not, there would be no way in the vocabulary test for him to demonstrate that he could learn this relation, perhaps quite easily. Other of the tests, however, require ability to find and use relations which can be discovered in the immediate stimulus pattern--relations which, even if they had been presented at previous times, would probably not have been learned as such. In the following Figure Classifications problem, for example, the subject is required to put together two "things" which are alike and different from three other things:

If it can be granted that the subject understands the language in which this task is presented and thus knows what he is supposed to do, it seems unlikely that the particular relation which is called for here would have been retained from a previous learning experience. In other words, what is measured is the person's ability to form a classification, not his exposure to any particular educational program. Some persons who have never heard the words "turgid" and "bloated", can solve quite complex classification problems of this sort, whereas some persons who know the words in question cannot solve the more complex of such classification problems.

Second, performance in some of the tasks depends upon knowledge which is very definitely conveyed through educational institutions which are more open to some than to others in our society, whereas the variance in other tasks is due much less to differences in this kind of knowledge. As an illustration of this, consider two tasks which could appear in a single verbal analogies test:

1. An abstruse-word analogy:

   Hippocrates-Galen: Aeschylus--Greece Euripides Pericles

2. A common-word analogy

   Here--there:: Now--Nowhere When Then Sometime

Which, really, is the more difficult problem? The first item would not only be difficult, it would be impossible for a person who had not gone to a school, lived in a home, etc., where he would have been forced--or allowed the opportunity--to read and hear about early history, Greek playwrites and the like. For one who had been exposed to these educational influences, the problem would probably be easy. The second item, on the other hand, could be about equally difficult for adults raised in the U.S.A., regardless of whether they ever heard of the early Greeks or not. The difficulty of the first item results primarily, <u>not</u> from the complexity of the relations involved, but rather from the abstruseness of the concepts dealt with, whereas the difficulty of the second item depends very little on this latter factor and almost exclusively on the former. By the assumption of this study, then, both items are said to measure intelligence in some degree, but the first item is said to be relatively loaded with intensive acculturation influences, whereas the second item, when given to an adult sample is assumed to be, not free of cultural influences--for the problem surely depends a great deal upon learning a given culture--but culture-fair in the sense that practically no adult can honestly claim that he has not been given the educational opportunity to learn the concepts and relations that are called for.

The variables near the middle of the list in Table 1 are intended to be particularly illustrative of tasks in which variance would be about equally due to each of the two major alternative mechanisms outlined above. In an analogies test comprised of some of both kinds of items listed above, one person getting a moderately high score, K, might do so because he has good ability to reason although a very poor education, whereas another person getting the same score might do so because he has had a very good (classic) education although he does not reason very clearly. In a test like arithmetic reasoning solutions to some problems can be rather easily obtained by mechanically coding the problem elements in standard algebraic form and using the formal relations of algebra to solve for X. Here a cultural aid is used--an aid which is taught in high school but which is largely denied to persons who do not attend high school or who, if they do, do not take the so-called college preparatory courses. But it is a fact that children and adults who have never heard of algebra, and do not have the foggiest idea about how to use the formal rules of algebra, do nevertheless solve such problems, apparently by diligent use of idiosyncratic aids or cultural aids which can be derived from learning opportunities that are widely disseminated.

The implication of the order of listing in Table 1 is that a test like Letter Series measures abilities that are developed largely independently of the human equivalent of a "laboratory education." This implication needs to be qualified, however. The Letter Series task will be primarily involved with measure of fluid abilities only when used with older children and adults, for in order for a high proportion of the variance of this test to be involved with these abilities, it is necessary that the people taking the test be familiar with the conventional way of listing the 26 letters of our alphabet. Given this, then, although some variance could be due to previous experience in taking such tasks and to specialized training in math courses in which are taught more or less specific aids for dealing with series problems, a major portion of the variance of the test could be said to be due to ability to use seriation aids which can be acquired from experiences that are available to almost all people. But by age six, say, many children would not have had opportunity to learn the conventional way of listing the letters of the alphabet. At that age, then, the Letter Series task would largely measure degree of acculturation, per se. It seems that by age twelve, however, almost all children in this country would have learned the conventional alphabet order; in this learning most adults would have long since reached what Ferguson has described as a "crude limit", and such limits would probably not vary much between upper-class college professors, and lower class unemployed ditch diggers.[14] It is more difficult to argue that the aids needed to solve Letter Series problems are not learned almost exclusively in educational settings that are more open to some than to others. However, it would seem that, aside from the exceptions noted above, the aids involved here would not derive so much from formal education as from experiences with problems that would be encountered quite generally by adulthood. However, as noted earlier, this must be an assumption in this study, although an assumption the plausability of which can be examined in the light of evidence.

In sum then, a principal hypothesis of this study is that some tests can be identified more or less accurately by inspection as largely involving a requirement that the subject demonstrate familiarity with relatively abstruse concepts and aids, whereas other tests can be identified as depending very little on the special training which leads to such familiarity. A substantial proportion of the variance of the first kind of test will thus reflect individual differences in the intenseness of acculturation. This variance will go to define crystallized intelligence, whereas that on tests which depend little on culture familiarity will, if they involve the education of relations and correlates in the attainment of concepts, help to define fluid intelligence.

5. The Development of Abilities in Adulthood

a. Introduction

Learning continues throughout an individual's lifetime. Thus insofar as intelligence is a product of learning alone, it is expected that it will increase over the entire span of life, from infancy to old age. Yet the viewpoint that it does not is commonly met. The suggestion ofteh made is that individuals reach a peak in intellectual development sometime during the teens or early twenties and that decline sets in sometime during the twenties or early thirties. However, some psychologists (e.g. Anastasi, 1958), have argued that any apparent decline of intelligence in adulthood may not be that at all, but instead the observed results may represent artifacts resulting from inappropriate samplings of tests and/or subjects, inappropriate control of extraneous variables, and the like. To what extent do these viewpoints correspond with the facts obtained from systematic study of the test performances of adults at various age levels?

Many studies attempting to answer questions like this have been based upon what can be called omnibus tests of intelligence--i.e., tests in which a single score is obtained by adding together subscores on several rather diverse kinds of subtests. The Stanford-Binet, Army Alpha, Otis and Wechsler tests are typical of such measures of intelligence. The answers which studies using these measures have provided concerning the development of intelligence in adulthood have often been contradictory. Some studies have found that intelligence increases (on the average) over a wide age range in adulthood; others have found that it decreases. Perhaps the most noteworthy observation on these results is their lack of agreement, for the contradictions point to the need for an organization scheme, such as is at least roughly outlined by Cattell's fluid-crystallized model, which allows for sensible and systematic interpretations of the findings. But to substantiate this position it is necessary to review, in a very general way, the results which have been brought forth to support various hypotheses about age changes in intelligence.

Before launching into this review it is perhaps wise to pause here at the outset and remind ourselves that data gathered on age changes in abilities are never fully adequate to allow unambigous answers to the questions asked. It is always possible, even when a large number of studies contribute similar results to suggest a particular kind of interpretation, that interpretations of observed age differences in performance may be grossly incorrect. Sampling in both cross-sectional and longitudinal studies can never be highly adequate in a strict experimental sense. As a simple matter, death rate may be relevant and yet it cannot be fully controlled. It is, of course, simply impossible to assign subjects at random to aging conditions, as is required in a fully adequate experimental design, and post hoc matching can never fully compensate for lack in this kind of control. In fact many studies presuming to show deficit in mental capacity with age have used institutionalized elderly persons in comparison with noninstitutional younger persons or in comparison with younger persons who have been institutionalized for quite different reasons than the older persons were institutionalized. And this is merely an exaggeration of the kind of lack of sampling control which enters into all studies of aging. Also, it is always possible that observed differences in ability performances really reflect differences on non-intellectual factors. It is often pointed out that motivating attitudes toward testing situations may vary between older and younger persons and that these could result in performance differences. Kuhlen (1945, 1958) argues that it is necessary to control for the anxiety level of subjects in studies of aging: he points out that people of any age tend to perform poorly under states of very high or very low anxiety and he suggests that older persons more frequently find a testing situation anxiety-provoking. Yet very few investigators studying age differences in abilities have heeded Kuhlen's advice. There is also the very difficult problem of separating possible peripheral from possible central effects.

In general, then, the results here reviewed and the interpretations offered for these results must be seen to contain some, and perhaps much, error. However to not review the results and not interpret them would be completely in error, for some knowledge can be gleaned from the available data.

b. Findings With Omnibus Tests

Most of the cross-sectional studies using well-known tests like the Stanford-Binet, Army Alpha, Wechsler, Otis and similar omnibus measures, have shown that older adults obtain lower total scores (on the average) than do younger adults. Typical of such findings are those reported in early investigations by Beeson (1920), using the Stanford-Binet, Yerkes (1921), Willoughby (1927) and Jones and Conrad (1933), using the Army Alpha, and Miles (1934) and Miles & Miles (1933) using the Otis. More recently the standardizations of the Wechsler tests, both in this country (Wechsler, 1944; 1955; 1958), and in Germany (Riegel, 1958) and Italy (Maleci and Montanari, 1953; Maleci and Pessina, 1954), have shown a peak in overall performance occuring somewhere between the late teens and 30 years of age, and a general drop in average scores beginning in the late twenties or in the thirties.

Corsini and Fassett (1953) have convincingly argued that the Wechsler standardization samples are not representative of adults at the various age levels. They put forth the notion that a more representative sample could be drawn from the inmate populations of prisons. Accordingly, using the people committed to San Quentin prison, they obtained Wechsler-Bellevue scores on 100 cases in each 5 year age group from 15 to 60. Contrary to what they had predicted (viz., that intelligence does not decline from early to late maturity) their results indicated a drop in average overall score for each five year age group from 30 onwards.

Similar results have been reported for studies using other kinds of omnibus tests. Thus, for example, Osborne and Saunders (1955) found that Graduate Record Examination total scores were generally lower for each successive age group from the mid-twenties onward.

But, in at least one cross-sectional study using a well known omnibus test, results contrary to the above were reported: Wagner (1960) found that the average WAIS IQ for older (average age 50.4) business executives was slightly higher than that for younger (average age 31.2) executives. One suspects, however, that economic facts of life would tend to select executives on the basis of the attribute (intelligence) here in question, and that such facts would have worked more frequently and perhaps more rigorously to select the sample of older executives.

Lorge (1936) has argued that apparent decreases in intelligence with age may not be decreases in the attribute, per se, but rather may represent a change in preferred rate of working on tasks, generally, and on intellectual tasks in particular. If tests were not speeded, the argument continues, the apparent decline would disappear. In his own study Lorge matched subjects according to their performance on the CAVD, a power test, and then looked at their performances on the Army Alpha and Thorndike tests, both of which are speeded. As predicted, he found that older adults whose CAVD scores were equal to those for younger adults had lower scores on both the Army Alpha and Thorndike tests. Such results could represent differential regression resulting from drawing extreme CAVD cases from the population of older individuals. In support of Lorge's position, however, Ghiselli (1957) reported findings which are not subject to this criticism, although the test Ghiselli used is not well known. He put together Vocabulary (similarities and opposites), Number Series, Analogies and Proverbs items in a device which he titled the Analysis of Relationships Test. When he allowed some 1423 subjects to work as long as they needed to complete all the problems in this test, he found no consistent trend--either upward or downward--in average scores for age groups extending from 20 to 65 years. But Doppelt and Wallace (1955) got different results using a better-known test. They found that allowing unlimited time on the WAIS did not appreciably alter the picture painted by other cross-sectional studies using the Wechsler tests; older adults still averaged lower in overall scores than did younger adults.

Results obtained in several longitudinal studies have often been interpreted (cf. Anastasi, 1958; Tyler, 1950) as contradicting the results from cross-sectional studies. They do tend to suggest that older adults perform better on omnibus tests than do younger adults. Owens (1953), analysing the scores obtained on the Army Alpha in 1950 by 127 Iowa State alumni who had taken the same test as freshmen at Iowa State in 1919, found an average gain in total scores amounting to .55 of a standard deviation (as determined on the younger sample). Jones (1958), using the Terman Group Test, found that his sample of 83 persons averaged higher scores when tested at age 33 than when tested at age 17. Bradway and Thompson (1962) gave the Stanford-Binet to 111 individuals once at an average age of 13.6 and again some 16 years later at an average age of 29.5 and found that the observed rise in mean IQ from 112.3 to 123.6 was significant. In the Bayley and Oden (1955) study using the Concept Mastery test with the Stanford "Gifted" sample, both men and women improved significantly over a 12 year period extending from a time when they were in their twenties or early thirties to a time when they were in their late thirties or forties.

There are several possible explanations for these various findings. Depending upon which is selected or emphasized, one can retain either the hypothesis that intelligence declines, the hypothesis that it improves or the hypothesis that it does not change in adulthood. For example, Anastasi (1958), who apparently favors one of the last two hypotheses, argues, in effect, that observed differences in mean values for groups of younger and older individuals mainly reflect educational differences. The number of years of education obtained by successive generations in this century has generally gone up steadily in the last 50 years, so that in most cross-sectional studies the older individuals would have had less formal education than younger persons. The cross-sectional differences favoring the younger individuals reflect this fact. In the longitudinal studies, on the other hand, since the individuals would have had more formal education when they were tested at older ages than when tested at younger ages, the differences tending to favor the older subjects could again reflect these educational differences.

But in contrast to this kind of argument, it can be maintained that the more numerous cross-sectional studies really give the more accurate picture, that decline is in evidence, but that this is hidden in the longitudinal studies by the fact that the initial measures were generally taken before subjects had reached full maturity and later measures were taken before an appreciable decline would be expected to have set in. Several cross-sectional studies have agreed in showing that total scores on omnibus tests of intelligence rise until the early 20's (Bayley, 1955; 1957; Freeman and Fory, 1937; Thorndike, 1926; 1948; Barnes, 1943; Hunter, 1942; Linesay, 1939; Shuey, 1948;) and most cross-sectional studies have suggested that decline is not large until the late 30's or 40's. In the longitudinal investigations cited above (except that by Bayley and Oden) the initial measurements were taken before the peak performance in the early 20's would have been reached. Hence the decline from this peak could not be recorded. Also, in all but the Bayley and Oden and Owens studies the final measures were taken in the 30's before much decline would have been expected.

c. General Information, Vocabulary, Judgment and Experiential Evaluation Factors

Now, in fact, each of the above arguments would seem to have some merit and yet neither is fully adequate by itself. It seems instead that the abilities measured in omnibus tests both decline and improve (and remain much the same) with age and that whether or not average total scores on a particular omnibus test go up or down with age depends upon the factor composition of the test. This point can perhaps be made by considering the results obtained with the Concept Mastery test in the Bayley and Oden study mentioned above.

Strictly speaking, the Concept Mastery test is not an omnibus measure of intelligence. Rather, it is an analogies reasoning test. It is probably highly saturated with V. Moreover, most of the items of the test are examples of what were called (in the last section) "abstruse analogies"--i.e., the items are difficult in large part because they involve concepts and/or concept labels (signs) which are rather unusual elements of the culture: a person can fail such an item not because he is incapable of perceiving or educing the relations in question, but because he is unfamiliar with the terms between which the relations exist. Thus, for example, one may easily fail the item: parquetry--wood::cloisonne--? because he does not know what the first and/or third words stand for, not because he cannot educe the relation given that he knows these meanings. Moreover, it is apparent that knowing the meanings of these words is not so much a matter of intelligence, in the sense of being able to attain the concepts in question, as it is a matter of intelligence in the sense of having acquired the kind of education which makes one familiar with the broad segment of the collective intelligence of a culture which includes the elements in question. The results from the Bayley and Oden study thus suggest that adults who are already rather well-informed about their culture tend to increase their knowledge throughout the age range from about 25 to 40 years.

This poses the question: "Do people in general--i.e., people who are not labeled "gifted" as well as those who are--tend throughout adulthood to increase their knowledge about the more or less abstruse elements of their culture?" On this question the evidence seems to answer with a "yes"!

There are no less than 20 studies, cross-sectional as well as longitudinal, showing that for subtests like Vocabulary, General Information, Similarities, Judgment (as found in the popular omnibus tests mentioned above), the average scores for older adults are either no lower, or else are higher, than the average scores for younger adults. Of the studies mentioned above, for example, those by Jones and Conrad (1933), Corsini and Fossett (1953), Owens (1953), Riegel (1958), Foster and Taylor (1920), Doppelt and Wallace (1955) and Beeson (1920) demonstrated just such a pattern when the Vocabulary, Comprehension, Judgment, etc., subtests of the various scales are analysed separately. Similar results have been reported by Birren (1955); Foulds (1949), Foulds and Raven (1948), Shakow and Goldman (1938), Thorndike and Gallup (1944) and others. For example, Sword (1945) compared 45 university professors aged 60-80 with 45 academic men aged 25-35 and found the former to be superior in vocabu- and general information. Whiteman and Jastak (1951) found that WAIS comprehension improves with age. Scores on the Practical Judgment subtest of the Army Alpha have been found to improve with age (Owens, 1953; Jones, 1959). Wellford (1958) found that older persons often do better than younger persons on tests requiring considerable pre-planning and decisions concerning what is not worth doing. Several studies have involved matching groups of younger and older individuals on total omnibus IQ score and comparing performances on various subtests; the general finding has been that older subjects score higher on tests like Vocabulary, Information, Similarities, etc. (cf. Norman and Daley, 1959; Miner, 1956; Fox and Birren, 1950; Kamin, 1957). Christian and Paterson (1936) found that although younger adults attempted significantly more vocabulary items than did older adults, the average number correct did not differ significantly and that, moreover, when only the number correct among the first 60 items was counted, the older subjects had the higher scores on the average. Jones (1959) similarly found that when the ratio of the number correct to the number attempted was taken on vocabulary and information subtests, the ratios were generally higher for older subjects.

Several writers--but particularly Sorenson (1933; 1938) --have pointed out that people in certain occupations and with certain kinds of living styles, so to speak, do much more to acquire and maintain knowledge than do people in other occupations and/or with other kinds of living styles. That is, people who get into what might be loosely referred to as "intellectual" occupations and/or who acquire what might be called "intellectual" tastes and interests would be expected to maintain and increase their awareness of the collective intelligence of the culture, while people who are in other kinds of occupations and who have other interests perhaps would not. Sorenson's own studies, that by Gilbert (1941) and the above-mentioned study by Bayley and Oden tend to support this notion, but the data presented by Miles and Miles (1933) and perhaps that of Pacaud (1955) do not lend support, although they are not necessarily contradictory.

In general, then, the results uphold the common sense notion that intelligence defined as knowledge--i.e., as one's awareness of the collective intelligence of his culture--tends either to increase or at least not to decrease in adulthood: older adults tend to be more intelligent in this sense than younger adults.

This is, of course, just another way of putting Anastasi's notion that age differences in performance on intelligence tests mainly reflect educational differences, with here the added important qualification, however, that "education" be defined more broadly than Anastasi defines it. Living in a society which possesses a given culture, doing a job in that society, etc., all are here regarded as "educational" influences. Also, whereas Anastasi argues that the results obtained on omnibus tests in cross-sectional studies reflect the fact that older adults tend to have less <u>formal</u> education than younger individuals, here the argument is that the results obtained with omnibus subtests are not consistent with this kind of interpretation. The very tests which are most clearly measures of educational achievement (formal and otherwise) are the tests on which older adults perform best! The evidence thus suggests that older adults do not score lower on omnibus intelligence scales <u>primarily</u> because they lack education. The important question is where do they fall down?

d. Spatial and Reasoning Factors

There is some suggestion that the rise in vocabulary scores with age reflects mainly an increase in familiarity with the labels that are used to tag concepts rather than an increase in comprehension of concepts as such. Thus the results of Fufel (1949), Yacozniski (1941) and Bromley (1957; 1958) suggest that if tests are scored for refinement in the use of vocabulary, average scores may go down with age. Bromley reported, for example, that older subjects showed lower ability at autocriticism and evaluation in the interpretation of proverbs. By contrast, however, Bradway and Thompson (1962) found that their subjects improved more on the Stanford-Binet proverbs items than on any other in the battery, Gorham (1956) has argued that proverbs items, such as Bromley and Bradway and Thompson used, contain the factor V, which generally improves with education, but also a general reasoning factor which does not improve with age and may decline. Whether scores on a proverb test rise or fall with age would thus depend upon the extent to which the test variance is comprised of one or the other of these factors.

A similar kind of interpretation seems to be called for to explain the results obtained with analogies tests <u>other</u> than the Concept Mastery device. As noted in section D-4, such tests may involve words that are quite familiar to most people and yet contain relations that are complex. For example, most adults probably know the words "flame," "heat" and "rose," but perhaps many would find it difficult to solve the analogy flame-heat::rose--? The interesting finding suggested by both the cross-sectional and longitudinal studies (Jones and Conrad, 1933; Gilbert, 1935; Owens, 1953; Riegel, 1959;

Willoughby, 1927) is that while vocabulary scores for older adults are generally somewhat higher than for younger adults, the scores obtained on "common-word" analogy tests (i.e., tests involving items like the one above) have repeatedly been found to drop steadily throughout an age range extending from 30 onwards. The suggestion thus is that while adults are gaining in familiarity with some of the more abstruse aspects of their culture, they may be losing some ability (which they formerly possessed) to perceive relations and form abstractions among more or less elementary concepts.

Cross-sectional studies with the Wechsler scales agree in showing that "performance IQ" declines with age and declines more steeply than "verbal IQ" (Cohen, 1959; Corsini and Fassett, 1953; Doppelt and Wallace, 1955; Fox and Birren, 1950; Heston and Cannell, 1941; Riegel, 1958; Wechsler, 1944, 1955). In their matched-group study Norman and Daley (1939) found their older subjects to be down on the so-called performance subscales of the WAIS. Of course some of these subscales--the digit symbol task, for example--do not have a very high logical claim to be measures of noegensis (eduction and perception of relations) and such tests also involve a large speed component. But this is not true of Block Designs, for example, and yet older adults have been found rather consistently to score low on this subtest (see the above and also

Bromley, 1956a). Perhaps, however, this represents decline only, or primarily, in one or more of the spatial factors--i.e., spatial orientation, visualization, flexibility of closure, speed of closure (French, Ekstrom and Price, 1963).

The evidence reviewed in Birren's (1958) Handbook of Aging indicates that with increasing age there tends to be a reduction in visual acuity, sensitivity to light, breadth and width of the visual field, color discrimination, and the like. These changes, may in turn, be most directly related to peripheral receptor changes, such as the decrease in range between minimal and maximal pupillary diameters of the eye, the flattening of the eye lens, the decrease in permiability of the lens, etc.(Lansing, 1958; Magladery, 1958). And such changes could well produce changes in performance on spatial tests. In a strict sense these changes would not indicate any necessary decrease in the ability to educe and perceive relations, as such.

There seems to be little doubt but that aging is accompanied by a decrease in at least some of the spatial abilities mentioned above, although the comprehensive study of changes on several of these factors was not undertaken until the present investigation. In both Kamin's (1957) study and that by Schaie, et al (1953) spatial orientation was one of the abilities that declined most with age. Fox and Birren (1950), Doppelt and Wallace (1955) and Norman and Daley (1957) all found Block Designs, Picture Arrangements, and Picture Completions to be among the tests which most clearly showed aging effects. Bromley (1956a) found that his blocks test correlated-.52 with age. Tests such as USES's Block Counting and Spatial Relations, Bechtold's Shape Constancy and Harrell's Tracing have been found to load negatively on factors that are prominently marked by chronological age (Bechtold, 1947; Harrell, 1940; USES, 1944).

In the introductory section it was pointed out that some of the above-mentioned spatial tests, although they have been found to load El Koussey's k or similar (perhaps lower order) spatial factors, have also been found to have rather high loadings on a general intellective factor interpreted in accordance with Spearman's theory of G. This suggests that perhaps not all of the variance associated with aging in these tasks is to be accounted for in terms of peripheral changes. It also suggests that performances on reasoning tasks which do not involve the spatial factors to any great extent may also show age decrements.

This latter supposition seems to be born out by existing evidence, although some of the tests which tend to prove the point may (it is difficult to say for sure) have noteworthy variance in spatial factors or in other factors which would represent peripheral changes in receptor or effector organs. For example, a consistent finding has been that tests which load the inductive reasoning factor (French, et al, 1963) show consistent negative correlation with age (Bechtold, 1947; Owens, 1953; Gilbert, 1935; Kamin, 1957; Schaie, et al, 1953; USES Report, 1944; Willoughby, 1927). It is not yet clear where the Matrices (such as are used in Cattell's and Raven's tests) belong in the "primary" factor structure of abilities, although it appears from the work of Rimoldi (1948) and Adkins and Lyerly (1952) that they would probably have most of their variance in I, Induction. But wherever their variance may go, it is evident that performance on these tests drops off sharply with age (Raven, 1948, 1954; Foulds and Raven, 1948; Foulds, 1949; Nyssin and Delys, 1952) beginning perhaps in the teens and almost surely in evidence by the mid-twenties.

Bromley (1956) matched subjects in four age groups extending from below 35 to over 65 on Wechsler-Bellevue IQ and "social background" and then looked at their performances on the Shaw Test of logical classification, a test in which the subject is required to arrange wooden blocks to reveal various possible principles of classification. He found that both the number of classifications (the test is given without time limits) and the number of highly abstract classifications decreased regularily with age.

The induction factor tests might involve a spatial visualization component even if not one of those components usually labeled as a space factor. Likewise both Matrices and the Shaw Test could be said to have noteworthy spatial variance. Also, the tests of the induction factor are usually administered under rather highly speeded conditions, so perhaps much of the age decrement noted on these devices is due to a speed factor, although this would not generally apply to results obtained in Britain with Raven's Matrices. But the fact that scores on tests like common-word analogies also tend to drop with age calls into question the adequacy of these explanations. Analogies and the aforementioned tests seem to involve somewhat similar requirements and yet verbal analogies surely do not involve very much spatial variance and they are not usually given under highly speeded conditions. What they appear to have in common with spatial reasoning tasks is an abstracting, noegenetic process. The suggestion is, therefore, that these functions are to some extent impaired by changes which accompany aging.

This argument would be more convincing if it were found that all reasoning factors showed aging trends similar to those found for common-word analogies, matrices and spatial reasoning tasks. What is termed the General

Reasoning factor, R (French, 1963), should therefore be considered in terms of this supposition.

The Arithmetic Reasoning task--the most consistent marker for R--is one of those which can be solved by means of the alternative mechanisms which are, in a sense, being contrasted in this study. That is, the problems in Arithmetic reasoning tests can be solved by use of more or less formal aids, such as are taught in algebra courses, or by means of aids which are acquired more informally. For example, one can gain experience in solving such problems by merely encountering a situation in which it is necessary to figure out how many stamps of several values can be purchased for a given amount of money or, again, by having to decide on how many gallons of paint to buy to paint a given number of rooms--i.e., the sort of problems that adults meet every day. Thus, it can happen that a young person with little experience in solving such"adult" problems but, let us say, with a good and recent course in algebra under his belt, may solve arithmetical reasoning problems primarily by the book, so to speak, i.e. using the formal rules of algebra. An older adult with experience and no formal training in algebra might solve the same problems by use of aids that perhaps bear little formal relation to the rules of algebra, but accomplish the job. And, finally, a young person with neither adult experience nor formal education in algebra might solve the problems by generalizing with only the aids that can be acquired without either of these kinds of experience--aids which might be quite different from those used by mature adults and those of algebra. Of course, these kinds of alternative mechanisms may be involved in performances on almost any ability measure, but it seems that they might be particularly evenly balanced on tests like arithmetical reasoning.

The results showing the relationship between aging and performance on arithmetic reasoning tasks are perhaps interpretable in terms of these considerations. Wechsler Arithmetic--which consists largely of "real-life" problems of the "change-making, stamp-buying, paint-estimating, job-finishing" type--seems to hold up fairly well with age. Doppelt and Wallace (1955) found the peak in performance on this test to occur at about age 40, and the drop thereafter, if any, was slight and slow. In the Norman and Daley (1959) matched group study, Wechsler-Bellevue Arithmetic was up slightly for the older subjects. Corsini and Fassett (1953) did not find noticeable drop in this performance. The suggestion thus is that this task is one which people continue to perform and practice in adulthood and on which their ability does not decline.

However, it would seem that some arithmetic reasoning tests bring into play much of the kind of reasoning variance which is involved in verbal analogies and spatial reasoning and that, there is age decline in performance on these tests. In Owens' (1953) longitudinal study, using Army Alpha Arithmetic Reasoning, and in the cross-sectional studies of Beeson (1920), using the arithmetical reasoning problems of the Stanford-Binet, and Willoughby (1927), using the Army Alpha, there did seem to be some decline in R.

e. Speeded Functions

Speed of performance on most psychological tasks has been found to decline with age in adulthood (Birren, 1958; Braun, 1958; Jones, 1958; and Welford, 1958).

Notweorthy exceptions to this may be simple reaction time, as such, which if it increases at all with age, does so only very slightly (Welford, 1958), and verbal fluency: although the results of Birren and Botwinick (1951) suggest that older adults write more slowly than younger adults, Kamin (1957) and Schaie, et al (1953) found that word fluency was on of the measures which showed least decline with age. Perhaps fluency scores hold up with aging for much the same reason that vocabulary and general information hold up: as a result of increasing contact with the culture, the adult acquires an increasing number of cultural concepts (and concept labels) about which he can then be fluent.

But with these exceptions the consistent finding is that speed of performance declines with age. This shows up, for example, in simple clerical tasks--tasks such as are involved to some extent in all intellectual tests. Numerous studies have shown an age-related drop in performance on the Wechsler-type digit-symbol tests (Birren and Botwinick, 1951; Birren and Morrison, 1961; Doppelt and Wallace, 1955; Loranger and Misiak, 1960; Norman and Daley, 1959; Whitman and Jastak, 1957; Willoughby, 1929). Crossman and Szafran (1956) have noted that the average time to sort playing cards or weights into different classes rises steadily with age. Pacaud (1955a; 1955b) found that complex reaction time--i.e., complex in the sense that different kinds of responses were required for different kinds of signals--increased with age. In Tolland's (1962) study, older subjects were found to take longer to manipulate a mechanical counter and to select different colored beads with tweezers than did younger subjects.

It is possible that the slower responses of older persons in most psychological tests is due mainly to changes in peripheral organs, such as the muscles or receptors. After reviewing a considerable body of evidence on this point, however, Welford (1958) concluded that this is probably not the case:

> We may sum up the results surveyed in this chapter by saying that slowing of sensori-motor performance with age is due not to longer time required to execute movements, as such, but to longer time needed to initiate, guide and monitor them, owing to limitation in the capacity of central processes. Experiments relating performance to age have shown that, although peripheral organs may set limits in tasks requiring fine sensory descrimination or, at the other end of the chain, strenuous muscular activity, most sensori-motor performance among older people is limited by central mechanisms. These may be conceived as having a finite capacity in the sense that there is a maximum amount that can be done at any one time and in any given period of time.

> Compensation can to some extent be made for loss of capacity by taking a longer time, and this appears to be a major cause of slowness of performance among older people. If this longer time is not taken, accuracy appears to suffer, and speed and accuracy can be shown to be in principle compensatory....Where there is a choice open to them, older subjects appear rather consistently to shift the balance between speed and accuracy towards the latter. (Welford, 1958)

Welford cites several studies in support of these viewpoints. In one, subjects performed a grid-plotting task under unspeeded (unpaced) conditions and under speeded (paced) conditions. Older adults were slower but more accurate than younger adults on the first task, but both speed and accuracy dropped with age on the second task. Welford also cites the Crossman and Szafran (1956) and Goldfarb (1941) experiments suggesting that the slower speed displayed by adults is not primarily a function of reaction time, as such, but rather of complexity in the sense of having to do two or more things at once (make discriminations and otherwise behave); that is, when subjects were required to (1) merely deal cards into two piles (no choice), (2) sort according to color (black or red), (3) sort according to the four suits, and (4) sort according to the four suits and according to whether a card was a court card or not, there were practically no age differences for the first condition, but there were noteworthy differences for the conditions in which decision was required. Birren (1954) and Clay (1954) have likewise presented data suggesting that as task complexity in this sense increases, age differences in speed of performance become greater. When simple number ability tasks--addition alone, subtraction alone, etc.--are given with liberal time limits, little or no age decrement in performance is noted (Sword, 1945; Schaie, et al, 1953; USES, 1944), but if the tasks are highly speeded, decrement becomes evident (Kamin, 1959; Birren, 1954; Ghiselli and Brown, 1949). Moreover, if the number tasks are made to involve several operations, such as addition, multiplication and division in a single problem, then the age decrement becomes even more pronounced (Ghiselli and Brown, 1949).

The "task complexity" discussed in this context probably should not be equated with other possible connotations of this expression. For example, Cattell (1940; 1963), in discussing the complexity of items used to measure intelligence in culture-fair tests, has reference to the abstractness of the relations which the subject is required to perceive or educe. In the above examples of simple speeded clerical tasks, on the other hand, complexity is introduced by increasing the number of things the subject has to do or to keep in mind at one time.

Particularly when the emphasis of the task is upon this latter requirement, however, complexity in the simple clerical task may be in some respects similar to complexity in the intelligence test involving complex abstractions. That is, there is some suggestion that, even when the abstractive reasoning test is given under untimed conditions, persons fail by virtue of an inability to keep the several relevant aspects of the problem all in mind at one time. It is thus possible that the older person's failure on both the speeded clerical task, which is made complex by requiring the subject to perform several kinds of functions at once, and on the unspeeded abstractive reasoning task, which is made complex by requiring the subject to integrate several kinds of relations into more inclusive classes of relations, is due to a dimunition in some process like span of immediate awareness or capacity for short-term memory.

f. Memory Functions

Although the evidence is not clear on this point it would seem that there is little or no aging loss of what can be called long-term memory. As already noted, many studies have demonstrated that over-learned information, vocabulary problem-solving aids, and the like, are retained over many years in adulthood. Of course this retention may be partly a function of at least sporadic practice over the aging period. Kay (1958) argues, for example, that "...long-term memories from the past (which older persons preserve) remain because they have some part to play in the person's life and are recalled at intervals...". However, there is some indication in the learning-and-recall studies of Clay (1956), Shakow, et al (1941) and Speakman (1954) that once the older adult learns something, he retains it over periods of several days, several weeks and several months just about as well as does the younger adult; and this seems to be true whether or not the learned material was initially novel or unusual. The Thorndike (1928) and Sorenson (1930) studies of scholastic-type learning also indicate that, provided the older subject is not too far out of touch with the academic routine, he can memorize in the school situation about as well as younger subjects.

But Welford (1958) cites several studies suggesting that impairment to short-term memory accompanies aging and that this impairment is most pronounced when observed under conditions in which the subject is required to store information as he carries on other activities. In the Kay (1953) and Kirchner (1958) experiments, for example, subjects were required to simultaneously detect signals and prepare responses for signals previously detected. The older subjects were less able to recall correct responses than were the younger subjects. Clay (1956; 1957) and Heron (1963) likewise found that older persons were particularly subject to distraction in a task requiring simultaneous use of both immediate memory and other behavioral processes. Conditions for interference are present in the usual digit span task and this span has usually been found to decrease steadily from the early twenties (Gilbert, 1941; Pacaud, 1955; Willoughby, 1927). Although Bromley (1958) recorded no significant age differences in auditory memory for digits when the task was to repeat the digits in the order given (thus to some extent contradicting the above results), when the subjects were required to give the digits in reverse order, there was decline with age. Ruch (1934) found that paired associates memory decreased under all conditions which he tried, but that the decrease was less marked when the associates were "meaningful" than when they were "nonsensical". Gilbert (1941), Kubo (1938) and Thorndike, et al (1928) also found that paired-associates memory declines with age, although the suggestion from Kubo's work is that if motivation is adequate (but not extreme, cf. Kuhlen, 1959) and distractive elements are not introduced into the task, the decline of immediate <u>willed</u> recall may be very slight. In the early studies of Jones, Conrad and Horn (1928) and Willoughby (1927), it was found that immediate incidental memory,--the memory which occurs under conditions where no instructions to memorize are given--dropped steadily and rather sharply with age. Thus, although no one study is convincing in itself, the evidence overall suggests that there are, indeed, adult age differences in the number of elements which can be simultaneously stored in what can be termed an immediate memory storage compartment.[15]

g. Some Physiological Considerations

Most investigators of aging changes in adulthood have found evidence for either an age-related physiological breakdown or an accumulation of damage in sensory and central structures. Changes in sensory receptor structures produce a general loss of sensitivity in all sensory modalities --i.e., a loss in visual, auditory, gustatory, olfactory, vestibular, pain, kinesthetic, touch, and vibration sensitivity (Welford, 1958). No doubt these changes reflect in performances on intellectual tests, but, as noted previously, Welford concludes his evaluation of the evidence with the surmise that to a considerable extent the age differences in performance on even rather simple perceptual tasks reflects changes in central structures.

Some of the major kinds of differences--as determined from osteoplastic craniotomy, autopsy and the like--between the brains of older and younger persons are listed in Tables 2 and 3. In Table 3, particularly, some attempt has been made to indicate similarities between characteristics associated with aging and those associated with the kind of brain damage that results from known disease or known assault on the central nervous system.

Most of the characteristics listed in Table 3 are not invariably associated with aging, in the sense that each and every older person necessarily shows the characteristic in question, and the same sort of thing can be said for the brain damage column in Table 3. Also, many of the characteristics have been found at least occasionally in young people who have not been classified as having suffered brain damage. Hence the tables indicate statistical facts, not necessarily functional facts, although at the cellular level, particularly, it seems likely that some of the characteristics would typify old brains, if not because of intrinsic aging degeneration then because "normal" living produces some (irreversible) brain damage and this accumulates as one continues to live.

According to Bondareff (1959), Magladery (1959) and Korenchevsky (1961), one of the most uniform findings

TABLE 2

Actual (g) and Relative (g per kg) Weight of Human Brain

Determined On Samples of People of Different Ages

(After Korenchevsky, 1961, Using Several Sources*)

	Brain Weight of Males		Brain Weight of Females		Males and Females	
Age	Average	Range	Average	Range	Average	Relative
0-7 days	239	70-370	247	90-400		
7-12 mo.	830	550-1360	817	720-930		
3 yrs.	1208	1090-1310	1088	1000-1220		
1-5 yrs.					1134	80
6-10 yrs.					1298	60
10-14 yrs.	1400	1270-1640	1215	1010-1340		
11-15 yrs.					1402	40
16-20 yrs.					1360	29
20-29 yrs.	1392	960-1650	1252	1000-1480		
21-30 yrs.					1397	26
30-39 yrs.	1367	1110-1690	1246	1030-1475		
31-40 yrs.					1387	25
40-49 yrs.	1358	1000-1670	1247	980-1680		
41-50 yrs.					1361	24
50-59 yrs.	1357	1100-1620	1227	1032-1440		
51-60 yrs.					1338	23
60-69 yrs.	1326	1100-1630	1208	1020-1650		
61-70 yrs.					1306	24
70-79 yrs.	1282	1100-1490	1175	920-1470		
Over 70					1218	24
Over 80	1250	1080-1430	1126	1020-1310		

*Marchand (1902), Handmann (1906), Korenchevsky (1942), Roessler and Roulet (1932) Burger (1957).

TABLE 3

Some Gross Central Nervous System Characteristics Associated With Aging and Brain Damage

(After Bondareff, 1959 and Korenchevsky, 1961)

Characteristic	Frequency higher in Samples of older persons (relative to younger persons)	Brain-damages Persons (relative to uninjuried)
Macroscopic (naked-eye) Examination		
1. Atrophy, less grey and white matter, smaller brain		
a. Low brain weight	yes	yes
b. Low brain volume relative to skull capacity	yes	yes
c. "Empty" space in brain area	yes	yes
(i) space between inner surface of cranium	yes	yes
outer surface of brain	yes	?
(ii) wide and deep cerebral ventricles and sulci	yes	yes
(iii) missing areas (missing lobes, or the like)	?	yes
d. Narrow, small gyri (convolutions)	yes	yes
e. Few nerve cells	yes	yes
2. Abnormalities of meninges and covering membranes	yes	yes
a. thick dura and pia-arachnoid	yes	yes
b. Fibrous meninges	yes	yes
c. Adherence of meninges to brain tissues	?	yes
3. Accumulation of cerebro-spinal fluid in subarachnoid areas	yes	yes
4. Sclerosis	yes	yes
Microscopic Histological Examination		
1. Disentegrated nerve cells	yes	yes
a. Alzheimer's neurofibrillar degeneration	yes	?
b. Lipofuscin pigment accumulation	yes	?
c. Fatty degeneration	yes	?
d. Neuronophogia, Satellitosis and similar disintegration	yes	?
e. Fewer Nissl granules	yes	?
2. Abnormal cell appearance	yes	yes
a. Presence of Alzheimer's cells and plaques	yes	?
b. Presence of cells in white matter	?	yes
c. Unusual arrangement of cells in layers of brain	yes	yes

TABLE 3 (Cont'd)

Characteristic	Frequency higher in Samples of older persons (relative to younger persons)	Brain-damages Persons (relative to uninjuried)
3. Vascularization inadequacies and abnormalities	yes	yes
4. Cellular atrophy	yes	?
a. Uneven cell outlines	yes	?
b. Small cellular nuclei	yes	?

in the literature on aging is the age-related decrease in brain size (although the scatter about the means has generally been found to be high, too). Many of the characteristics shown in Table 3 may indicate this change, but the most notable, easily observed signs are the actual decreases in brain weight and volume, and the increase of "empty"[16] spaces in the brain area. At the cellular level there is microscopic decrease in cell size and in the number of neural cells in a given area. There is some evidence (Critchley, 1942) that decrease in total number of cells is most marked in the frontal cortex. The narrowing of gyri and the widening of ventricles and sulci also indicate a decrease in actual brain size and an increase in "empty" space in the head.

Bondareff (1959) regards the accumulation of lipofuscin in neuron cells as one of the events most reliably associated with aging. Sosa (1952) stresses the relationship between the accumulation of lipofuscin pigment and neurofibrillar degeneration. The pigment accumulates in the cell proper, thus forcing out the cell's active cytoplasm. For some reason the cytoplasm cannot lyse, reabsorb or excrete the substance. Thus the pigment continues to build up like, to use Korenchevsky's analogy, "clinkers in the burning coal in (an) oven...: if not removed, clinkers choke and finally extinguish the fire."

(Korenchevsky, 1961). According to Sosa, the accumulation of lipofuscin causes a breaking apart of the neurofibrillar network. In the final stage this results in neurofibrillolysis and death of the cell. Although these changes occur very frequently in the brains of normal old people, they do not, according to Korenchevsky (1961), always appear in cases of senility. Also, some of this pigmentation build-up has been found even in children and there are a few investigators who argue that the pgiment may be a material that is useful to the cell (Altschul, 1938; Hyden and Lindstrom, 1950). Both Bondareff and Korenchevsky cite evidence suggesting that the accumulation is a degenerative condition, however. It would seem in fact, that both lipofuscin build-up and neurofibrillolysis are caused by "various diseases, intoxications and other exogenous damaging factors associated with aging." (Korenchevsky, 1961).

A decrease in cerebral blood flow and a consequent decrease in oxygen consumption in brain cells is also frequently observed to accompany aging, as viewed by comparisons of means for groups of persons of different age. Korenchevsky points out, however, that contrary to popular thought, these changes are probably not so frequently associated with arteriosclerosis as they are with arteriofibrosis--at least this is true for non-senile cases. Both kinds of "osis" appear to be more common among older persons and both result in a reduction of blood supply to neural tissues, thus producing at least mild anoxia and consequent loss of nerve cells. But both kinds of "osis" have been found to be virtually absent in some old brains and to be very much in evidence in some young brains. Hence again the suggestion is that the results do not so much reflect an immutable aging process as they do a series of events which tend to occur with some (unknown) frequency, perhaps partly as a function of individual living habits but probably also merely as a function of the experience of living, and which, for this latter reason, are most likely to occur, and to occur most frequently, to persons who have experienced the most living.

The story for the other characteristics listed in Table 3 can be written in the same way. That is, in each case the characteristic is found in a high proportion of very old brains, less frequently in middle-aged brains and still less frequently--but with some frequency--in young brains; and in many cases there is the suggestion of a likeness between the characteristic observed to occur more frequently as a function of aging and a characteristic which is observed in known cases of brain damage.

h. Anlages and Compensatory Aids

Quite early in the development of ideas about the nature of intelligence, considerable attention was given to the role which a function like short-term retention might play in intellectual behavior. Spearman (1927) discussed this concept under the headings of "span of apprehension" and "mental competition." He noted that evidence from a wide variety of sources indicated that a person could generally keep in mind at one time at most only about seven distinct elements, but that this "span" varied considerably between individuals and might vary considerably from time to time within a single individual, the range being from less than four to, as noted, perhaps seven or eight elements.

It would seem that performance on both complex clerical tasks and complex reasoning tasks would be conditioned by span of apprehension. In the former kind of task it is necessary merely to get the instructions into separate storage compartments and to keep them there without confusing them, so that they can be used continually to monitor on-going motor behavior. If the span is narrow, or there is some tendency for the stored elements to get confused with one another, or if the elements fade out, so to speak, then the monitoring of the clerical task cannot be done efficiently because the person has to keep stopping to get the instructions organized properly in storage. This is the kind of explanation that Welford, Birrens, Heron and others give for the fact that speed on simple clerical tasks declines with age, although accuracy may not if the person is not required to work fast. Welford, in fact, argues that the adult implicitly recognizes a change in his ability to keep elements simultaneously in mind and shifts his problem solving "set" in the direction of emphasizing accuracy rather than speed.

In the problem-solving that is required in abstract reasoning tests, such as Matrices, it would seem that it likewise is necessary that one hold the various elements of the problem in the narrow focus of immediate awareness. To "see" the relation which must be educed to solve a Matrices problem, for example, it may be necessary (i.e., it is difficult to actively introspect on this process, as was learned early in the history of psychology) to hold in mind several relations indicated by the horizontal array of problem elements, several indicated by the vertical array, perhaps several more suggested by the diagonal elements, etc. It is conceivable that a person could correctly perceive the relations in each of these arrays separately but fail the problem through lack of ability to get the relations all into focus within his span of immediate apprehension. Here, too, as noted, there is suggestion that as aging progresses there tends to be (on the average) some loss in breadth of this span. It would seem too, that persons tend to shift their problem-solving "sets" in a way to at least partially compensate for this loss. In the context of the present study this is to say that they tend to develop new aids, viz., compensatory aids.

The suggestion thus is that problem-solving in tasks like Matrices depends upon processes which, it would seem, operate largely independently of previous learning. One's span of immediate apprehension, in itself, would seemingly not be very much influenced by previous learning, although, to be sure, the aids which one might use to compensate for narrowness of this span would be acquired abilities. And immediate memory (or span of apprehension) is merely an example of a class of such largely unlearned processes which operate in the display of intelligent behavior. Here the generic term anlage will be used to refer to the class of such historical processes. It is a problem for future research to distinguish specific anlages. Judging from what Welford has done thus far on this question it would appear that attention-span or short-term memory are complex processes, involving perhaps input and output subprocesses. For present purposes it is sufficient to recognize that some processes in intellectual functioning appear to be largely independent of learning. Malfunction in these is probably rather directly symptomatic of malfunction of the physiological substrate upon which intelligent behavior must be based.

There is some suggestion in the literature that the older person's difficulty in certain kinds of problem-solving situations stems from an inability or unwillingness to ignore some information. Particularly when problem complexity increases to the point where the full storage capacity of the short-term memory drum is needed, it is necessary to focus only on those aspects of the problem which are most relevant. Berlyne (1960) has noted that failure on intelligence items, or in ability tasks administered to animals, seems often to be due to an inability to properly focus on the most relevant aspects of the problem. Hayes' (1962) has cited studies (e.g. Thomas, Moore, Harvey and Hunt, 1959) suggesting that one of the important characteristics of the rather unintelligent activity which can accompany brain damage is an inability to ignore irrelevant stimulus configurations.

It is possible that the slowing down and emphasis on accuracy which accompany aging may in part be due to the fact that older persons tend to have relatively large stores of potentially relevant concepts and aids and may therefore experience greater difficulty in excluding the irrelevant in problem-solving. It is as if the cup runneth over with information and problem-solving methods. This actually adds to the complexity of the problem. The older subject is therefore more apt to become confused and to require extra time to unravel this confusion (Welford, 1958).

6. Some Relevant Factor Analytic Findings

a. Primary-Level Factors

Factor analytic studies on putative tests of thinking and perception have yielded evidence for a rather large number of what are sometimes referred to as "primary" mental dimensions. Some of the better established of these, as recorded by Cattell (1957), French (1953 and French, Ekstrom and Price, 1963), and Guilford (1960), are listed in Table 4. In his early monograph, French listed some 59 replicated factors among "aptitude and achievement tests." In the later work directed by the same investigator, several of the factors defined almost exclusively among scholastic tests and several which seemed to involve primarily non-intellectual variance were dropped, leaving 24 "cognitive" factors. Most of these are included also in Guilford's (1960) list, where, however, separate identification is claimed for several other factors, the total in this list being 52.

With a few exceptions, the refinement in dimensions implied by this work is not pointedly directed at the problems posed in this monograph. That is, whereas the work of people like Guilford is seemingly aimed at very detailed analysis, showing each of the various elementary functions which go into intellectual performances, the present work aims at synthesis. Thus it is not surprising that very

TABLE 4

"Primary" Mental Ability Factors

A. Factors involving (primarily) figural content

Name(s)	UI	French 1963	French 1951	Guilford 1960
1. Visualization	14	Vz	Vi	CFT
2. Flexibility of Closure, Gestalt Flexibility, Visual Cognition	2	Cf	Gf	NFT
3. Speed of Closure, Gestalt Perception,	3	Cs	GP	CFU
4. Spatial Orientation, Spatial Relations	11	S	SO	CFS
5. Perceptual Speed, Speed of Symbol Discrimination	12	P	P	ESU
6. Figural Adaptive Flexibility		Xa		DFT
7. Semantic Redefinition		Re		NMT
8. Spatial Scanning, Perceptual Forsight		Ss		CFI
9. Length Estimation		Le	LE	
10. Figural Relations				CFR
11. Figural Classification				CFC
12. Speed of Alternating Reversals, Figural Spontaneous Flexibility			PA	DFC

B. Factors involving (primarily) symbolic content

Name(s)	UI	French 1963	French 1951	Guilford 1960
13. Induction, Symbolic Correlates	5	I	I	NSR
14. Symbol Cognition				CSU
15. Cognition of Symbolic Classes				CSC
16. Symbolic Relations				CSR
17. Convergent Production of Symbolic Systems				NSS
18. Symbolic Identification				ESU
19. Symbol Manipulation				ESR

C. Factors involving (primarily) Semantic Content

Name(s)	UI	French 1963	French 1951	Guilford 1960
20. Verbal Comprehension	13	V	V	CMU
21. Mechanical Knowledge, Mechanical Information	8	Mk	ME	
22. General Reasoning, Deduction	4	34	D	CMS
23. Syllogistic Reasoning, Logical Evaluation	4	Rs	D	EMR
24. Sensitivity to Problems		Sep		EMI
25. Judgment			J	EMT
26. Semantic Relations				CMR
27. Experiential Evaluation				ESU
28. Conceptual Classifications				CMC
29. Penetration				CMI
30. Conceptual Foresight				CMI
31. Concept Naming				NMU
32. Convergent Production of Semantic Classes				NMC
33. Semantic Correlates				NMR
34. Ordering				NMS
35. Semantic Redefinition				NMT

TABLE 4 (Cont'd)

	UI	French 1963	French 1951	Guilford 1960
D. Semantic Fluency Factors				
36. Ideational Fluency	6	Fi	IF	DMU
37. Word Fluency	15	Fw	W	DSU
38. Associational Fluency		Fa		DMR
39. Expressional Fluency		Fe	FE	SSS
40. Spontaneous Flexibility		Xs		DMC
41. Originality		O		DMT
42. Semantic Elaboration				DMI
E. Memory Factors				
43. Associative Memory, Rote Memory	7	Ma	M	MSR
44. Memory Span		Ma	Sm	MSU
45. Meaningful Memory				MMR
46. Memory for Ideas				MMU
47. Visual Memory				MFU
48. Memory for Spatial Order				MFC
49. Memory for Temporal Order				MMS
F. Speed Factors (Listed elsewhere above)				
Perceptual Speed, Figural Identification	12	P	P	ESU
Symbolic Identification	12	P	P	EFU
Symbol Manipulation				ESR
G. Miscellaneous				
50. Number Facility, Number	10	N	N	NSI
51. Carefulness			C	
52. Schooling			Sc	
53. Perceptual (USES)				

little, if any, evidence relating directly to the hypotheses of this study can be found in the mass of previous factor analytic work summarized in Table 4.

A possible exception to this generalization is the schooling factor defined in four analyses (Thurstone, 1938: 1944; USES, 1944) which French summarized in his early monograph. In several respects this factor is very much like the hypothesized Gc dimension, as can be seen in Table 5. Although it was ostensibly a first-order factor,[17] in each analysis it was quite broad--i.e., either "broad" in the sense that it involved a rather large number of diverse tests (in Thurstone, 1938) or "broad" in the sense that it was defined by variables that could be considered factor measurements at the "primary" level (e.g., in Thurstone, 1944). Most of the high-loaded variables for the factor are hypothesized markers for Gc--i.e., they reflect intensive acculturation such as would result from prolonged and intensive education. Some of these "markers" are tests in which many of the problems could be solved by alternative mechanisms, either skills acquired through intensive acculturation or techniques which might be developed without this.

Unfortunately for this interpretation a few of the high-loaded variables (as viewed across all 4 studies) would

TABLE 5

The Schooling Factor

(After French, 1951)

USC	13	Fractions	69
THD	53	Verbal	65
**USC	14	Arithmetical Reasoning	61
THD	54	Number	59
**USC	11	Proverbs	59
**USC	19	Letter Series	59
**THA	39	Arithmetical Reasoning	58
USC	12	Decimals	58
THA	60	Word Knowledge	55
USC	10	Same-Opposite	55
**THD	56	Letter Series	55
USA	5	Arithmetic (N)	54
USA	11	Vocabulary	54
THA	38	Numerical Judgment (N)	53
THD	55	Word Fluency	51
THA	11	Vocabulary Completion	48
USC	8	Arithmetic (N)	47
THA	58	Vocabulary	46
*USA	16	Paper Form Board	45
*USC	7	Figure Series	44
*USA	6	Blocks	42
**THA	25	Mechanical Movements	41
**THA	56	Spelling	41
USA	3	Number Writing	40
THA	36	Estimating	39
*THA	17	Block Counting	36

*By the reasoning of this monograph, these variables would be expected to be reasonably pure markers for Gf, not, as here, Gc.

** These variables would be expected to split their variance between Gf and Gc due to the fact that alternative mechanisms are likely in reaching solutions.

be expected to mark Gf, not Gc. The suggestion thus is that Gf and Gc were not clearly separated in the analyses in question. In fact, the dimsension French referred to as "schooling" was identified as general intelligence in the two USES analyses. And in all but one of the four studies no factor at all similar to the hypothesized Gf dimension was separately isolated. Hence, assuming that Gf and Gc can be separated but can also be highly correlated, the suggestion is that the two were merged into a single general intellectual factor in three out of four of these investigations.

In the two Thurstone studies the failure to separate Gf and Gc can be understood as due in part at least to the homogeneity of the samples of subjects. In both cases the subjects were college undergraduates at a rather exclusive institution (University of Chicago), highly similar in terms of age and, one would suppose, in terms of exposure to educational opportunities, encouragements, and the like. Hence Gf and Gc could be expected to be highly correlated, highly cooperative and therefore highly difficult to distinguish as separate factors.

But this explanation (or rationalization) does not apply to the failure to effect the expected separation in the two USES studies. In the first of these the age range for 1079 male vocational trainees was 17 to 39 years and the group would also be heterogeneous with respect to social class and other variables associated with acculturation. Here the difficulty (assuming, of course, that the hypothesized Gf and Gc dimensions do in fact correspond to reality) would seem to be with the sampling of variables. The tests were concentrated in one section of the personality sphere--the ability section--and even here the range of variables was not very great.

Cattell (1957 and elsewhere) has pointed out that a factor must be conceived of not only in terms of the variables which it primarily involves, but also in terms of the variables which have random relationships with it and thus provide the ground against which the figure of the factor can be seen.

More technically the requirement is that there be hyperplanes for the factors in question. Also, as Thurstone (1947) pointed out some years back, a factor needs to be over-determined by (usually) more than three rather pure markers if it is to be defined clearly. In the case of Gf and Gc, where the two factors are broad and themselves correlated and cooperative, this means that analyses aimed at separating the two must involve a fair sprinkling of nonintellectual variables, largely uncorrelated with either dimension, and several variables which more or less uniquely characterize one or the other of the dimensions. These conditions were simply not met in the first USES study. There were a few non-intellectual variables but not enough to define adequate hyperplanes and there were few, if any, variables which could provide the expected distinction between Gf, the general visualization (Gv) and general speed (Gs) dimensions with which it might be confused, and Gc.

The story was perhaps a little different in the second USES study[18] and, interestingly, the hypothesized distinction between Gf and Gc is there adumbrated (Table 6). This study, too, suffered from a lack of sufficiency of variables to provide good hyperplanes and it lacked truly discriminating markers, but nonintellectual variables, such as those defining aiming and manual dexterity, provided some "ground," and there were a few variables which, on hypothesis, would distinguish Gf from Gc and other factors. The relevant results are presented in Table 6, where it can be seen that the factors tentatively identified with Gf and Gc are cooperative on Paper Form Board, Figure Series, Decimals and Letter Series and that the distinction between Gf and Gv rests only on the rather tenuous assumption that the Decimals and Letter Series, defining Gf, can be

TABLE 6

The USES-C Results Showing
A Possible Gf and Gc Distinction
(After French, 1951)

Variable	Gf?	Gc?	Gv?
Identical Forms	59		27
Paper Spatial Relations	51		39
Figure Series	45	44	37
Number Comparisons	45		41
Decimals	31	58	
Paper Form Board	28	32	51
Letter Series	27	59	
Fractions		69	
Arithmetical Reasoning		61	
Proverbs		59	
Same-Opposites		55	
Arithmetic (N)		47	
Age	-48	-29	

regarded as largely devoid of spatial variance. The small negative loading for age on Gc is not as expected (although the somewhat large negative loading for this variable on Gf is quite compatible with the theory). This loading, together with the fact that several of the lower loadings for Gc are on variables which should characterize Gf, suggests that in this analysis, due in part to a weak hyperplanes against which to rotate, Gc has been rotated too close to Gf, thus tending to define the general factor which represents the correlation between the two.

Judging from these results, tests which might be used to define Gf in distinction from Gv are Identical Forms, Paper Spatial Relations, Figure Series and Letter Series. The first of these is probably a marker for Guilford's CFC; the next two would measure Guilford's CFR; Letter Series has been a marker for I. It would appear that Gc might be defined by the "primaries" V (Proverbs, Same-Opposites), N (Decimals, Fractions, Arithmetic) and R (Arithmetical Reasoning).

b. Hierarchial Theory Results

Assuming that the kind of factoring represented by Table 4 gives an overly (for present purposes) detailed analysis of intellectual phenomena, it follows that the place to look for the desired synthesis might be in second-order analyses based on the factors of Table 4. Actually, the desired synthesis might be accomplished either by higher-order factoring, with, perhaps, additional transformation to bring the higher order factors into the space of the tests (as suggested by Cattell, 1963; Humphreys, 1962; Schmid and Leiman, 1957; Thrustone, 1947 and Wherry, 1959), or by procedures which retain broad group factors--i.e., not rotate in a way that tends to equalize factor variances. The latter kind of procedure has been employed for years by most British psychologists (cf. notably Burt, 1940; 1949 and Vernon, 1950).

Perhaps the contrast in two methodologies implied in the last paragraph is not necessary because the two kinds of approaches lead to virtually the same end. Indeed, some writers, such as Burt (1940), sometimes argue (in effect) that since factoring methods are merely ways of classifying data (a position we can accept) and (by implication) one way of classifying is about as good as another (a position we can not accept), then it really does not make much difference anyhow. In fact, Burt in practice (as opposed to Burt in theory) does not accept this position himself. He asserts as vigorously as the next factorist that the methods he employes are really much better for revealing the essential characteristics of data than are other methods.

Burt's (1940; 1949) psychological theory is rather similar in several respects to that suggested in previous chapters. He argues that the "architecture of the central nervous system or 'brain'," as well as the events of development, have a hierarchical form and from this he deduces that "the mind is organized on what can be called a hierarchical basis" in which "...the processes of the lowest level are assumed to consist of simple sensations or simple movements, such as can be artificially isolated and measured by tests of sensory 'thresholds' and by the timing of 'simple reactions.' The next level includes the more complex processes of perception and coordinated movement, as in experiments on the apprehension of form and pattern or on 'compound reactions'. The third is the associative level--the level of memory and of habit formation. The fourth and highest of all involves the apprehension or application of relations. 'Intelligence', as the 'integrative capacity of the mind', is manifested at <u>every</u> level, but these manifestations differ not only in degree, but also (as introspection suggests) in their qualitative nature," (Burt, 1949). From this it follows, too, that the structure among ability performances, if a wide enough sampling of behavior is taken, can be expected to reveal a hierarchical pattern of organization.

It would seem that in one way or another a hierarchical organizational model somewhat like Burt's is very widely accepted in Britain, and there are signs (e.g., Humphreys, 1962) that it is now being looked upon with favor in this country. Most of the theorists who employ such a model seem to agree tha an attribute very similar to that described by Spearman as G exists as a monarch at the top of the hierarchy. But there is perhaps some disagreement concerning the number and nature of the abilities at lower orders in the hierarchy. In contrast to Burt's description above, for example, Moursy (1949; 1950) describes a distinction between "practical abilities" and "intellectual abilities" just below the general cognitive ability; the practical abilities are seen as descendants of more elementary sensori-motor and "perceptual" processes, whereas the intellectual abilities derive from "associative" and "relational" processes. Somewhat similarly Vernon, discussing results obtained on large samples of British Army and Navy recruits, describes two factors just below the general intellectual factor as "the verbal-numerical-educational on the one hand (referred to as v:ed factor) and the practical-mechanical-spatial-physical (referred to as k:m factor)." And he goes on to say that "if the analysis is sufficiently detailed, i.e., if sufficient tests are included, these types themselves sub-divide. The v:ed factor (cf. Table 7) gives minor v and n (number) group factors. In other analyses, k:m splits similarly into mechanical information, spatial and manual subfactors" (Vernon, 1950).

As can be seen in Table 7, there are several points of similarity between the hypothesized Gf and Gc dimensions and the two factors which are defined just below G in Vernon's (and most British) hierarchical group-factor solutions. Vernon's v:ed has most of the markers expected for Gc and his k:m dimension seemingly involves noegenesis and yet is not highly saturated with intensive acculturation, as would be expected for Gf. There are several points of detail, however, which do not allow for a clean matching of k:m with Gf and v:ed with Gc.

For one thing, if k:m is to be identified with Gf, Matrices should probably have higher loadings and the information tests should probably have lower loadings. Also these latter should have larger loadings on v:ed if this is to be identified with Gc. In fact, it would appear that k:m was not, except perhaps in the analysis on Seaman, satisfactorily distinguished from the spatial visualization dimension (Gv) here suggested, and, although Vernon

TABLE 7

Results Summarized From Vernon's Extensive Work
Group-Factor Analysis on 1,000 Army Recruits

Test	Factors						
	G	k:m	v:ed	Gv*	V	N	Mk*
Matrices	79	17					
Assembly	24	89					
Squares	59	44					
Bennett Mechanical	66	31					
Non-verbal Group Test	78	13					
Verbal	79		29		45		
Dictation	62		54		48		
Spelling	68		41		43		
Instructions	87		23		09		
Arithmetic 1	72		49			39	
Arithmetic 2	77		36			32	

*Not identified in this analysis.

Group-Factor Analysis On 500 Ordinary Seamen

Test	G	k:m	v:ed	Gv	V	N	Mk
Matrices	71						14
Bennett Mechanical	55	40					29
Mechanical Information	26	45					64
Electrical Information	50	31	14				65
Memory For Designs	54	40		40			
Squares	51	23		40			
Mathematics	76		32			34	
Arithmetic	33		69			34	
Dictation	49		54		30		
Abstraction	79		17		30		

Group-Factor Analysis On R.A.F. Ground Recruits

Test	G	k:m	v:ed	Gv	V	N*	Mk
Matrices	69	30	27				
Silhouettes	59	30		34			
Spatial	66	57		11			
Squares	52	51					
Group Spatial	68	44					
Electrical-Mechqnical information	51	13	21				55
Practical Problems	63	25					33
Mechanical Diagrams	70	12					42
Mechanical Information	67		17	15			52
Verbal	67		40		40		
Spelling	59		31		45		

TABLE 7 (Cont'd)

	G	k:m	v:ed	Gv	V	N*	Mk
Reading Comprehension	59		29		38		
Clerical	74		35	22	25		
Calculations	61		70				
Arithmetic	62		67				
Scale and Graph Reading	88		33				
Dial Reading	80		32				

*Not identified in this analysis

definitely allows for the possibility that speed components may be substantially involved in intelligence test performance (cf. pp. 80-86 in Vernon, 1950) the speed component (or components) involved in the tests of Table 7 was not at all clearly separated from k:m, v:ed and Gv. Also, it will be noted, the loadings on some tests, such as Matrices, are quite variable from one analysis to another.

There are several reasons why these British investigations might fail to lead to solutions that are highly compatible with the theoretical position put forth in this monograph. Some of these reasons are the same as were discussed above in evaluation of the USES analyses. However, in addition to these, a more crucial point is that the rotational criteria used to locate factors in the British work was not independent of hypotheses--i.e., an objective criterion like simple structure or the least squares principle used to "fix" the principal axes factors was not used in the British analyses. Instead, the solutions were "guided"--and one might be a little less charitable and say "forced"--by the investigator's preconceptions.

Now it can be argued (cf. Burt, 1940) that such "guiding" of a solution does not necessarily impugn the validity of results; that although an infinite number of rotational solutions exists for a factor problem, the one which would fit a given preconception need not be among that infinite set. On this basis one can maintain that to show that a given kind of solution does indeed fit the data, even if this solution is forced, is to reveal one valid way of organizing the data: and, as noted, Burt sometimes goes on to argue that one of these "valid" solutions is about as good as another anyway. But now is this really a defensible position for a scientist to take?

Logically the methods here implied fall into a class of what might be described as "Procrustes" procedures, although the specific techniques employed by the British workers are not the same as those described as "Procrustes rotation" by Hurley and Cattell (1962). Horn (1963d) has recently tried out such "guiding" or "Procrustes" rotational methods in an effort to see just how far one can force nonsensical data into "scientifically meaningful" preconceived positions, and his results are a bit shattering to the argument that a forced factorial solution is one, among perhaps many, truly valid solutions for a set of data.
A matrix of normally distributed variables was generated to simulate scores for 297 people on 66 tests. These variables were named just as if they had been actual measurements, whence they were intercorrelated and factored by conventional means, after which an attempt was made to force the factors into positions that "made good psychological sense," as

indicated by the names assigned to variables[19]. The outcome of this analysis was that quite "meaningful" factors could be obtained; the random, obviously nonsensical variables gave results which agreed quite nicely with preconceived theory. The loadings were not as high as are sometimes desired--many were in the .30's and .40's, however--but then the communalities did not provide much variance to work with. All in all the suggestion was that data probably can be pushed around a good deal to conform with one's preconceived notions about the way it ought to be structured!

This is not to say that the results from this random variable study necessarily imply that the British psychologists are chasing their tails by pushing factors into the hierarchical position. For one thing, the hierarchical solution was not arrived at exclusively in the arm chair: the data have to some extent structured themselves, so to speak, over years of work. For another thing their judgmental procedures are probably not as efficient as a least-squares procedure even if they were to "push" very hard. For still another thing the sample size in much of the British work, such as that reported by Vernon, has often been large and the number of variables reasonably small; this implies that the degrees of freedom in the data do not allow for as much "pushing around" as was possible in the random data analysis on 66 variables and only 297 subjects.

Nevertheless, the results from the random variable study, taken together with the fluctuation in loadings on some variables in the results of Table 7, surely do suggest that the British hierarchical solutions are to be regarded with some scepticism. Replications of results, particularly when some crucial variable does not behave consistently, cannot be taken at face value. Unless full freedom to determine structure is left with the data, true replication is not accomplished. The possibility thus clearly exists that a better solution--viz., one that will replicate in truly independent studies--can be found. Blind simple structure rotations might provide this solution and the hypothesis here is that this will tend to bring v:ed and k:m into positions more similar to those suggested for Gc and Gf.

The British work does add to that previously discussed in suggesting that some of the mechanical reasoning tests, such as are contained in Bennett Mechanical, may have substantial Gf variance. Vernon's results with the Seaman sample also indicate that immediate memory (Memory for Designs) involves Gf. Tasks like Instructions and Reading Comprehension, which might be expected to have some Gf variance in societies where almost everyone reads, would seem, however, to mainly involve Gc.

c. Higher-Order Analyses

The early Thurstone and Thurstone (1942) study, demonstrating that the so-called primary mental abilities might be resolved into a single general factor, was followed by several other investigations suggesting much the same thing (Blewitt, 1954; Goodman, 1943; Mellone, 1944; Wright, 1943). Schmid (1957) has shown that the first factor in a bi-factor hierarchical solution like that preferred in Britain is in some cases equivalent to, and, by implication, often at least similar to the second-order factor derived from primary factor intercorrelations. The conclusion seemingly following from these findings is that the G factor isolated first in the British studies is equivalent to the second-order factor isolated last in some American studies, and, indeed, this would appear to be the conclusion most investigators on both sides of the Atlantic have drawn. It would appear, too, that it is often implicitly assumed that the ability factors which are regarded as "primary" in the U.S.A. (viz., those in French's list) are at least roughly equivalent to the factors just below v:ed and k:m in the British hierarchical solutions. But there is a contradiction in these assumptions, for the last one implies that not one but two factors should be found at the second order among "primaries" and that G should be isolated at the third order. This is not the approach that has been taken in most higher order factorings of primaries in this country, however. Except for Cattell's (1963) study, all of the higher order analyses on abilities have stopped at the second order.

The Wechsler subscales are sometimes treated as if they were markers for primary factors, whence factor analyses among these measures are taken as somewhat indicative of structure at the second order. Perhaps the most important feature of factor analyses on the Wechsler subscales is the fact that they allow some link to be forged between studies of structure among abilities and the numerous studies on age changes in adulthood which have been conducted using the Wechsler scales. For example, in Birren's (1952) factor analysis of the Wechsler subscales one factor was located which involved Vocabulary, Information, Similarities and Comprehension, i.e., the subscales which in several studies besides those of Birren have been found to show either increase or very little decrease in mean performance with age. This could be merely the primary level verbal comprehension factor, but it seems evident that it is a component of the hypothesized Gc. A second factor in Birren's analysis involved Block Design, Digit Span, Arithmetic and Digit Symbols. The latter (involving a substantial speed component) is not a primary marker for the hypothesized Gf, and Arithmetic would be expected to split its variance between Gf and Gc, but the factor over-all would seem to be a substantial compenent in the hypothesized Gf. Block Design, Digit Span and Digit Symbols are among the tests which show consistent age decline.

In a large number of factor analyses on the Wechsler Tests (Bellevue, WAIS and WISC), there has been high agreement in finding the two factors identified above, plus a spatial visualization dimension involving Block Design, Object Assembly, and Picture Completion (e.g., Balinsky, 1941; Burt, 1960; Cohen, 1957; 1959; Davis, 1956; Jackson, 1960; Maxwell, 1959; Riegel, 1959; Saunders, 1958 and Wechsler, 1958). Davis, for example, factored the Bellevue along with several reference tests for the factors in French's list and obtained results quite similar to Birren's except that Comprehension had a lower loading on V and loaded, instead, with the reference marker for R and Arithmetic on a factor which could be interpreted as Verbal Reasoning. This together with V might define Gc at the second order. Davis also showed that a factor define by Picture Completion, Object Assembly and Block

Design pulled off much of the spatial visualization variance in the Wechsler test battery. Cohen (1957) and Zwart-Houwink (1958) located essentially the same factors in the WAIS. Balinsky's (1941) and Cohen's (1949) results have shown that the two main factors of the Wechsler scales appear rather consistently in separate analyses on different age groups in later childhood and adulthood, but that the other factors are considerably more difficult to replicate using only the Wechsler subtests.

The results obtained with the Wechsler tests are thus reasonably consistent with those previously reviewed in suggesting that V and R will help to define Gc, and that CFR (Block Designs) and Ma will mark Gf.

Corter (1952) and Smith (1958) have done what are sometimes referred to as second order analyses on primary factors, but neither study provides much insight into the hypothesized Gf-Gc distinction. Corter used marker tests for five of Thurstone's primaries, viz., Vocabulary (V), Letter Series (I), Figures (S), Adding and Subtracting (N), and First Letters (W), but since some 16 other ability tests were analysed along with these five, the eight factors he obtained are probably best regarded as themselves at the primary level. However, his results show a fairly broad "Academic" factor (as he called it) which would probably be a prominent component in Gc. Several reasoning factors were identified. Some combination of these might define Gf at the next higher order, but in fact Corter rotated his factors into virtually orthogonal positions, so the higher order structure is not at all evident in his data.

In contrast to Corter, Smith was able to identify essentially only a single intellectual factor. He factored nine ability tests along with fifteen interest and personality questionnaires using a homogeneous sample of college freshmen. His ability variables were the "factor-pure" tests provided in the commercial PMA and DAT batteries, viz., markers for V, N and I, one for each in the two batteries, and tests for S, W and M in the PMA alone. Although N was defined separately by the two markers for it, the variance on the other ability variables defined essentially only a G-like dimension (small amounts of ability variance were found in other factors, but these were determined primarily by non-intellectual variables).

It will be recalled that Kelley (1928) argued that the general factor was a kind of artifact. Taking a somewhat similar position, Rimoldi (1951) pointed out that the general factor isolated in different studies involved quite different patterns of variables and in many, if not most, studies the reported pattern was not very closely linked to Spearman's (or anyone else's) theory about a central intellectual function. In his own analysis Rimoldi was especially careful to select variables to represent the principles of noegenesis. He was then able to argue that the unrotated centroid found at the second order in his analysis can be identified with G because "In the first order, factors that seem to represent the first and second principles of noegenesis have been found. The existence of synthetic and analytic activities and their interplay in intellectual performances is indicated" (Rimoldi, 1951). Interestingly, however, Rimoldi extracted and rotated three factors at the second-order and these give some support for the proposed Gf-Gc split. A summary of Rimoldi's results at the first and second order is presented in Table 8.

Factors have been labeled in accordance with Rimoldi's interpretations, rather than in terms of the French or Guilford systems, because they are not clearly matchable with the "primaries". However, it seems that VR is a mixture of V and R; GL is probably more closely aligned with I than is IR, which may be Guilford's CFC; NR may be a mixture of N and R; PR is perhaps Rs or CMR; EC is probably either CMC or CMR and IR would seem to be CSC.

At the second order, factor B would appear to correspond

TABLE 8

Summary of Rimoldi's Results

First Order Factors

Tests	G*	VR	PR	NR	IR	EC	GL	LR
Arithmetic Reasoning	64	45						
Inventive Synonyms	44	33						68
Inventive Opposites	50	39						32
Absurdities	49	33	30					
Inferences II	34	34						
Inferences I	22		63					
Verbal Analogies	62		34			20		
Coding	51		32					
High Numbers	39			52				
Areas	28			51				
Number Patterns	42		20	26	38			
Secrete Writing	45		20		55			
Geometric Forms I	48				44			
Geometric Forms II	28	46			36			
Pedigrees	55					87		
Directions	51					36		
Figure Class	45						41	
Letter Grouping	52						41	
Numerical Judgment	53						38	
Letter Series	62						26	
Figure Grouping	33							59

Second-Order Factors

		Primaries**	A	B	C
GL	Globalization	(I)	60		37
LR	Likeness Relations	(CFC)	45		
EC	Education of Correlates	(CMC)	25	20	45
VR	Verbal Reasoning	(V,R)		59	
PR	Plastic Reasoning	(Rs, CMR)	25	47	
NR	Numerical Reasoning	(N,R)		50	
IR	Induction of Relations	(CSC)			54

* Loadings of tests on unrotated second-order Centroid.

** Factors are labeled in accordance with Rimoldi's interpretations, but the letters here indicate possible links with the Guilford or French lists.

roughly to what is expected for Gc, and factor A can be tentatively identified with Gf. Factor C may be pulling off much of the spatial visualization variance and thus be the hypothesized Gv. Both IR and GL can be seen to involve this source of variance, and thus fit with the hypothesis, but the spatial variance in EC is not obvious. It is possible, too, that C is better characterized by the speededness of the tests involved than by apparent content, in which case this could be the hypothesized Gs (speed).

The suggestion from Rimoldi's work is that Gf may be defined by the Figure Grouping, Figure Classifying, Letter Grouping, Letter Series tasks of the primary factors known as I, CFC, CFR, CSF, as well as perhaps by the Verbal Analogies and Inferences tasks of CMR and Rs, whereas Gc can possibly be found with V, R, N, and possibly, also, CMR and Rs. The need to distinguish Gf from Gv is evident in Rimoldi's data.

Botzum's (1951) second-order study also gives some indication of a distinction between Gf and Gc dimensions. Botzum first isolated 10 factors among 46 ability measures at the first order. Eight of these could be readily identified with Thurstone's primaries. Botzum based his second order analysis on the intercorrelations of these eight factors. The results from this last analysis are summarized in Table 9 along with the table of correlations between the three second-order factors.

In this case factors E and C would appear to be principal Gc components. Factor B with its loading in V and W suggests a crystallized reasoning component, while C, with its loadings in V and W suggests a crystallized component of awareness of the verbal labels that are used to tag cultural concepts. The loading on N in this factor is reasonably consistent with this interpretation if it is allowed that the simple operations of arithmetic are largely matters of definition: that is, in a sense 2 and 2 can be defined as 4 much in the same way as dog can be defined as canine; the operations of arithmetic are aids only when they are used as principles to solve problems in "real life", as in arithmetical reasoning problems. In addition, subtracting, etc., problems one merely redefines one number as equal to 2 others; he does not use the principles of the number system to solve problems, as would be the case if the operations were being used as aids.

Factor D would appear to be a combination of spatial visualization components and speed (cf. W), whereas factor A would appear to be close, in a theoretically complete factor space, to the hypothesized Gf.

The correlations among the four second order factors

TABLE 9

Botzum's Second-Order Factors

Primaries

		A	B	C	D
I	Induction	68	39		
R	General Reasoning	67	77		
Cf	Flexibility of Closure	64			56
V	Verbal Comprehension		57	49	
W	Word Fluency			57	
N	Number			58	
Cs	Speed of Closure			-46	40
S	Spatial Orientation	74			33

Correlations Between Factors

	A	B	C	D
A	-			
B	43	-		
C	-15	20	-	
D	17	-22	-17	-

suggest that at the third order the A dimension (Gf component) could pull off some of the reasoning elements of B to define Gf and thus the remainder of the variance on B might go with C to define the expected Gc.

In terms of its indications for clean defintion of the hypothesized factors in future research, Botzum's study indicates that Cf may contain a substantial Gf component, but that probably flexibility of closure, speed of closure and spatial orientation are prime markers for the hypothesized general visualization function. There is no clear indication of what the speed variance is doing in Botzum's variables, but there is perhaps some indication that at least word fluency, if not fluency in general, might be used to help measure a general speed component if such exists.

Martin and Adkins (1954) did a second-order analysis on some of the results from the Adkins and Lyerly (1952) factor analysis of reasoning tests. One of the analyses in this latter study was based on a battery of 66 measures, many of which were chosen to represent various facets of reasoning ability. Thriteen factors were identified at the first order. As can be seen in the left columns of Table 10, not all of these can be unambiguously identified with the primaries now known (as listed in Table 4). Martin and

TABLE 10

Summary of Martin-Adkins Second-Order Factor Loadings on Primary Factors*

No.	Primary ID	Primary Name (and selected markers)	A	B	C	D	E	F
			Second-Order Factors					
1.	I? R? N?	Numerical Operations and Reasoning: (Arithmetical Operations, Number Series, Letters Series, Blocks)	61			24		
2.	CFR?CFC?	Perception of Abstract (Figural) Relations: (Matrices, Block Counting, Topology, Identical Forms)	52		-45			
3.	CMR? CMC? NMU?	Perception of Abstract (Verbal) Relations: (Verbal Classifications, Analogies, Word Squares, Word Group Naming)	52	36		47		
4.	Vz? S?	Spatial Visualization: (Block Counting, Figures, Cards, Paper Folding)	33				55	
5.	CMR? DFT?	Classifying and Planning:(Figure Classification, Map Planning, Verbal Classification, Verbal Analogies)		45				
6.	V	Verbal Comprehension: (Vocabulary, Absurdities, Reading Comprehension)			61			
7.	CMR? NMU?	Concept Attainment: (Word Group Naming, Analogies, Picture Group Naming)			51			
8.	Fw	Word Fluency: (Suffixes, First-Last Letters)				72		
9.	Fi	Ideational Fluency: (Topics, Things Round, Reasons)				52	-32	
10.	Mk? Vz?	Mechanical Knowledge: (Mechanical Information, Mechanical Movements)					46	
11.	Rs?	Deductive (Syllogistic) Reasoning: (False Premises, Identical Forms, word Squares)						60
12.	Cs	Speed of Closure (Gestalt Completion, Mutilated Words)						-37

*One of the first-order factors is not listed here because it did not show loadings above .30 any of the second-order factors.

Adkins extracted six factors from the intercorrelations of these "primaries" and rotated to the positions shown in the right section of Table 10. Then, using the procedure outlined by Thurstone (1947), they projected the second-order factors into the space of the original variables, with results as summarized in Table 11.

Table 11 reveals a hierarchical structure in these data. The general factor A can be seen to be general intelligence, representing the correlation between a person's intellectual capacities and his degree of intensive acculturation. Factor B can perhaps be identified with Gf. This is distinguished from general visualization by the fact that it involves substantial correlations with variables like Verbal Classifications, Verbal Analogies and Word Squares and by the fact that Gv is separately identified in factor E. Factor D would appear to be a broad version of hypothesized Gc. There again is the suggestion that at the second order Gc may be comprised of two components, the other being represented here by factor C. Speed functions have not, however, been isolated in this analysis. It is evident that factor D contains a substantial speed component, as represented here in the fluency measures, and no doubt speediness also enters into the performances of factor B (although Matrices E, which is the most highly speeded

TABLE 11

Summary of Martin-Adkins Second-Order
Factor Loadings on Variables

Variable Name	Second Order Factor					
	A	B	C	D	E	F
Numerical Operations	53			30		
Block Counting	47					
Number Series	46					
Matrices IV	46					
Figure Series	45					
Letter Series	44					
Picture Analogies	43					
Overlapping Circles (Topology?)	41					
Identical Forms	40					
Matrices E	40					
Figure Classification	41	40				
Verbal Classification	50	34		41		
Word Squares	49	30		34		
Decoding	38	30		36		
Verbal Analogies	34	30	24	42		
Incomplete Outlines	50	27		39		
Circles	40	26		38		
Figure Analogies	39	26		38		
Mixed Series	36	26		39		
Matrices C	32	26		30		
Reading			41	38		
Vocabulary	30		34	45		
Sentence Order	30		34			
Picture Group Naming			31	41		
Word Group Naming	36		23	45		
Inferences	30		28	29		20
Suffixes				57		
First-Last Letter				55		
Things Round				52		
Reasons				44		
Word Selection	31			36		
Conclusions				32		
Mixed Figure Squares				41	46	
Cards	34				41	
Surface Development	40				34	
Paper Folding	42				34	
Figures	34				33	
Planning a Circuit	30				30	
Mechanical Movements				26	30	
Designs	34				26	
False Premises						25
Education	33			48		

subform of the Progressive Matrices, loads only on the G factor, not on B, the Gf dimension).

Considered in terms of its suggestions for future research at higher orders among primaries, the Martin-Adkins research indicates that primary factors like CMR (containing, particularly, common word analogies) and CSC, since they presumably involve very little visualization, can be used to distinguish Gf from Gv. DFT could also (presumably) be used to define Gf, although on inspection this can be seen to involve some visualization variance (e.g., in match problems). The fluency dimensions are here seen to be cohesive in Gc and there is some suggestion that these may be used to make a distinction between either a speed and power component in Gc or the distinction, previously adumbrated, between a crystallized component characterized by long-term memory for cultural concepts and concept labels and another characterized by ability to recall and use crystallized aids. Finally, too, there is evidence here that Gv is largely involved in the Mechanical Movement tests which have often been prominent in the k:m dimension isolated in British studies.

Cattell (1963) has presented a study which differs from those just reviewed in three major respects: (1) he deliberately set out to examine the Gf-Gc hypothesis, (2) he intentionally included several non-intellectual variables, marking several previously established non-intellectual factors, in order to provide hyperplanes against which to rotate Gf and Gc, and (3) he went to a third order analysis. But the battery of tests which Cattell employed was not by any means ideally structured to bring out the essential relations and distinctions for the factors here discussed.

At the primary level Cattell defined V, S, I, N and Fw by using the separate half versions of the markers for these factors which are provided in the PMA commercial test. Other "primary" ability factors were similarly defined at the first order by using the Figure Classification, Figure Series, Topology and Matrices subtests of the Culture-Fair Test (Cattell, 1957). As near as can be guessed without actual empirical analysis, the factors defined in this way would correspond to the following primary-level factors as determined in Guilford's work.

Cattell Subtest	Guilford Factor
Figure Classification	CFC Figural Classification
Figure Series	CFR Figural Relations
Matrices	CFR Figural Relations
Topology	DFT Figural Adaptive Flexibility

First order primaries to provide "hyperplane stuff" for the rotation of ability factors were obtained by using two separate forms of each of the 13 Q-data personality dimensions measured in the HSPQ.

At the second order Cattell isolated eight factors, two of which accounted for almost all of the common variance of the ability tests. The first of these, identified as Gf, was defined by the four subtest factors of the Culture-Fair, plus S. Thus Gf was not separated from Gv. The second factor, involving V, N and I (but not Fw), was identified as Gc.

At the third order Cattell found a single ability factor defined exclusively by the Gf and Gc second-order dimensions.

Cattell's "primary" factors in this study may be looked upon as reliability factors--i.e., factors defined by the components which would ordinarily be used to determine the reliability of a single test. The factors are narrow and specific in the sense that a test is narrow and specific; that is, such factors do not involve sampling of behavior over different methods of measuring the same function and thus do not have the validity that is usually associated with the term factorial (or construct) validity. This implies, too, that Cattell's analysis is truly a second-order analysis only insofar as his measures are unifactor and common-factor-pure. They must be unifactor if it is to be argued that the position they determine at the first order is not overly confounded by specific factor variance and they must be common-factor-pure to insure that the factor which is defined at what is assumed to be the second-order will not be instead merely a primary-level factor, i.e., to the extent that the tests which are used to determine first order factors in this study involve more than one "primary" common factor, the possibility exists that two such tests will define a "primary" level factor.

A related question concerns the order of generality represented by the first-order factors defined by the subtests of the Culture-Fair Test. Of course, estimating the level of factors as influences is a bit of a metaphysical issue,[20] but nevertheless it seems that the factors defined here are narrower than those usually regarded as at the "primary" level. It was noted above that both Figure Series and Matrices define a single factor, CFR, in Guilford's system, rather than two separate "primaries" as is implied in Cattell's study, and Guilford's factors, as such, are narrow by usual standards. In French's system both CFR and CFC as well as (perhaps) DFT would go into a single primary level factor, It was pointed out above, however, that the primary-level factor composition of the culture-fair subtests has not been accurately determined. Hence, all that can be fairly asserted is that it seems likely that the "primary-level" factors in Cattell's analysis are probably rather narrow and specific as compared with the "primary-level" factors defined in the analyses that were reviewed earlier.

There were no markers in Cattells' study which would allow a distinction to be drawn between Gf and Gv and no provisions were made for separating out possible speed components.

I

Footnotes

[1] Letter abbreviations are used throughout this report for various more or less well-established factors. Generally these letters are the ones used in the catalog-like listings of factors offered by French (1951; 1963) and Guilford (1960), but some like Spearman's "G" and El Koussy's "k", are letters which, through being associated with early discoveries, have become established in the language of differential psychology.

[2] Here Burt has reference to Jackson's (1898) theory of a neural hierarchy.

[3] As usual in discussions of Spearman's model and the organization and development of abilities, there is ambiguity in use of the term hierarchical. In the present monograph three more or less distinct meanings of this term may be discerned. In one usage reference is made, as here, to the pattern of correlation coefficients in a properly arranged matrix when the above-mentioned conditions of independence of specifics and single attribute measurement are met. In a second usage reference is made to a multiple factor analytic solution in which less general factors involve nested sets of variables which also define more general factors. In a third usage reference is made to a developmental process whereby later-developed attributes are outgrowths, as it were of early-developed attributes.

Actually, as Cattell (1963) has clearly pointed out, there are a number of distinct patterns which might collectively be termed hierarchies--only one of which involves non-overlapping nested sets, as implied above-- and many writers, such as Hunt (1961), who speak of a hierarchical process of development imply nothing more specific than that what goes before influences what comes later and this direction of influence cannot be reversed.

In any case the modifiers used with terms like hierarchy, hierarchical, etc., in this paper will make the intended meaning clear.

[4] Thurstone was, of course, clearly aware that other methods could be used at this step and, indeed, he tended to regard the centroid procedure as mainly an expediency, necessary because calculations were so tedious by other means (Thurstone, 1947).

It is interesting in this regard that Thurstone (1931) first thought that the criterion for establishment of principal axes factors might serve to solve the indeterminacy problem in factor analysis.

[5] In his first presentations of his model Thurstone had orthogonal factors. Later, however, he argued that simple structure might not be achieved if factors were required to remain orthogonal and that, therefore, the general model would best be one which allowed factors to be correlated.

[6]Here and elsewhere in this paper we use the terms "education", "educational", etc., to refer not only to that which is taught and learned within formal educational institutions, but also to that which is taught and learned within what might be termed the "informal educational institutions" of the culture, such as the home, church, etc. The implication is, however, that "education" refers primarily to knowledges which reflect the values of the dominant culture. In other words, if a child learns in the home that paying taxes helps in the upkeep of the community, this is considered "education", whereas if the learns that taxes are mainly contributions to greedy politicians, this is probably not considered "education" (more specifically, the former answer would get 2 credits in the Wechsler Test, whereas the latter would probably be given zero credit).

[7] For as the work of biologists such as Von Frish (1950) illustrates, it must be acknowledged that the complex adaptations achieved by other animals--even the lowly insect--also exhibit a kind of "intelligence" and one for which man is not noted.

[8] That is, the conclusion must be hedged about with consideration of many near-unavoidable methodological difficulties which plauge this kind of study--i.e., questions of possible age-group differences in the sampling of tests, in the unit of measurement of the tests, in test ceilings, in sample variability, etc. (See particularly, Anastasi (1936, 1958), Emmett (1950) and McNemar (1942) for discussion of these.

[9] Incidentally, although up to this point we have referred primarily to changes occurring from birth to adulthood, there is no reason to suppose that the simplex pattern will not fit retest correlations extending over a period from young adulthood to old age. We don't have good evidence on this point, but the following data presented by Dennis (1956) is perhaps suggestive.

Correlations between degrees of productivity of 56 scientists

Age in Decades	Age in decades				
	30's	40's	50's	60's	70's
20's	57	46	46	35	33
30's		49	50	47	55
40's			80	75	62
50's				65	61
60's					84

[10] Ferguson would encounter the same difficulties as have others if he attempted to provide anything other than a <u>post hoc</u> definition of "similarity"--or whatever it is that helps determine whether (and to what extent) learning at a given time is facilitated or inhibited by prior learning; but in fact he doesn't go into this kind of detail.

[11] The term "system" is used here in a way suggested by Torgenson (1960) to indicate the "things" of which the universe is comprised and which are known by their particular constellations of properties.

[12] "As for the distinction here made between the 'ideal' and the 'real' classes, this descends from an ancient controversy as to which relations possess real existence over and above that of their fundaments. In general, such a prerogative has been asserted by those which are called real, but denied of those which are called ideal. This point, however, is a metaphysical nicety with which we fortunately need not here concern ourselves." (Spearman, 1927).

13 Or, as Hooton (1942) more darkly notes, "there comes a time when the perfection and power of tools contrived by a few ingenious brains put within the hands of the most moronic human animals almost unlimited constructive and destructive potentialities. Many of us are almost as incapable of inventing and understanding the scientific contrivances which we use as are chimpanzees".

14 Always, of course, such broad statements need to be qualified by recognition of exceptions. Some adults do not know that convention favors putting X after W in listing the characters of the alphabet. In a few such cases it is reasonable to suppose that this lack of knowledge is the result of quite extreme cultural isolation (as when severe sensory defects are in evidence). But in many cases it would appear to be more difficult to argue that such lack of knowledge is due to lack of educational opportunity than it is to argue that it indicates an inability which is directly related to the person's learning capacities, for it is evident that many persons who suffer quite extreme educational deprivation do nevertheless learn this cultural concept. Of course, it remains possible that the kind of inability implied here reflects very early perceptual deprivation, such as Hunt (1962) has suggested. As was argued in a previous section, however, if such a factor does operate, there would seem to be no good reason to suppose that it would be related to the same social, economic, etc., factors which are associated with intensive acculturation. In other words, the very early perceptual deprivation which Hunt postulates would affect the development of fluid abilities directly. This would limit, also, the development of crystallized abilities. But it would not alter the essential argument that fluid and crystallized abilities tend to become distinguished as a function of the fact that people are differently exposed to acculturation influences.

15 It may be useful to think of this "compartment" as analogous to the short-term memory drum on a computer. That is, it would seem that just as there are at least two somewhat different memory systems in most computers, there are at least two memory functions in thinking, functions which are similar in some respects, as the short-term and "permanent" memory drums of a computer are similar, but which play somewhat different roles in problem solving and differ in the ease with which they are brought into use. Thus an immediate-access drum stores information as it comes in, until a spot can be found for it on the "permanent" drum, and it holds information taken from the "permanent" drum or

from the outside for immediate use in calculations. The actual operations of problem-solving are carried on with information that is stored on the immediate-access drum and the amount of information on it at any one time is small relative to that which can be put on the permanent drum. The permanent drum keeps large amounts of information. This can be used for problem-solving if it can be located and shuttled to the immediate-access drum.

[16] That is, empty of neuronal elements. The spaces of the brain are filled with neuroglia cells, which serve to support various neuronal elements, ependyma cells lining the ventricles of the brain and a ground substance in which all three kinds of cells are immersed.

[17] As Coan (1964), Humphreys (1962) and Vernon (1950) have pointed out, it is by no means a simple matter to infer the order of generality of an influence from the order of a factor in factor analysis. Depending upon the way variables are sampled from the variable domain, first-order factors can correspond either to general influences (such as are sometimes found at the second or higher order) or to very narrow, "splintered" (to use Humphreys' term) influences.

[18] Actually there are three such studies reviewed in French (1951) and reference here is to the third (USC), whereas the reference of the previous paragraph is, as implied, to the first (USA). The range of variables for the second (USB) study was, if anything, even narrower than for the USA study, but in this case the concentration was in visualization and number tasks. There is perhaps a suggestion of a distinction between Gf and the visualization dimension in this analysis, but the evidence there presented is not at all compelling.

[19] The idea for this kind of analysis, although not the specific procedures eventually employed, was first suggested to Horn by Humphreys in a course on human abilities. At that time Humphreys mentioned a study that Leonard Wevrick might have conducted (i.e., it was not clear whether Wevrick had actually done the analysis or had only talked about doing it) which would perhaps be similar to that outlined above. A description of the Wevrick study has not been located, however.

[20] Although most investigators who work with factor analysis for any length of time get some "feel" for the order of the factors they work with, as is attested to by the fact that the factors isolated in Thurstone's early studies are widely regarded as "primary" level factors.

PART II-REFORMULATION AND SOME DESIGN ISSUES

A. The Theory of Fluid and Crystallized Intelligence

1. General Features

The foregoing provides the basis for a full statement, now, of the basic theory. This theory states that there are two general and somewhat independent classes of influence operating to produce individual differences in behavior that is said to involve intelligence (in some acceptable sense of this term) and that these two influences are manifested in somewhat distinct patterns of performance on ability tests. It is believed that if care is taken to sample adequately among different kinds of ability tests and to obtain a subject sample which is heterogeneous in terms of the influences in question, the distinct patterns here in question can be revealed, at least to a first approximation, by the linear-combination methods of factor analysis. Two very general factors with appropriate marker variables can be defined at some level of analysis, and these, since they can be separately measured as broad dimensions of intellect, may be referred to as distinct intelligences, viz., fluid and crystallized.

The major classes of influences referred to here are, on the one hand, those affecting physiological functioning and structure directly, as through heredity and injury, and those affecting this only indirectly through learning. Fluid intelligence is said to be most directly related to the former set of influences, while crystallized intelligence reflects primarily the fullness and intensity of the latter set. This is not to say that fluid intelligence does not involve learned abilities: at least as it must be measured, it certainly does. Nor is it to say that one's level of crystallized intelligence is not determined in part by heredity and injury: it almost certainly is. What is implied here is that one or the other of these major classes of influence can be said to produce the <u>major</u> proportion of variance on measures of one or the other kinds of intelligence. To some extent both abilities are due to both kinds of influence, but, as measured in a given sample of people, the two can be separated by careful analysis with appropriate variables.

Fluid intelligence is the outgrowth of the functioning of anlages. There are presumably many genes determing the structure upon which these functions are based. This gene-potential of an individual may perhaps best be viewed as a set of instructions which, if proper nutritive substances are provided, will be carried out through maturation (Cf. Clark, 1962). The functioning of anlages, and hence the display of intelligent behavior, insofar as it is an outcome of this functioning, will thus depend upon what is written in these instructions and on the rate at which the instructions are set to be carried out. This functioning will also be determined, however, by injury to physiological structures. Such injury could occur quite early in life (perhaps often in the prenatal period). The amount of injury could vary considerably between individuals and from one time in life to another. Hence no claim is made that GF is primarily an indication of inherited potential. All that can be said is that it is more closely tied to immediate physiological functioning than is Gc.

Fluid intelligence involves concepts and aids which, relatively speaking, are not abstruse--concepts and aids which, at least by adulthood, can be obtained from experiences and opportunities that are afforded to the vast majority, if not to all, people who have been arised in a given society. This is not to say that these opportunities are equal for all persons at each age level in childhood. At very young ages these opportunities might not be evenly distributed at all, but children who miss out at one time get another chance at another time and still another chance at still a later time, so that as development proceeds these kinds of opportunities tend to be equalized. In general, older children would have encountered more of these opportunities than younger children, so that between-age differences in fluid abilities reflect learning differences as well as, perhaps, maturational differences and differences in exposure to potentially injurious environmental conditions.

Thus, Gf involves learning and is a product of acculturation, but it does not result primarily from differential opportunities in learning or from highly intensive acculturation, such as is promoted through educational programs, which, in one way or another, exclude substantial numbers of individuals. Particularly when the concept is defined as a factor among a diverse set of tests, it will be found that although some of the measures of the factor involve some variance due to exclusive opportunities such as are provided by particular kinds of schooling, the variance of the factor over-all will not be associated with this kind of educational opportunity, nor will it be associated with other indicants of intensive acculturation.

The mathematical model which would best represent the lawful combination of the above (and probably many other) factors might be highly complex, but in general form the theoretical terms can be represented as follows:

$$(1) \quad Gf = f(H, M, I, L_1, T_1, O_1)$$

where Gf represents a performance involving fluid intelligence almost exclusively, f represents a function, H refers to a hereditary component, M to the maturational rate, I to injury, L_1 to learning, T_1 to the time over which these factors have operated, and O_1 indicates the extent to which each of these factors has interacted optimally with each other and with environmental circumstances (the subscripts are needed to distinguish some terms in this expression from similar terms used in equation (2) to represent crystallized intelligence). It might be expected that several of these factors would combine to give, at least to a reasonable approximation, linear combination terms which could be teased out by refined factor analyses or other methods. But here it is assumed that these elements together constitute a more or less unitary influence, and hence, to a first approximation at least, a single term in a linear expression representing performances which involve some Gc as well as Gf.

Developmentally speaking, Gc is an outgrowth of Gf. In the early years of development and under certain other conditions the two may be so highly related and cooperative as to be virtually indistinguishable. But over the course of development, when a properly broad view of this is taken, they may be seen to become separated by virtue of the fact that manifested intelligence is produced by a large number of factors which operated largely independently of those seen as accounting for basic (physiological) intellectual potential. In general these can be classified as factors promoting intensification of acculturation. As they come to operate over time, they are not only factors of opportunity and encouragement presented to some and not others more or less independently of their personality attributes, but also factors relating to the non-intellectual characteristics of the person himself--his experience-producing drives and other motivational characteristics, his personality integration, his various traits of temperament, etc. The possibility exists here, also, as with Gf, that there are certain combinations of factors which if they exist at certain stages in development, have an optimal influence. Perhaps, for example, certain conforming traits, coupled with ability to suppress experience-producing drives are relatively important in the early school years, but less so at later stages. Indeed, the interactive possibilities are quite great. Here the assumption is, however, that these may be seen to constitute a single function, as indicated in equation (2)

$$(2)\ Gc=f(Gf_1, C, E, P, R, L_2, T_2, O_2)$$

where Gc represents a performance involving crystallized intelligence to a high degree, C refers to opportunities and encouragements (chances), E to ergs and sentiments (motive traits), P to non-intellectual personality traits (temperament), R to a factor of long-term memory, L_2 to the degree of intensive learning distinct from that which is provided for most people, T_2 to the time over which these factors have operated, O_2 to the extent to which the combination of factors and developmental stages was optimal for development of Gc, and Gf refers to the level of fluid intelligence that operated over this period.

Thus a performance which is said to characterize crystallized intelligence is also seen to contain at least a trace of fluid intelligence, so that to some extent the Gc measure can be said to be confounded with measure of Gf. Practically, it must also be recognized that the learning component in Gf is not completely devoid of exclusive and intensive acculturation, so that it, too, is to some extent confounded with Gc. But the essential hypothesis of this study is that the functions of equations (1) and (2) can be separated as distinct linear components in performances on a wide sampling of putative tests of intelligence.

Cattell (1957) has likened crystallized intelligence to a coral deposit left after the "polyps" of fluid intelligence have done their work of perceiving and educing the essential relations needed to build up concepts and aids. This analogy is a bit misleading, however, in implying that the skills deposited in Gc constitute a rather dead residue. Far from this, these learned skills are perhaps the most dynamic parts of intelligence. New learning is facilitated by previous learning and new concepts and aids are created out of the old. Gc is thus a very active, forward-looking component of intelligence. Indeed, in many prediction situations, such as in schools and in industry, particularly when predictions are made over relatively short periods of time, Gc will account for a greater proportion of the cri--terion variance than will Gf. In part this may be due to greater confounding of the predictor with the criterion--i.e., the fact that some of the same cultural acqusitions are as--sessed in both measurements--but in part it is due, too, to the fact that what is learned and deposited in Gc serves to facilitate learning and performance in a wide range of situations.

Some implications of these theoretical statements on development are represented graphically in Figures 1 to 3. The points on the curves are averages at each age level. First, consider figures 1 and 2. These are intended to suggest that:

1. Both Gc and Gf develop rapidly in childhood at decelerating rates. In Gf the rate becomes particularly slow after the point where growth ceases and in Gc after the point where formal education ceases. The latter tends to occur somewhat later than the former in our society, but both points tend to be reached by the late teens and/or early twenties for

Figure 1: Development of Fluid Intelligence (Gf) and Crystallized Intelligence (Gc) in Relation to Maturational Growth and Decline to Neural Structures (M), Accumulation of Injury to Neural Structures (I) and Accumulation of Educational Exposures (E)

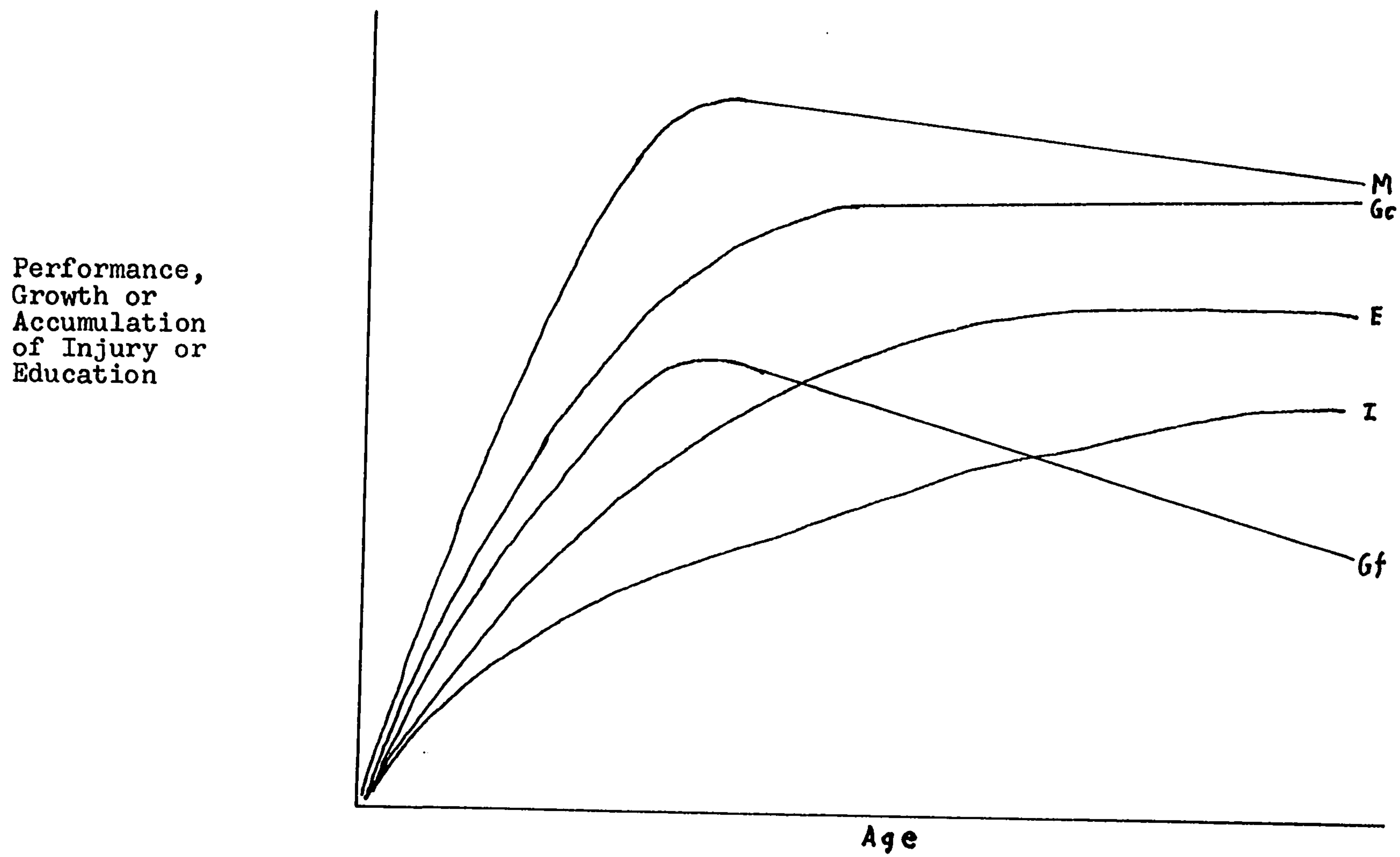


Figure 2: Variance on Gf and Gc as a Function of Factors Operating in Development

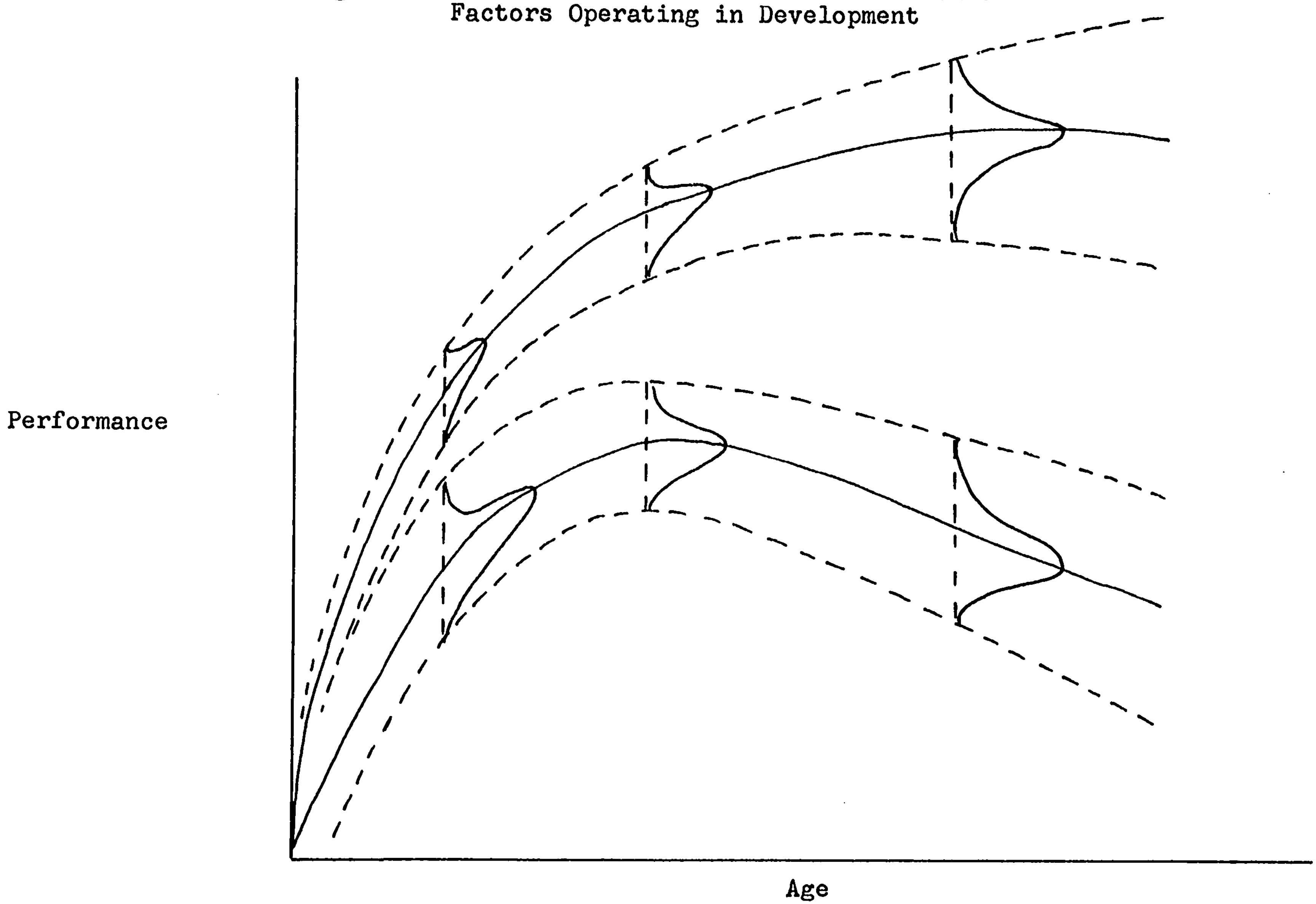
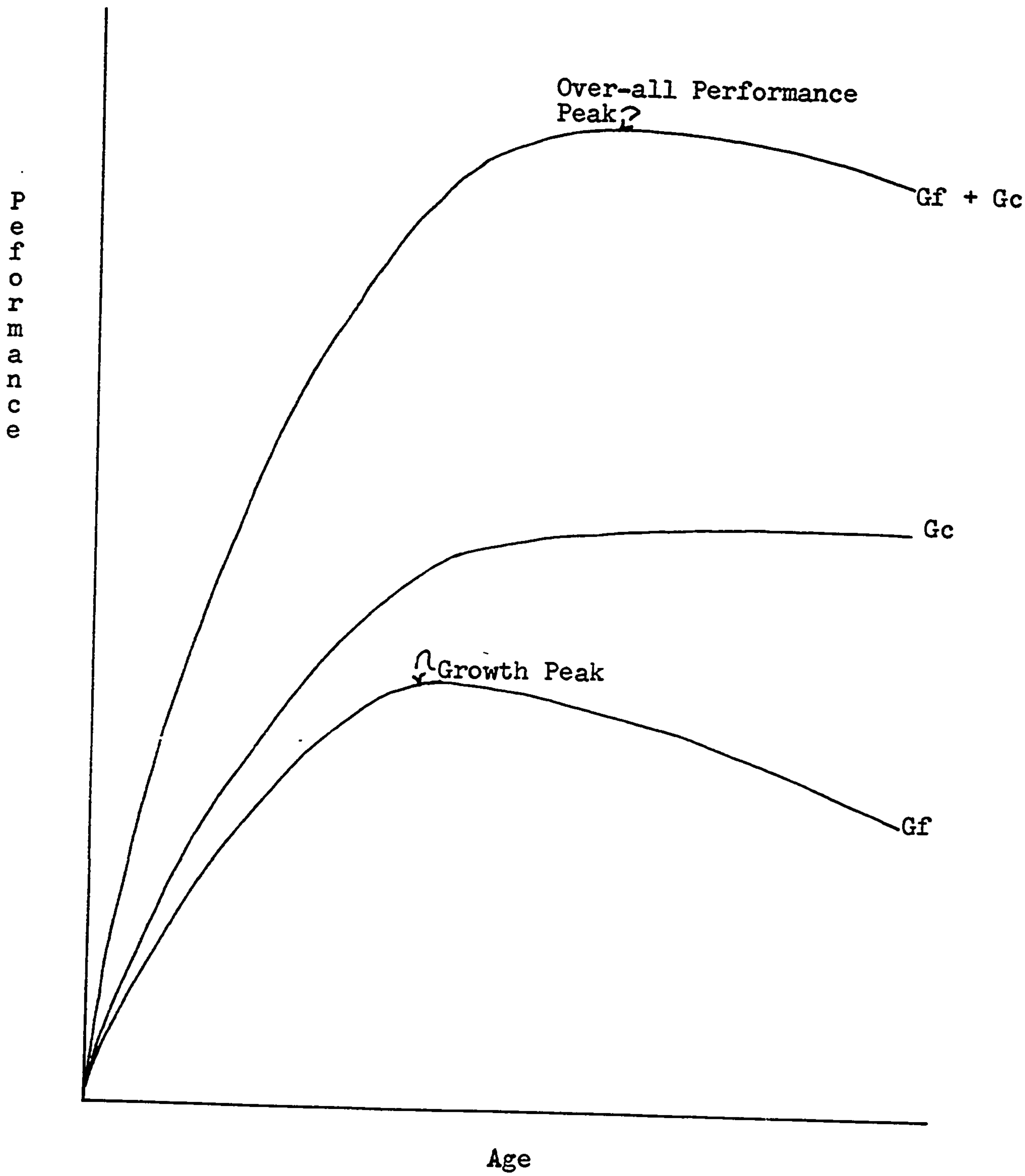


Figure 3: Overall Performance As a Function of Both Gc and Gf



most people.

2. Gc and Gf are virtually indistinguishable in the very early years of development. They come to be distinguished as a function of various influences operating in development.

3. The development of Gf is crudely the sum of the functions representing maturational growth and decline and the accumulation of CNS injuries.

4. Decline of Gf in adulthood as a result of intrinsic maturational degeneration is probably small relative to the decline due to the accumulation of injuries. There are wide individual differences in amount of such injury, as a function of living habits, working conditions, etc., and this is manifested in increase in variance on Gf as age increases, as suggested in Figure 2.

5. Gc is a function sum of Gf and the accumulation of educational exposures. Since the latter increases throughout life, Gc will tend to increase as long as the rate of increase in E exceeds the rate of decline in Gf. Worded another way, Gc will tend to increase as long as the accumulation of educational exposures exceeds the sum of decline due to maturation and to the accumulation of injuries.

6. As shown in Figure 2, the variance in intellectual performances associated with Gc increases steadily as a function of the intensification of the acculturation which accompanies

aging throughout both childhood and adulthood.

Figure 3 extrapolates to some points not previously alluded to. The suggestion here is that overall intellectual performance may be viewed as a sum of the Gf and Gc functions. This may be what is measured in some omnibus tests, but in fact it would seem these represent rather arbitrary mixtures of the two kinds of intelligence. A better indication of the way these two functions seem to yield over-all intellectual functioning may be found in the work on "real-life" creativity and productivity reported in the works of Lehman (1953) and Dennis (1956).

Taken together, these two researches suggest that the greatest productivity in intellectual work, such as science, literature, the arts, etc,, is achieved on the average in the third or early part of the forth decade of life. However, if Lehman's data are taken at face value, the results indicate that the most creative work--contribution of greatest merit--is often accomplished before the period of maximum prodcutivity. Of the 52 greatest discoveries in chemistry (as judged by three chemists) half were made before 29, 62% were made before 40 and all were made before 60. The greatest works in less technical fields, such as literature, tended to be completed at even earlier ages, although in all fields, but perhaps particularly music, quite outstanding work was completed by people of all ages up through the 50's, 60's and, in some cases, 70's and 80's. Of course much of Lehman's data is based on achievements occurring before the period of formal education became as protracted as it is in technologically-advanced nations today. A look at recent Nobel prize winners and the ages at which their great discoveries were made suggests that the most creative works are being completed somewhat later in life today than they were in previous times.

In any case it would seem that a high level of intellectual creativity and productivity is most likely when the sum of Gf and Gc is a maximum. This maximum is almost certainly reached after a peak in growth of neural structures is reached. The actual age of over-all intellectual peak will probably vary a great deal between individuals as a function of wide differences in prolongation of intensive education, amounts of brain damage, etc.

2. Measurement Properties Allowing For Distinction Between Hypothesized Factors

The factor analytic results reviewed in the previous section have been summarized in Table 12. Here, it will be noted, it is implied that some four more or less distinct kinds of function might be identified at a second-order level of measurement. Most of the primaries are assumed to involve more than one of the second-order dimensions, but a clear discrimination between the latter is nevertheless suggested.

It is assumed that both Gf and Gc involve the processes of noegenesis and abstracting in reasoning. As revealed (in theory) by differences between persons, the two differ in terms of the relative efficiency of anlage functions, in terms of the fullness and adequacy of the store of concepts in long-term memory, and in terms of the aids which can be brought into use to solve problems.

The primaries which most sensitively reflect Gf function are those containing problems in which difficulty is introduced by requiring the subject to perceive complex relations, educe correlates, etc. in the immediate situation and among fundaments (i.e., in "content") that are either novel for all subjects or very common--i.e., simple shapes, every-day words, etc. CFR and CFC are clearly seen to satisfy these assumptions. I, based on Letter Series,

TABLE 12

Hypotheses Derived From Previous Research Concerning Higher Order Factors Among Primary Mental Abilities

Primary Factor Symbols		Title and Representative Markers	Second-Order Factor Gf	Gc1	Gc2	Gv
1.	CFR	Figural Relations (Figure Series, Matrices, Spatial Relations (Topology)	**			*
2.	CFC	Figural Classification (Figure Classifying Identical Forms)	**			*
3.	I, NSR	Induction, Symbolic Correlates (Letter Series, Number Series, Letter Grouping)	**	*		
4.	CMR	Semantic Relations (Verbal Analogies, Word Squares)	*	*		
5.	CMC	Conceptual Classification (Word Classifying, Directions (Sentence Evaluation)	*	*		
6.	R, CMS	General Reasoning (Arithmetic Reasoning, Distances, Areas)	*	*		
7.	Rs, EMR	Syllogistic Reasoning, Logical Evaluation (False Premises, Inferences)	*	*		
8.	EMT	Judgment (Practical Problems, Absurdities)	*	**		
9.	N	Numerical Operations (Additions, Fractions)	*	*		
10.	MK	Mechanical Knowledge (Mechanical-Electrical Information)		*		*
11.	EMS	Experiential Evaluation (Proverbs, Social Situations)		**		
12.	V, CMU	Verbal Comprehension (Vocabulary, Information		**	*	
13.	NMU	Concept Naming (Picture-Group Naming, Word-Group Naming)		**	*	
14.	FW,DSU	Word Fluency (Suffixes, Prefixes)		*	**	
15.	Fi,DMU	Ideational Fluency (Topics, Things)		*	**	
16.	Fa,DMR	Associational Fluency (Conclusions, Associations)		*	**	
17.	Vz,CFT	Visualization (Paper Form Board, Paper Folding, Punched Holes	*			**
18.	Cf	Speed of Closure				**
19.	Cs,DFU	Speed of Closure (Gestalt Completion, Mutilated Words)	*			**
20.	DFT	Figural Adaptive Flexibility (Map Planning, Matches)	*			**
21.	MFU	Visual Memory (Memory for Designs, Map Memory)	*			*
22.	Cf,DFT	Flexibility of Closure (Gottschaldt Figures, Designs)	*			**
23.	S	Spatial Orientation (cubes, coads, Figures)				**

Letter Grouping, etc., can be seen to involve some crystallized-like awareness of the order of the alphabet, but it can be assumed that most adults would have had ample opportunity to learn this. CMR and CMC insofar as they involve common, everyday words would be expected to yield Gf variance.

On the other hand, the primaries which measure Gc-function most clearly will be those which reflect the comprehensiveness and complexity of the sample of aids and concepts which an individual has drawn from the collective intelligence of his culture. It is implied that the <u>more</u> elements the person has mastered, the greater his Gc. This implies, too, that Gc is characterized by the abstruseness of the knowledge a person possesses. Gc, like Gf, can be measured in tasks calling for reasoning in the immediate situation, but in order that it be distinguished from Gf it is necessary that the problems also require rather esoteric concepts or use of some rather advanced cultural aids (e.g. calculus). Thus CMR and CMC will tend to measure Gc rather than Gf to the extent that they involve unusual terms, and R or Rs will measure Gc rather than Gf to the extent that they require, in the first case, use of advanced mathematical techniques and, in the second case, use of the formalized techniques of logic. To the extent, then, that a task requires reasoning in the immediate situation and the fundaments of the task are abstruse, Gf and Gc can be cooperative and difficult to distinguish.

As one comes down the list in Table 12, from about the fourth factor to about the thirteenth, the tasks tend to involve less reasoning, abstracting, etc., in the immediate situation and more ability to recall relations, concepts and concept labels learned at a previous time; more and more of the variance of the tasks comes to represent familiarity, and the lack of it, with the formal culture. This variance tends to be more exclusively associated with Gc than with Gf.

At some point in this transition, however, according to the present evidence, it may be necessary to make a distinction between a Gc_1 component, representing primarily variance in subtlety of understanding of cultural concepts and ability to actually use cultural aids, and a Gc_2 component, representing mainly a fluency in recalling (and perhaps in manipulating) concepts and/or the signs for concepts.[1] The suggestion thus is that if Gc is a unitary function, it may be necessary to find it so, not at the second order among primaries, but at the third order.

Both Gc_1 and Gc_2 are related to a long-term memory function. It would seem, in fact, that both involve in this sense the same function: the same information in the same permanent storage compartment is involved in both. But in Gc_2 there appears to be variance on an added function of ease of transfer from the big memory "drum" to the immediate-access or short-term memory drum. The implication is that this ease-of-transfer function is somewhat independent of both Gf and Gc_1 and that, in fact, Gc_1 depends rather more on the span-of-apprehension function which partially governs Gf than does Gc_2. In other words, it would seem that the ability to reason, abstract, and to educe correlates, as represented in Gf and, with crystallized content, in Gc_1 may be largely independent of a facility in recall of information; or if the fluency factor does not so much represent the concepts or information, as such, but only the labels that are used to tag concepts, then the suggestion is that ease in translating such labels from the big memory drum to the immediate-access drum may be a deceiving indicant of the complexity of problems a person can solve.

Related here is the role of short-term memory in the definition of Gf, Gc_1 and Gc_2. Although the factor analytic evidence does not strongly suggest it, the hypothesis is that Gf, principally, should be defined by this kind of memory, as presumably represented in immediate meaningful memory (MMR), etc. (see Guilford, 1960), as well as immediate memory span (MSU). There is a suggestion from Ruch's (1934) early work that perhaps this Gf function is related to a kind of "plasticity" in the sense of a capacity for "extensive reorganization of pre-existing habits". If so, when a memory task requires no "extensive reorganization" of existing habits, as in meaningful memory, there may be relatively little Gf function involved, whereas if the task is purely rote or, worse, involves nonsensical contradictions of what is meaningful, as in Ruch's False Equations test (where the subject is required to remember that 9-1=4), it should have relatively more of its variance on Gf. Thus a task like Meaningful Memory would be expected to split its variance rather evenly between Gf and Gc_1, whereas a task like Ruch's False Equations should load almost exclusively on Gf, and neither task is expected to correlate substantially with Gc_2.

It will be noted that the second-order factors are assumed to be defined across several of what Humphreys (1962) has described as "facets". That is, Gf, for example, is assumed to transcend a content facet: it will be manifested in some primaries involving figural content, some emphasizing semantic content and some utilizing sumbolic content (according to Guilford's (1960) Classification of Content). Looked at another way, the theory states that Gf function should be identified by several of what Campbell and Fiske (1959) refer to as "methods" or be carried by several of what Cattell (1961) has defined as "vehicles". This latter emphasizes that there is a behavioral consistency, a sub-trait, as it were, associated with "content" or "method". This is more nearly in accordance with the Spearman (1928) and Burt (1950; 1962) idea that intelligence is manifested in many perceptual and sensory processes, which, themselves, are traits of individual differences at a low level in a hierarchy of such processes. Thus when Gf is measured in primaries like CFR and CFC it may be said to be carried by a vehicle which might be termed "visualization": intelligence is manifested in visualization functions. By this notion, too, Gf is expected to transcend the facet of speededness of test administration or to be "carried" in the vehicle of speediness of performance. Likewise Gc may be said to be "carried" in the vehicle of fluency of performance.

The problem posed by this consideration of facets and vehicles is one of distinguishing what is assumed to be broad central intellectual functions from various possible, narrow and perhaps peripheral functions. In this regard, the past evidence indicates that there probably is a rather general visualization "vehicle" and that, unless care is taken, this can be confounded with the measure of Gf.[2]

It so happens that performance on many tests of intelligence depends very heavily on use of vision. Yet it seems that various kinds of defects in vision are fairly common: these appear to be roughly normally distributed among children (White House Conference, 1931; Hayes, 1941) and, as has been noted, the incidence of such defects rises steadily with age in adulthood (Korenchevsky, 1961). When such defects exist from birth or early childhood, they may retard development of certain intellectual skills, but the argument is here that they do not retard development of Gf, as such, although they will adversely affect the ability to perform on those tests for Gf which are couched in terms of problems that require visual discrimination of relations. As Table 12 indicates, Gf will be distinguished from Gv primarily by the fact that, although both may involve visualization in figural or spatial content, the former will more definitely involve the processes of educing correlates, abstracting and reasoning with fundaments, whereas the latter will entail, primarily, a kind of fluency and acuity in actually seeing the fundaments and their differences. Most figural tasks will be cooperative on Gf and Gv, this indicating that all figural visualization tasks involve some perception of relations and that all attempts to use fluid intelligence on such fundaments must be premised on some ability to visualize. But if the complexity of the relations of a visualizing reasoning problem can be increased without increasing the need to employ visual acuity and fluency in perception, the proportion of variance on Gf will increase relative to that on Gv, whereas if the complexity of the relations is reduced and the demands for visual acuity are increased, the opposite will occur. More importantly, Gf will not be defined exclusively by tasks which involve figural-visual content, whereas Gv will be defined only or primarily, by such tasks (but see footnote 2).

Humphreys (personal communication) has cited some evidence indicating that the Gv variance in visual tasks can perhaps be increased by increasing the speededness of the task, whereas Gf (or possibly Gc_1) variance can be introduced by reducing the task speededness to a low point. In using the spatial relations factor to predict pilot success, it was found that the largest, stable beta weight resulted when the task was given under moderately speeded conditions. It appeared that if given enough time, an intellectually able person could "figure out" the right answer even in the absence of ability to "see" the right position more or less directly. But apparently the former was not (as measured in this factor, for it was picked up in other factors) the ability needed to fly an airplane. What needed to be measured in S was an ability to quickly visualize correct position, etc., without resort to intellectual analysis. Somewhat paradoxically in this regard Vz tasks were found to yield the best beta weights when administered under power conditions, or when a K-"wrongs" score rather than the "rights" score was used. It is possible that, particularly when this latter kind of scoring was used, a persistence or carefulness attribute was measured, rather than Gv (which, by the above arguments, was already represented in the prediction equation by S) but it is also possible that when used in this way Vz was picking up Gf variance that was not otherwise represented in the equation.

There would appear to be no real problem in distinguishing Gc and Gv, but it is anticiapted that in tasks like Mechanical Movements there should be substantial Gv variance (as well as some on Gf) and, insofar as mechanical information is involved, some Gc variance, as is indicated in Table 12.

The relationship of speediness function (or functions) to the proposed Gf-Gc dimensions has been most difficult to cope with, both theoretically and in terms of existing results. It seems evident that some speed variance of one sort or another is involved in most ability measures, even in so-called power tests, as Morrison (1960) has pointed out. Such variance could be the result of individual differences in the maximum rate with which thinking and problem solving could proceed, and in theory such a maximum rate might or might not be highly related to the maximum complexity of the problems individuals could solve.

It will be recalled that Spearman (1927) pointedly rejected the notion that "goodness" and "speed" of problem solving "constitute distinct group factors or produce noteworthy specifics...The almost unanimous view that some persons are on the whole unable to think quickly and yet are quite able to think clearly would seem to be a most grave error" (Spearman, 1928). The substantial-to-high correlations frequently found between tests administered with and without time limits, as well as the factorial results obtained using tetrad difference analysis of specifics and similar techniques (e.g., Bernstein, 1924; Spearman and Hunt, 1914; Sutherland, 1934), have frequently been taken to support this view. However, the more recent results from several investigations (e.g., Baxter, 1941; Davidson and Carroll, 1945; Furneaux, 1952; 1956; 1961; Hall, 1945; Himmelweist, 1946; Howie, 1956; Ford, 1956; Morrison, 1960;

Myers, 1952; Nummenma, 1960; Rimoldi, 1951; Slater, 1938; Tate, 1948) suggest that speediness and level of performance in ability tests can be separated and that some speediness functions may be largely independent of general intelligence or a function like the fluid ability hypothesized in this study.

Morrison (1960) emphasized a distinction between:

1. "pure" speed tests -- i.e., speeded tests comprised of items so simple that all subjects would get all problems correct if the test were not speeded
2. power tests or tests in which subjects are given virtually as much time as they want to work on difficult problems, and
3. Intermediate speed-power tests in which items are of average difficulty and time limits are set so that not all subjects attempt all items.

In his test administration, Morrison distinguished over-all timing of a test from pacing, in which the subject is given so much time for each and every item. In his scoring of tests he distinguished between a "rights" score --i.e., counting the number of correct answers - and a "wrongs" score - counting the numbers of incorrect answers. This procedure was based on the previous work of David (1947) and Fruchter (1950) who had found separate "carefulness" factors defined by the complement of the "wrongs" scores.

Although his rotation procedure was by no means "blind" , Morrison's results nevertheless indicate a "paced speed" factor, interpreted as an ability to produce correct responses rapidly on demand (intellectual speed component), a speed factor in timed but unpaced tests, and in accord with the results of Davis and Fruchter, a "carefulness" factor, defined by the complement of the "wrongs" score.

Howie (1956) found that carefulness and speed in performance on IQ-test problems were largely independent, and that speed appeared as a broad factor in a variety of such problems. Davidson and Carroll (1945) concluded from their analyses that the contribution of speed and power factors to the variance of a test depended on the content of the test as well as the difficulty level of its items. But they found a speed factor common to all speeded tests in addition to factors of intellectual speed and power. Likewise Lord (1956) reasoned that there might be separate speed factors for various kinds of tests or "primary" abilities. He analysed timed and untimed versions of parallel tests for V, S, R and N along with several other markers for the factors French (1951) has listed. He found evidence for separate N - Speed, S - Speed factors (but none for R) in a space which also included P and Fw (other speeded functions), as well as a verbal-academic grades factor. It would appear that, at a higher order, these several speed factors would resolve into perhaps two general dimensions, one involving rather simple intellectual tasks and one involving some variance in common with R and other reasoning factors. Rimoldi's (1951) results suggest just this kind of distinction between a speed factor of temeprment, style, effort or the like and one of intellect.

In his early monograph French (1951) listed a primary factor which he said.."looks like a very general speed factor". Although in one study he reviewed (viz. that by Rethlingshafer, 1942) there were loadings on very simple non-intellectual variables like tapping speed, in most of the studies the dimension was found to be defined by loadings on intellectual tasks like common sense reasoning, Same-Opposite Vocabulary, Verbal Analogies, Speed of Reading in a variety of topic areas, and simple relation-perceiving, "perceptual ability", (Cf. Davidson and Carroll, 1945; Hall, 1945). By inspection at least, the function involved here would seem to be that which Furneaux (1956; 1961) has isolated and labeled as "intellectual speed". Furneaux presents methods for measuring this factor which may allow it to be defined somewhat independently of the speediness which, according to the work reviewed by Pawlik and Cattell (1965), is primarily associated with temperment and/or motive traits.

Furneaux's main argument is that score on ability tests (regardless of content) is largely a function of three "relatively independent", fundamental subject determinants, which he terms "speed", "accuracy" and "continuance". By speed he means "the rate at which a 'search' process, ahving as its object the solution to a problem, can proceed". By accuracy he means the adequacy with which trial solutions evolved by the "search" process can be, or are, checked against the demands of the problem. Worded otherwise, accuracy refers to the ability to distinguish "nearly right" from "truly right" solutions to problems (and, in a test, as these "truly right" solutions are defined by the test constructors). By continuance Furneaux has regard for the fact that no rational subject is willing to, and no subject is able to, spend infinite time on any one problems or set of problems, and that, contrary to what sometimes seems to be supposed, a subject does not necessarily stop work or guess on a problem simply because of lack of persistence. Furneaux then goes on to list several factors which logically might underlie an apparent instance of continuance.[3]

To obtain measures of these three "relatively independent" attributes, Furneaux has gone through some rather elaborate and complex scaling procedures, details of which will not be fully reproduced here. Only the speed and level factors will be considered in this study.

To measure the speed function it is necessary, according to Furneaux's position, to use problems which involve complex relations, so that noegensis is involved and not all of the variance can be ascribed to temperment and/or motive, but the complexity should be of an order such that the person can actually cope with it. In other words what should be measured is the rate at which correct solutions, and only correct solutions, are produced to problems of more than trivial difficulty. This is the basic idea although the actual procedures used to obtain SP measurement are a good deal more complex than this.[4]

But the question posed here is whether a speediness function like this should have substantial variance in Gf or be largely independent of Gf. It will be recalled that in Birren's and Welford's discussions of aging changes in abilities, it was suggested that the inability to perform quickly, even on rather simple clerical tasks (if they required the subject to keep several different bits of information simultaneously in immediate memory), could be an indication of breakdown in the function of anlages and these are greatly involved in the Gf function. The implication from this reasoning is that tasks which involve very little by way of reasoning or abstracting (i.e., noegenetic proces) may nevertheless show up with fairly high correlations with the Gf factor. But this should not be taken to mean that Gf must, or should be, measured by speeded tasks, as was implied in some of the earlier statements of the theory (cf. Cattell, 1957). The above-mentioned relationship of Gf to a simple speeded task is, in a sense, artifactual--i.e., if it is interpreted as meaning that the task involves abstracting and noegenesis in a high degree. The essential characteristic of such a measure (when it is sensitive to Gf differences) is that it requires the subject to use the full span of his capacity for immediate apprehension, or taps some similar anlage function. It is not the speediness, per se, which defines Gf. Gf spans the facet of speeded test administration.

The intellectual level factor which Furneaux defines may allow for some test of this hypothesis. This seemingly involves reasoning (abstracting, etc.) in the immediate situation and with relatively culture-fair materials (thus a measure expected to help define Gf) but it is largely devoid of speed variance. The measure consists of a set of open-ended letter series items arranged in cycles of difficulty. "The first problem in each cycle is very easy, each succeeding item is of greater difficulty than its predecessor, and the last is so difficult that few can solve it correctly even when given unlimited time." (Furneaux, 1961). There are five items in a cycle and seven cycles in the test. The subject is encouraged to strive for the correct answer without greatly concerning himself about how long it takes. However in the instructions to the test an example is given in which there is no apparent answer and the subject is told that:

> This example is given in order to show you what to do if you find you can't work out a satisfactory answer for some of the problems of the test. Several of the problems are quite difficult and you may find that you have to give up on them. When this happens just put a dash in the answer space before passing on to the next problem. (Furneaux, 1956)

In the scoring, the proportions correct out of those attempted at each level of difficulty are summed. The score thus represent the average difficulty of the problems the person is able to solve independently of how many problems he attempts in the time period. For example, the two subjects below would get the same scores even though one attempted twice as many problems in the time period as did the other.

		Subject A			Subject B		
		# Items Attempted	# Items Correct	Proportion Correct	# Items Attempted	# Items Correct	Proportion Correct
Difficulty Level	1	3	3	100	6	6	100
	2	3	3	100	6	6	100
	3	3	2	67	6	4	67
	4	3	1	33	6	2	33
	5	3	0	00	6	0	00
Score				300			300

It might seem at first glance that the carefulness factor (C) which has been sound in several researches (See French, 1951, and Fruchter, 1950; 1953) would be the same as the intellectual level measure described above. Carefulness is obtained from wrong-response scores on various kinds of speeded ability tests (again, as in the speed and level measures, the test content does not seem to be crucial, but only a facet of the measure). However, on more careful examination it can be seen that there is no necessary relation between carefulness and level measures and psychologically they could be quite distinct. Carefulness is obtained from speeded tests in which, usually, items are of moderate difficulty. Thus a correct answer indicates ability to cope with moderate complexity. The carefulness score itself indicates an unwillingness to guess and the subjects' unwillingness to leave a problem until he is "absolutely sure" that his answer is correct. The level measure, on the other hand, is obtained under pure power conditions in which the score indicates the level of complexity of a problem a person has solved, whether or not he is willing to guess or to leave a problem before he is "absolutely sure" his answer is correct. In fact the carefulness measure would seem to be more closely related to Furneaux's "continuance" measure than to the "level" factor. At any rate the hypothesis is that the two are at least somewhat independent and that carefulness is probably related to a non-intellectual attribute such as the one referred to in some of Webb's early work on persistence and will-control (see Spearman, 1928) or one of the factors found in studies of neurotic debility (Eysenck, 1953; Scheier, Cattell and Horn, 1961).

Gc is also expected to transcend the speededness facet. This, again, is not to say that it should be measured in speeded tasks. Rather it is to say that Gc will be defined by both power and speeded factors. For example, Gc is to some extent manifested in speeded fluency tasks, as well as in power-like Vocabulary and General Information Variables.

Christensen and Guilford (1963) and Taylor (1947) have pointed out that the relationship between speed of production in fluency and ultimate amount of production is theoretically complex. For example, it may be that if a person has a great number of elements on the big memory drum, time may be consumed in searching through these for the elements that are relevant to the task at hand. Thus performance might tend to be slow even though, because there is a large store of relevant elements on the big drum, the ultimate amount produced might be large. But if a task were highly speeded the person with much on his big drum could obtain a lower fluency score than the person with a relatively small store of relevant elements. If, however, a task allowed persons sufficient time to nearly exhaust their stores of relevant elements, the first-mentioned person would get the higher score. On the other hand it is possible that if a person has very few elements on the big drum, he must still search through the same number of "cells" as the person with a large store of elements: to again use the computer analogy, employed in previous sections, it might take just as long to clear a nearly empty memory drum as it does to "clear" one in which almost all of the cells are filled with information. In this case the person with much on the drum would not only obtain the higher ultimate score, he would also obtain the higher score over early, short time periods.

Christensen and Guilford (1963) have presented some results which favor this latter position, although the evidence is by no means unequivocal. They obtained scores on Ideational Fluency and Associational Fluency in four time periods--first half-minute, next 1.5 minutes, next

1 minute, next 2 minutes--and then they noted the difference in factor loadings of the various time-period subtests on the relevant factors. Thus for Fa in their first study, for example, the loadings were .42, .42, .33, and .32 respectively for the four periods mentioned above. This particular example illustrates the closest thing to a trend that Christensen and Guilford found. In Ideational Fluency the loadings were about the same for all four periods. Taking this evidence at face value, then, it would appear that fluency under fairly speeded conditions involves much the same factors as fluency under more leisurely conditions.

In terms of the present hypotheses, the suggestion from Christensen and Guilford's work is that fluency performances, generally, whether or not speededness enters into these, will tend to indicate size of store of information on the big memory drum and facility in getting this information from the big drum to the immediate-access drum. The former, i.e., the amount of information on the big drum, is directly related in theory to Gc, but the latter may not be. Theoretically, it could be an anlage related to Gf. But the evidence summarized in Table 12 does not support this theory.

Introspection on the process of performing on intellectual tasks like the fluency measures surely suggests that some of the variance in such performances results from a kind of motor speed, motivational ardor for the task at hand, and the like--i.e., factors which would theoretically be expected to be largely independent of the speed of central intellectual functions, as such, or of valid measures of intellectual functions. The extent to which these non-intellectual sources of variance on speeded tests obscure the view and distort the measurement of intellectual processes is an empirical matter, but one which is particularly difficult.

Thus distinction must be drawn here between non-intellectual factors which involve intellectual variance and intellectual factors, as such, and the distinction is by no means easy to make. Pawlik and Cattell (1963) have recently reviewed a mass of data relating to mainly non-intellectual personality factors in objective tests, and in this they show that several dimensions which are defined by stated attitudes and beliefs, self-evaluations, and the like, also involve substantial variance on motor-type speed measures and, in several cases, on measures such as those of P (Perceptual Speed) and the various fluency factors, i.e., factors which would ordinarily be said to belong in the intellectual realm (see Table 13). This points up the fact, of course, that the boundaries in

TABLE 13

Some Speed-related, Carefulness-related Non-intellectual Personality Factors in Objective Tests (After Cattell, 1957; Pawlik & Cattell,1965).

UI-16	Assertive Ego vs. Disciplined Ego. Fast tempo (leg circling, reading); fast motor and perceptual performance (tapping, Gottschaldt figures); "highbrow" tasts; agreement with platitudes.
UI-17	Timid Inhibitedness vs. Lack of Inhibition. Cautious slowness (Gestalt completion, high index of carefulness on several tasks); confidence in doing skills and "highbrow" tastes.
UI-18	Hypomanic Smartness vs. Slow Thoroughness. Rapid, superficial judgments; fast motor and perceptual performance (total CMS score, spatial integration); innacuracy (errors on CMS and perceptual closure); shift attitudes towards those of "successful" people.
UI-19	Promethean Will vs. Subduedness. Controlled, exact, low-distractability; self-complacent criticalness of others.
UI-21	Exuberance vs. Suppressibility. Word and idiational fluency; fast motor and perceptual performance (letter comparisons); less experience and confidence claimed.
UI-22	Cortertia vs. Pathemia. Fast tempo; fast immediate responsiveness but low endurance; fast reactions.
UI-23	High Mobilization vs. Neurotic Regression. Lack of rigidity (writing flexibility); fast tempo (reading, number ability); accuracy (coding reversed drawings); high endurance of difficulty.
UI-24	Unbound Anxiety vs. Good Adjustment. Many anxiety-tension symptoms checked; verbal fluency, high ratio of accuracy to speed in variety of tasks.
UI-36	Foresighted Self-Sentiment vs. Low Self-Integration. Few problems missed on PMA tests; high verbal ability; Life goals distant in time; dynamic self-sentiment in MAT.

personality which we draw in theory and ultimately in measurement are to some extent arbitrary conventions. And even in theory it is necessary to recognize that intellectual functions influence the development, and thus the manifestation, of non-intellectual functions, and vica versa. However, it is to be supposed that the influence which determine intellect are in large measure independent of those which determine temperment and motive, so that in the long run in structural research it whould be possible to isolate intellectual and non-intellectual dimensions which are quite independent (although perhaps correlated) even though both involve speediness of performance and, in some cases, speediness on the same tests.

A summary of the major characteristics of the hypothesized general dimensions has been set out in Table 14.

TABLE 14

Summary of Task Characteristics Allowing for Measurment of, and Distinction Between, Gf, Gcl, Gc2, Gv & Gs

A. Gf Will be reflected in

1. Anlage functions

a. tasks requiring S to keep several "things" in mind at once; e.g.

i) complex reasoning tasks wherein the "things" are relations which must be perceived and where relations between these relations must be perceived or educed in order to reach solution, whether or not these tasks are speeded.

ii) simple clerical speed tasks wherein the "things" are simple items of information which have to be used from time to time in performing the task.

b. tasks requiring "extensive reorganization of pre-existing habits" (if any); e.g.

i) memory for information that may contradict previously learned information

ii) learning in an area where unlearning or previously learned material might (for some persons) be necessary.

c. tasks requiring good incidental memory or good immediate memory of any kind

d. tasks requiring fluency in perceiving and/or educing novel relations

2. Reasoning in the immediate situation in tasks requiring abstracting, concept formation and attainment, perception and education of relations, particularly when the task materials are culture fair i.e., the fundaments are either novel for all persons being measured or else are extremely common, usually overlearned elements of a culture, and the aids which are needed for solution are not skills which are made available (through the formal educational institutions of a society) to some persons and not to others among those being measured.

B. Gc will be reflected in

1. Gcl, and this in turn will be reflected in

a. breadth of awareness of and subtlety of relations previously perceived, concepts previously attained, etc., as indicated in tasks requiring recognition or recall of such relations

b. reasoning in the immediate situation in tasks requiring abstracting, concept formation and attainment, perception and education of relations but also requiring use of concepts and aids that are relatively abstruse elements of a culture.

TABLE 14 (Cont'd)

2. Gc2, and this in turn will be reflected in

   a. tasks requiring fluency in production of the labels (signs) standing for cultural concepts
   b. tasks requiring recognition of the signs for cultural concepts or aids.

C. Gv will be reflected in tasks involving visual acuity, sensitivity to light, breadth and width of visual field, depth perception, etc., in visualizing the movements and transformations of spatial patterns, maintaining orientation with respect to objects in space, unifying disparate elements and locating a given configuration in a visual field. Gv will be distinguished from Gf particularly when these tasks must be performed under moderately speeded conditions.

D. Gs will be reflected in

   1. tasks requiring speed of production, particularly when there is very little need to perceive relations (or when the relations are quite simple) or to visualize in the manner described under C above.

   2. tasks involving expression of attitudes, self-evaluations, beliefs, etc., as obtained in questionnaires, opinionnaires and objective tests not involving ability vehicles.

B. Consideration of Strategies For High-Order Factor Analyses.

The principal hypothesis of this study states that the so-called primary mental abilities listed in the left column of Table 12 are organized in a manner such that a simple structure factoring among their intercorrelations should reveal a pattern very much like that indicated for the second-order factors listed on the right in this table. The question now asked is how best to indentify these latter factors?

The procedure usually adopted in second (or higher) order analyses involves, first, factoring the correlations among tests to obtain the primary factors and then going to the second order by factoring the R_1 matrix of correlations between these primary factors as this is obtained directly from the transformation matrix that is used to carry the orthogonal primary factors into the oblique simple structure.5 In terms of the usual development of the common-factor model (see, e. g., Harmon, 1960) R_1 _is_ the matrix of intercorrelations among factors--i. e., it is not merely an estimate of these. Because this is so, it might seem that a second-order analysis would best be based on this, the "exact" correlations. However, in terms of broader scientific and sampling considerations, R_1 is obviously only a rather fallible estimate of the "true" correlations. One might therefore ask: "Is it the best estimate in the sense that second-order results based on it will tend to be more stable than those based on any other estimate?"

As argued more fully elsewhere (Horn, 1963d; 1965a; 1965b) it can be maintained that the computation of factors in a given sample of subjects tends to capitalize on chance fluctuations in the data in somewhat the same way as the computation of a multiple correlations tends thus to capitalize on chance. A graphically rotated factor is not usually a least-squares estimate, but the analytic (i.e., least square) rotation procedures (e.g., Varimax) remind us that it is approximately this because the solutions obtained under the two kinds of conditions are often quite similar (cf. Horn, 1963b). It is evident that the values of loadings for a factor obtained in a given sample are, to some extent, determined by the chance fact that in this sample a few correlations tend to be somewhat higher or lower than they would be if other samples were drawn.

If the factor scores were to be determined directly on the basis of the results obtained in a particular sample, the values of the factor loadings would come into this calculation (cf. Horn, 1964), thus implying that the differences between these loadings were noteworthy. And R_1 is the matrix of intercorrelations between factors determined in the manner here implied. Obviously it must be assumed that there is a noteworthy (and significant) difference between loadings for variables that are salient in the factor and the loadings for variables that are regarded as in the hyperplane, but it does not necessarily follow that the differences between loadings for variables in either of these two classes (i. e., those in the hyperplane and those which are salient)should be regarded as significant and noteworthy. For example, it is not unreasonable to argue that the variables in the hyperplane of a factor really have only chance relationships with the factor and that, therefore, the variation in value of the loading of these variables is not only significant, it is an indication of random variation. To utilize this variation to estimate the factor is thus to include random variables with different weights in the scoring equation. This argument implies that the hyperplane variables should not even be used in estimating the factor, much less be given different weights. Also, in general, to the extent that weights of a scoring equation are determined by procedures which capitalize on chance fluctuations, the equation which uses such weights will yield results that are less stable than those based on a equation which involves assigning equal nominal weights to all (salient) components (Horn, 1963c; Guilford, Lovell and Williams, 1942; Richardson, 1941). Thus to the extent that differences in factor loadings tend to be the result of chance fluctuations in a particular sample, the implied factor scores are less stable than those which could be obtained by merely adding the standard scores on the salient variables. By implication, then, the R_1 matrix, since implicitly it represents the correlations between factor scores based on the differential weighting procedure, will provide less stable estimates of the correlations than will a matrix based upon factor scores which are estimated by summing salient variables with equal nominal weights.

There are, however, some other aspects of this issue which should be considered. The arguments above are concerned with the sampling reliability of results, but they largely ignore questions dealing with the measurement reliability and representativeness of factors determined by simple unweighted linear combinations of marker variables. To see these problems clearly the focus of discussion must shift from the notion (above) of sampling subjects from some hypothetical population of people to the notion of sampling marker variables from some hypothetical domain of tests (Cf. Tyron, 1957). In other words it must be recognized that in factor analytic and similar multivariate work, there is need to generalize not only to a universe of subjects, but also to the universe of measurements which might be taken on these subjects.(Which is not to mention the universe of measurement occasions which is also implicitly involved in drawing conclusions from a multivariate study on traits).

Suppose single tests were taken to measure primary factors and a second-order analysis were based on the intercorrelations of these tests? If each test measured one and only one common primary, this procedure would presumably lead to a reasonably adequate definition of the second-order factors. However, if the tests overlapped in measurement on the same primaries, these latter could be mistakenly identified as the second-order factors; if the overlap on primaries were not great, and the second-order factors were very much over-determined, this might not be a serious matter because the unwanted primaries would be narrow and thus might not appear or, if they did, would not be likely to be confused with the more general dimensions which truly belonged at the higher order. As a practical matter, however, it is rather difficult to avoid extensive overlap on primaries when only a single test can be used to measure each primary-level factor.

But a factor viewed as a scientific concept must usually be seen to involve a much wider variety of behavior than is represented by a single test. In Humphreys' terms the behavior of a test may be regarded as a facet of the ability indicated in the factor. Thus, even when tests are reasonably common-factor pure, factors estimated by single tests are not likely to be highly representative, or valid in this sense (Cattell and Horn, 1965). On the other hand when representativeness of measure of a factor is achieved, the above-mentioned problem of unwanted overlap on primaries is also largely solved, because then the variance on unwanted components tends to be suppressed by other components in the scoring equation. It follows from these considerations, too, that the R_1 matrix mentioned above would usually represent correlations between primary factors that were representatively measured even though it might not yield the most stable second-order factors.

Taking all of the above considerations into account, it would seem that the most stable and yet representatively valid second-order analysis could be based on a matrix of intercorrelations among factors measured over several marker variables linearly combined with equal nominal weights.

C. Some Sampling Considerations

A primary concern in a factor analytic study (or any other study for that matter) must be to obtain a subject sample the size of which is adequate to meet the assumptions of the statistical model and the composition of which is adequate to permit generalization of findings and such that it will provide sufficient variance on the crucial factors under investigation.

As to the first matter, which is essentially a highly technical question for which there is, as yet, no thoroughly adequate answer, Tucker (personal communication) has pointed out that the factor model involces an assumption of zero off-diagonal elements in the uniqueness matrix of the basic factor analytic equation

(1) $X=AF + W$

He has also pointed out that these elements can tend to zero only as N becomes large. More analytically, the assertion is that the covariance matrix, C, is

$$C = \frac{1}{N} X X' = \frac{1}{N} (AF + W) (AF + W)'$$

which, for the purpose of obtaining the solution to the characteristic equation, may be represented by the super-matrices

$$C = \underset{\substack{V \\ (n,\ m+n)}}{A:U} \ \underset{\substack{L \\ (m+n,\ m+n)}}{\left[\begin{array}{c|c} C_{ff} & C_{fu} \\ \hline C_{uf} & C_{uu} \end{array}\right]} \ \underset{\substack{V' \\ m=n,\ n)}}{A:U}$$

(where W is an n,N matrix of unique-factor scores, X is an n x N matrix of original scores, A is an n x m matrix of common-factor coefficients, F is an m x N (factors by people matrix of common factor scores, and U is the n x n matrix of uniqueness coefficients). The assumption of the model is that the super-matrix L can be reduced to diagonal form. That is to say that the vectors represented by columns (say) of L are linearly independent. Now obviously if $N < n$, this condition cannot be met, because at least m of the roots of L must be zero-- e.g., L can be seen to be a product of matrices having maximum order N and the rank of a product of matrices cannot exceed the order of the smallest matrix in that product. If $N > m+n$, the possibility exists that L can be reduced to diagonal form, but insofar as there is any dependence implied by the sampling of subjects, the roots will tend to zero and this implies lack of linear independence. Hence, the requirement must be that N exceed m+n by a "considerable" amount, the excess $N-(m+n) = df$ being somewhat analogous to degrees of freedom as conceived in other statistical problems. Just how large df should be to assure the significance of the factor solution is still very much a debatable matter, but it seems generally to be conceded among those who work with factor analytic techniques and are aware of this problem (and the correlation between these two "events" is not necessarily very high) that the assumptions of the model are fairly well satisfied when $N = 3n$ and that size of sample is quite adequate on this count when $N = 5n$. Hence assuming roughly 60 variables, for example, a sample size of 300 would be adequate to determine factors which would tend to hold up in cross-validation.

The second issue broached above is a fundamental question of science rather than merely a technical-statistical matter, however, It does, of course involve the statistical concept of representative sampling from a population for which generalization of results is to be made, but strictly speaking, even this is not a question that can be answered by statistics: a population must be designated and this is a problem of scientific theory.

Now the theory here states that crystallized intelligence is derived from the interaction of fluid intelligence and a mass of influences which, for lack of ability to be more specific, are said to be represented in a process of intensive acculturation. At any given stage in development it is expected that people who possess a great deal of Gf will tend also to possess much Gc and likewise for these people who possess little Gf. The two intelligences are correlated, perhaps quite highly over persons all at a given stage of development. If opportunities for developing Gc were provided entirely on the basis of the intellectual merit indicated by Gf, if motives and other non-intellectual traits did not determine, in part, the extent to which these opportunities were used, if brain damage did not occur in different amounts and at different stages in development, etc., the theory would argue that Gf and Gc would be perfectly correlated among persons all at the same maturational level. Yet in order for the factors to be separable, this correlation must be considerably less than unity.

Now, of course, the conditions mentioned above could not be expected to exist in any sample one is likely to draw. Persons of the same age are not at the same maturational level, as the evidence here reviewed has indicated, and thus there is no way to draw a sample of persons all at the same maturational level. But even if this were possible, different amounts of brain damage, occurring at different stages in development would probably have preceded testing. And, of course, even in samples as homogeneous as those obtained at highly selective universities it would be expected that previous educational opportunities would not have been provided purely on the basis of "intellectual merit". There would be substantial motivational and temperament trait differences in most samples one can draw. Hence, on this basis it might be argued that just about any sample one can obtain to study human abilities is likely to contain enough variance on the factors in question to permit the hypothesized distinctions to be made (if Gf and Gc represent real phenomena). Following this dictate one might draw a sample of University of Chicago Freshmen.

On the other hand, however, it can be argued that the influences which are expected to allow for distinction of Gf and Gc (as well as Gv and Gs) may be small relative to the crudeness of the measures which must be used to detect them. As has been noted at various places in the preceding sections of this monograph, the performances which are supposed to characterize Gf and Gc are in fact brought about by many of the same influences. Both must reflect learning. This must occur under some of the same kinds of conditions. Much the same biological factors are operating in both. The distinction between intensive acculturation and merely acculturation is only relative. Gf, as it can be measured, is affected more by intensive acculturation than is ideally supposed and Gc cannot reflect this batch of influences exclusively. Likewise, the hypothesized differential effects of brain damage are only relative. Gf (again as it must be measured) is not affected as exclusively by these damages as is ideally supposed, and Gc, as it is manifested, may reflect more of this kind of influence than the theory argues. Thus these considerations imply that the correlation and cooperativeness between Gf and Gc might be great and empirical distinction might be very hard to make unless care were taken to draw a sample of subjects that was quite heterogenous with respect to the attributes in question. The implication thus is that a sample of University of Chicago Freshmen might not provide the needed heterogeneity.

It has been argued that the effects of intensive acculturation tend to be self-perpetuating and cumulative. In the early years of development the differences in intellectual performances which are caused by intensive acculturation are relatively small and haphazard as concerns the tests they affect. Time is required to produce a tendency toward equalization of opportunity to learn the concepts and aids of fluid intelligence. Tests cannot reflect the effects of intensive acculturation until such acculturation has occurred. For these and other reasons it might be very difficult to distinguish Gf and Gc at early ages. But as development proceeds, acculturation begets mere acculturation and the skills in Gc accumulate, with, perhaps, varying degrees of brain damage occurring along the way, Gf and Gc grow apart, as it were. Thus, the two factors can presumably be distinguished most readily at late stages in development, perhaps particularly in adulthood and after different amounts of small brain damages have had time to accumulate over several years. If it were argued that the correlation between Gf and Gc (as they must be measured) tends to be high under almost any circumstances and that, therefore, every effort must be made to reduce this correlation if the factorial distinction is to be found, then it would follow that one might draw a sample containing adults of different ages and from different social-educational backgrounds. The diagrams of Figures 1, 2 and 3 argue that, on the average, persons in the 30-50 age bracket would tend to be relatively high on Gc and down on Gf, whereas persons at their peak in Gf but not yet high on Gc could be found in the late teens and early twenties. Hence a sample over the age range from, say, 16 to 55 would be expected to provide enough heterogeneity to bring out the expected Gf-Gc distinction.

There is perhaps a logical difficulty inherent in the arguments of the last paragraph, for it can be maintained that if one is going to talk about two abilities changing with age, as is implied, then one needs to have evidence that these abilities are functionally distinct at each age level. If one must sample across different ages to bring out the proposed factorial distinction, then perhaps all the factors will represent is a miscellany of changes which occur with aging, not functionally distinct abilities at any given age. In a narrow sense of the theory here proposed, this does not matter, of course: the functional unities represented by the factors in question may be merely manifestations of processes inherent in aging. But in the larger sense of the theory, it does matter, for it is proposed that the Gf-Gc distinction is useful not only for making sense out of aging changes, but also for making sense out of, among other things, differences in performance associated with different amounts of brain damage among persons all of the same age. Yet it must be granted that two separate, worthwhile and functionally distinct patterns can exist and not show up as mathematically (statistically) distinct factors in a factor analysis: if brain damage were the only influence revealing the functional distinction, for example, and there was no brain damage among any of the people of a sample, factor analysis could not demonstrate the two functional unities. Thus the issue must again boil down to the question of deciding whether or not there is enough heterogeneity on the factors in question to allow for the proposed distinction.[6]

Given these contingencies, the "safe" procedure would seem to be to analyse a sample in which the variance associated with aging, say, (which is easier to include than variance associated with known brain damage) is allowed to operate. If the hypothesized distinctions do not appear in such a sample, the theory will be generally refuted.

Footnotes

[1] This latter would seem to be what some investigators (e. g. Anderson, 1959; Barron, 1958; Christensen and Guilford, 1959; Getzels and Jackson, 1962; Guilford, 1962 and perhaps Taylor, 1964) are calling creativity--particularly when the emphasis is put on the ability to manipulate concepts; but if it is this, according to the view presented here and as Burt (1963) has very cogently argued, it is so only in a rather narrow sense of the term. In fact, this kind of creativity, or this aspect of creativity, may relate more to non-intellectual personality than to intellectual abilities, as such. In any case both Gf and Gc_1 would seem to be better indicants of some kinds of creativity, or some very important aspects of creative thought and production, than would Gc_2.

[2] The fact that test constructors have tended to concentrate on figural content when attempting to devise relatively culture-fair tests reflects, in part, the fact that with young children, verbal tests cannot be used. According to the position taken here, however there is no necessary reason why culture-fair tests cannot be couched in verbal content, provided care is taken to use common verbal content. Test constructors of the future should probably work to develop parallel, cross-facet tests involving not only different content, but also requiring use of different sensory modalities--hearing, touch, etc. It is possible that the visualization function actually trancends the visual modality, and involves also an awareness of the way sounds reverberate in "space".

[3] The subject's estimate of length of test, chance he will ultimately solve the problem, time solution will take, progress thus far, how the test is scored, as well as his ego involvement with the test and item, his characteristic persistence and other factors.

[4] The details of Furneaux's scoring procedures are set out in Appendix I.

[5] That is, if T is the matrix which carries the arbitrary orthogonal factors, A, into the oblique simple structure, S, then R_1 is obtained by

$$R_1 = D(T^1\ T)^{-1}\ D$$

where D is a normalizing diagonal matrix containing the inverses of the square roots of corresponding diagonal elements in T. R_1 has often been referred to as the Cf matrix.

6 Also, if the Gf-Gc distinction obtained on the basis of sampling subjects with respect to age can, in subsequent study, be found by sampling subjects with respect to brain damage, or if the factors obtained in this manner are subsequently found to behave as predicted by corollary theorems in the general theory, such as the one predicting that Gf will show relatively large, reliable diurnal changes, whereas Gc will not, then it can be argued that the functional unity exists even if it cannot be identified factor analytically among normal subjects all of the same age.

PART III-AN EXPERIMENT FACTOR STRUCTURE AMONG LINEAR COMPOSITE MEASURES OF PRIMARY ABILITIES

A. Introduction

This is one of a series of descriptive, empirical studies designed to examine noteworthy implications of the theory of fluid and crystallized intelligence. The purpose here is to determine whether or not, when a broad sampling of so-called primary mental abilities is considered along with a sufficiency of non-intellectual hyperplane variables, two factors having the hypothesized measurement properties of Gf and Gc will be revealed at the second (or higher) order and there distinguished from possible visualization and speed functions.

The theoretical position adopted here argues that the concept of general intelligence stems from a recognition of a fairly consistent relationship between broad classes of influence operating during the period of development of abilities. On the one hand, the neural-physiological structures which exist to support display of intelligence (e.g., learning) at a given stage in development tend to persist and thus to continue to act to support display of ability at all later stages. Likewise, the learning which occurs at one time tends, through positive transfer, to facilitate learning at subsequent times. Thus, because the general influences operating at one stage are not fully independent of those operating at other stages, abilities measured at different ages tend to be positively correlated. Also, because the influences associated with physiological structure are not fully independent of those associated with learning, measures of various supposedly different abilities tend to be positively correlated. There results, then, a rather broad unitariness in the display of abilities and it is the perception of this which has led to the notion, found both in what might be called the "folk science" of people generally and in the more formalized discipline of psychology, that there is a single attribute of individual differences which can be labeled intelligence.

Insofar as the correlations referred to above are in--variant and high, the operational representation--i.e.,the measurement--of general intelligence can be unitary. However, insofar as these correlations are low and variable, there exists the possibility that the phenomena involved can be usefully conceived of, and measured, in terms of components which represent more cohesive sets of influences than the set represented by the general concept. In fact, of course, most factor analytic research on abilities has proceeded on the assumption that these last-mentioned conditions hold.

In the U.S.A., particularly, and particularly since the time of Thurstone's (1935) statement of the principle of simple structure and his development of multi-factor methods, but in fact dating from Burt's (1909) early criticisms of Spearman's

(1904) claim for empirical support for his two-factor theory of intelligence, there has been a steady increase in the number of "primary mental abilities" said to be established by means of factor analysis. The implication has been that the discovery of these factors supports the theory that the phenomena referred to in the concept of general intelligence can, indeed, be usefully conceived of in terms of more unitary components. In a general way, of course, this position is widely accepted in the field. But as Humphreys (1952) has pointed out, there is a good deal more involved in the definition of a worthwhile attribute of individual differences than merely isolating a factor and providing a plausible interpretation for it. And as he (Humphreys, 1962) has more recently argued, there is reason to suppose that some, perhaps many, of the so-called (or so-implied) "primary" components of intelligence do not qualify on these grounds as theoretically important or practically useful attributes. He suggests that some factors be looked upon, rather, as mere "facets" of the more truly "primary" or theoretically-meaningful abilities of man.

In a sense the issue which Humphreys provokes cannot be resolved, and perhaps should not be even if it could; for the issue has to do with the relative virtues of analysis and synthesis at a given stage in the development of a discipline and, as Comte pointed out many years ago, these questions can usually be answered only in retrospect, not at the time they are broached. Perhaps the "proliferation" of ability factors during the last 30 years--and particularly since World War II--has been excessive--"empiricism at its blindest,"[1] as Humphreys terms it. Yet it remains true that Guildord's work, for example, has generated considerable research on various kinds of problems concerning abilities and may yet turn out to be a major achievement of this period. Actually, as Comte also pointed out, analysis tends to call out efforts at synthesis. When investigation of phenomena trails off into seemingly endless listings of specifics, however accurate these may be, the human reacts by saying, in effect, "I must put these bits together into a meaningful whole if I am to understand." And so there are, in the history of a discipline, cycles of "elementarism" followed by "wholism." Guilford's own structure of intellect model, as well as the facet notion which Humphreys has championed, the multitrait-multimethod techniques of Campbell and Fiske, Cattell's perturbation-by-vehicle model, and various other proposals of this kind, are, in this sense, reactions to the incomprehensibility of the detailed findings generated by numerous factoral analyses. And the present study, likewise, may be viewed as a reaction to the trend towards proliferation of so-called "primary" mental ability factors.

The aim, thus, is to strike a compromise between the notion of merely listing large numbers of ability factors, as if they were unrelated books on a shelf, and the notion that the only theoretically-integrating concept in the ability area is that of general intelligence.

B. Overview of Hypotheses

The principal hypotheses of this study are set out in Tables 12, 14 and 16. Table 12 is based on second-order analyses by Botzum (1951), Cattell (1963), Martin and Adkins (1954), Rimoldi (1951), two USES studies summarized by French (1951) and several factor analyses of the Wechsler scales, as well as some of Vernon's (1950) hierarchical results. Although no one of these studies by itself confirms the hypothesis, taken together they suggest that some four stable and meaningful factors might be found at the second-order in a broad sample of primary factors. General dimensions of intellect are thus described in terms of the primary factors which mainly define them. (Detailed description of the primary factors themselves is given in French (1951, 1963), Guilford (1960) and in the source studies upon which these reviews are based.)

Table 12 indicates that two of the dimensions adumbrated by previous research have properties similar to those postulated for the two general kinds of intelligence, fluid (Gf) and crystallized (Gc1) which Cattell (1963) has described. In addition, however, the Gc2 column represents the hypothesis, that, at the second-order, crystallized intelligence splits into two general components, one largely involving the noegentic and abstracting processes in reasoning which Cattell specified in the crystallized concept (hence here labeled Gcl), the other defined primarily by sheer familiarity with language and facility in quickly using it. Table 12 also indicates a Gv, general visualization, function believed to account for variance in all primaries which involve figural content or require ability to see relations between objects in space.

It is supposed that the general dimensions described in Table 12 will span several of what Humphreys has referred to as facets. Fluid intelligence, in particular, is thought to be a broad reasoning factor involving figural, semantic, symbolic and other kinds of content (cf. Guilford, 1960). It is also hypothesized that it is revealed in both speeded and unspeeded tests: there is no need to measure it in speeded tests alone. Likewise Gc is expected to be revealed in speeded (e.g. fluency) tasks as well as those given under unspeeded conditions (e.g. vocabulary).

Table 14 describes the essential qualities of the major dimensions in terms of the processes they are supposed to entail. Here it is indicated that both Gc and Gf involve what is usually described as intelligence, and thus can rightfully be given that name, but that the two can be distinguished in terms of the kinds of fundaments (contents) upon which they can most efficiently operate and in terms of the efficiency of operation of certain span-of-apprehension and short-term memory functions collectively referred to as anlages: Gf operates most efficiently on so-called culture-fair materials; Gc is most effective when a problem requires that relatively abstruse knowledges of a culture be brought to bear to reach solutions. Gf is sensitive to differences in anlage functions, whereas Gc is not expected to depend on these to any great extent.

Table 14 also indicates that a non-intellectual speediness dimension, or several such dimensions might be expected at the second-order, although no such outcome was clearly implied by previous second-order analyses. As noted above, speed of intellectual function is expected to be involved in both of the hypothesized general intelligence dimensions. It is also expected that speed of visualizing is involved in the Gv function. But some past work (e.g. as reviewed by Pawlik and Cattell, 1965) suggests that in addition to speed variance which is intrinsic to the basic Gf, Gc and Gv functions, the variance on intellectual tasks can result in part from various "effort-to-hurry", "compulsive-accuracy", "slapdash-hurridness", anxiety, etc. traits or states (sets). These non-intellectual (and non-visualization) sources of variance could show up in several second-order dimensions. They could define a single general speediness function, but the description of Gs in Table 14 is not intended to imply that this is a major hypothesis of this study.

C. Variables and Primary Factors Measured

More detailed account of the major hypotheses actually considered in the design of this study is probably best given by description of the variables analysed. These are not tests in the usual sense, but, factors established in previous research and here measured as unweighted linear composites. Nevertheless the actual tests used to measure factors are described in Table 15. (The intercorrelations and factors among these tests, as well as other psychometric information about them, is given in appendix II.).

A name following a variable title in this table indicates that the variable was taken either from a test published under the authorship of the person whose name is listed or else it was taken directly from a study reported in the research literature by this person. The abbreviations for primary factors are those used by French, et al (1963) if they list the factor; if they do not, then the abbreviation is taken either from French (1951), Guilford (1960) or Cattell (1957). In the listings under "Scoring," R means number right, W means number wrong, N means number of responses given in specified time on a speeded open-ended test, K means score determined according to a specific key, and the other symbols merely indicate the way in which the variable was obtained from these basic kinds of scores. Thus 20-W, for example, means that the number of wrong answers given in a test was subtracted from the

TABLE 15

Tests Used in Estimating Primary Factors

Variable Number	Title of Variable	Title Abbrev.	Abbrev. Factor	r_{xx} Estimate	Number Items	Scoring
1	Letter Grouping (Botzum)	LG	I	67	24	R
2	Number Series (Botzum)	NS	I	59	20	R
3	Furneaux Speed (Letter Series) A (2)	FSL	(SP)	63	20	lnR
4	Carefulness Furneaux B(1)	CFB	C	57	20	20–W
5	Furneaux Level	FL	CFR	72	35	%R
6	Figure Series (Cattell II, III)	FS	CFR	69	24	R
7	Topology (Cattell II, III)	T	CFR	65	16	R
8	Matrices Speed (Cattell II)	MS	CFR	56	12	R
9	Matrices Power (Cattell III)	MP	CFR	53	13	R
10	Figure Classification (Cattell II)	FC	CFC	52	14	R
11	Careful Figure Classify (Cattell III)	CFC	C	45	14	20–W
12	Arithmetic Reasoning	AR	R	70	12	R
13	Match Arrangements (Guilford)	MA	DFT	69	20	R
14	Cards (Botzum)	CR	S	86	54	R
15	Figures (Botzum)	F	S	85	52	R
16	Paper Form Board (Thurstone)	PFB	Vz	81	28	R
17	Cued Nonsense Memory	CNM	Ma	68	20	R
18	Cued Meaningful Memory	CMM	Ma	87	26	R
19	Common Word Analogies	CWA	V (R)	65	30	R
20	Abstruse Word Analogies	AWA	V	67	30	R
21	Vocabulary	V	V	93	50	R
22	General Information	GI	V	84	28	R
23	Mechanical Information (AAF)	MI	Mk	71	15	R
24	Tool Identification (AAF)	TI	Mk	72	15	R
25	False Premises (Thurstone)	FP	Rs	41	22	R
26	Inferences (Guilford)	IG	Rs	66	14	R
27	Careful Practical Estimate (Guilford)	CPE	J		20	20–W
28	Social Situations (Guilford)	SS	EMS	61	16	R
29	Controlled Associations (Thurstone)	CA	Fa	73		N
30	Things Round (Taylor)	TR	Fi			N
31	Ideas (Man up Ladder)	IL	Fi			N
32	Adding	A	N	71	20	R
33	Carefulness Subtracting	CS	C	75	20	9–W
34	Carefulness Dividing	CD	C	66	20	20–W
35	Multiplying	M	N		20	R
36	Mixed Arithmetic Operations	MAO	N		20	R
37	Carefulness Fractions–Decimals	CFD	C		20	20–W
38	Backward Reading (Botzum)	BR	Cs	89	40	R
39	Street Gestalt Completion (Botzum)	SGC	Cs	73	24	R
40	Designs (See Σ) (Botzum)	D	Cf	85		R–W+20
41	Forward Writing (copying)	FW	22(Sc)			R
42	Forward Printing (copying)	FP	22(Sc)			N
43	Novel Writing (Backward and other)	NW	23(Wf)	58		R
44	Matching Letters and Numbers	MLN	P	81	50	R
45	Rapid Cancellation	RC	P	86		R

TABLE 15 (Cont'd)

Variable Number	Title of Variable	Title Abbrev.	Abbrev. Factor	r_{xx} Estimate	Number Items	Scoring
46	Agreement With Platitudes	AWP	16	75	20	K
47	Highbrow Tastes	HT	16	71	20	K
48	Critical Hostility	CH	19	50	20	K
49	Experience Claimed in Skills	ECS	21	76	20	K
50	Confidence in Doing Skills	CDS	21(32)	55	20	K
51	Self-Sentiment: Utilities	SSU	36	49	16	K
52	Self-Sentiment: Opinions	SSO	36	43	16	K
53	Early Risks Claimed	ERC	?	86	26	K
54	Denial of Brain Damage Symptoms	DBD	?	73	20	K
55	Test Anxiety Admitted	TAA	24	82	30	K
56	16 PF Q4: Tension	Q4	24	78	26	K
57	16 PF H: Adventurousness	H	32	73	26	K
58	16 PF Q1: Experimenting	Q1	?	64	20	K
59	16 PF I: Sensitivity	I	16(-)	57	20	K

constant 20 in order to obtain the variable measure in which a high score would indicate "good" performance (i.e., few wrong).

Test scores were combined in the manner indicated in Table 16 to obtain the factor scores that were actually analysed. In each case the test variable was converted to standard score form and added in with unity nominal weight.

The column to the far right in Table 16 indicates the major second-order hypotheses for the primary factor variables. The order of listing of the symbols for these hypotheses indicates primacy--i.e., the first-listed is considered to be the major hypothesis; the second indicates a lesser hypothesis. If Gc is listed without subscript it means that no hypothesis is made concerning whether the variable in question should primarily define Gc1 or Gc2, but that it should define one or the other if both appear. Most of the symbols used in Table 16 are carried over from Tables 12 and 14. In addition, however, it is indicated that second-order positive self-image (PSI) and will-control (W) dimensions have been found among non-intellectual primaries and might be anticipated here.

It will be noted in this table that most of the primaries marked by two stars in Table 12 (to indicate saliency on the hypothesized second-order dimensions) were measured over two or more tests. Some of the primaries marked with only one star were measured by only one test. The over-all design aimed at giving factorial breadth of measure to the most salient primaries

TABLE 16

Factor Variables

Matrix Number	Factor Symbol	Title	Tests Used to Measure Factor	Hypotheses
1	I	Induction	Letter Grouping (LG) & Number Series (NS)	Gf, Gs
2	SP	Intellectual Speed	Nufferno Speed Tests A(2) (FSL)	Gf, Gs
3	C	Carefulness	Nufferno Letter Series B(1)(CFB), Culture Free Figure Classifications II (CFC), Practical Estimates (CPE), Subtracting (CS), Dividing (CD), Fractions (CFD); all scored K-Number wrong	W, Gs(-)
4	L	Intellectual Level	Nufferno Level Tests, (FL)	Gf
5	CFR	Figural Relations	Topology II & III (T), Matrices II, III (speed & power)(MS & MP), Figure Classifications II (FC)	Gf, Gv
6	R	General Reasoning	Arithmetical Reasoning (AR)	Gf, Gc
7	DFT	Adaptive Flexibility	Match Problems II & III (MA)	Gf, Gv
8	S	Spatial Orientation	Card Rotations (CR), Figures (F)	Gr
9	Vz	Visualization	Form Board (PFB)	Gr
10	Ma	Associative Memory	Paired Related Words (LMM) & Nonsense Equations (CNM)	Gf
11	CMR	Semantic Relations	Common Word Analogies (CWA), Abstrupe Word Analogies(Concept Mastery)(AWA)	Gf, Gc
12	V	Verbal Comprehension	Vocabulary (V), General Information(GI)	Gcl
13	Mk	Mechanical Knowledge	Tool Identification (TI)	Gc
14	Rs	Syllogistic Reasoning	False Premises (FP), Inferences(IG)	Gc, Gf
15	EMS	Experiential Evaluation	Social Situations (SS)	Gc
16	Fa	Associational Fluency	Controlled Associations (CA)	Gc2, Gs
17	Fi	Ideational Fluency	Things, (TR), Ideas (TL)	Gc2, Gs
18	N	Number Facility	Adding (A), Multiplying (M) Mixed Operations (MAO)	Gc, Gs
19	Cs	Speed Closure	Street Gestalt (SGC), Backward Reading (BR)	Gv, Gs
20	Cf	Flexibility Closure	Designs (See Sigma) (D)	Gv, Gs
21	Sc	Speed Copying	Writing & Printing Copying(FW & FP)	Gs
22	Wf	Writing Flexibility	Backward Writing, Alternating Letters (MW)	Gf, W, Gs
23	P	Perceptual Speed	Matching Letters & Numbers (MLN), Rapid Cancelling (RC)	Gs
24	U16	Assertive Ego	Highbrow Tastes (HT), Agree with Platitudes (AWP)	Gs
25	U21	Exuberance	Experience & confidence in Doing Skills (ECS & CDS)	Gs
26	U36	Self Sentiment	Utilities(SSU), Opinions Device Measures (SSO)	W, Gc, PSI
27	ER	Early Risks	Age at Which Various Hazardous Skills attempted (ERC)	

TABLE 16 (Cont'd)

Matrix Number	Factor Symbol	Title	Tests Used to Measure Factor	Hypotheses
28	U24	Unbound Anxiety	16 PF Q_4 Tension, Q_4 Physical Symptoms (DBD), Test Worry(TAA)	PSI (-)
29	H	Adventurous	16 PF H Parmia	
30	Q_1	Experimenting	16 PF Q_1 Radical	
31	I_p	Sensitive	16 PF I Premsia (Sensitive	

and at over-determining the hypothesized second-order dimensions.

One of the principal markers for Gf--viz., CFR-- was measured over four kinds of tests. These are the subtests of Cattell's (1957b) culture-fair device. The primary factor composition of these subtests has not been clearly established by previous research, although they would seem to involve primarily CFR, as suggested. But Figure Classifications, for example, could be expected to load Guilford's CFC. (Although in separating CFR and CFC, Guilford has drawn a rather narrow distinction relative to what other investigators define as primary-level factors). Cattell (1963) found that the four subtests defined a single factor. He interpreted this as Gf. In terms of these results, variable 5 in Table 16 would be regarded as itself a second-order factor measure of Gf. However, the factor is probably too narrow in terms of content (figural only) to be regarded as a pure Gf measure in the present study. Because of its exclusive dependence on figural content, the factor would be expected to yield at least some visualization variance. Thus instead of defining it as a pure marker for the hypothesized second-order Gf factor, it would probably be best to identify it in terms of its primary content, which is mainly CFR.

Some of the primaries in Table 16 were measured by only one kind of test. In most cases these were entered in the analysis to test fairly specific kinds of hypotheses concerning the nature of the supposed Gf, Gc and Gv functions.

The hypothesis that Gf is manifested in both speeded and unspeeded performances (if these involve noegenesis and abstracting in reasoning with culture-fair materials) is represented by the more or less pure measures of intellectual speed and intellectual level obtained by using Furneaux's (1953;1961) procedures. SP is the sum of the common logarithms of the times required to obtain correct solutions only in an inductive reasoning task in which the subject must produce the correct answers, not select them from a multiple-choice format. According to Furneaux and the data he has accumulated, these operations, based on responses to fairly simple items, yield a measure of intellectual speed that is representative for all levels of difficulty. In other words, it is a general intellectual speed factor. The intellectual level measure (L) is obtained from responses to items arranged in sets wherein there is a continuum from very easy to very difficult problems, and the score indicates the average level of difficulty of the problems the person has correctly solved independent of the number of problems worked or the total number correct. Here the expectation is that both SP and L involve primarily the same Gf function as do CFR, I, CMR, etc.

Similarly it is predicted that although CMR is based on verbal content alone and thus would not be a so-called non-verbal or performance test, it nevertheless can be made to be relatively culture-fair, and when it is, part of its variance will go into Gf. Two kinds of analogies were included in this measure: one set based on very common words, thus:

Broom-Floor: Spoon- ? Fork Table Soup Dish,

the other based on more abstruse concepts:

Hippocrates-Galen::Aeschylus- ? Greece Euripedes Pericles Heroclitus

The task over-all could therefore be expected to yield variance on both of the crucial intelligence functions, Gc being mainly involved in the last-mentioned kind of analogy, whereas Gf would produce substantial variance on the first kind. Hence the hypothesis indicated in Table 16 should be interpreted to mean that CMR will split its variance between Gf and Gc.

The primary factor labeled R represents a similar kind of hypothesis. Solution to some of the problems of this factor is aided by knowledge of the more or less formal rules of algebra and the like. But some of the problems can be solved without this knowledge, using aids that can be obtained from every-day experiences. Hence, again, the variance of R is expected to be divided between Gf and Gc.

The hypothesis that Gf will transcend content facets is represented by the prediction that it will be defined by factors like I and SP, involving symbolic content, CFR, involving figural content and CMR and R, involving semantic content.

The primaries labeled Ma and P represent hypotheses concerning the anlage functions supposedly involved in Gf, as described in Table 14.

The Ma factor is obtained over a meaningful memory task and one involving nonsense equations. The immediate memory for meaningful material might be expected to be facilitated by Gc, whereas that for nonsensical material would not be expected to contain this variance. Hence, the factor overall might be expected to split its variance between Gf and Gc. However, the hypothesis is here that Ma mainly represents an anlage capacity to maintain items in immediate memory and that the limits on this exist whether the material memorized is meaningful or not. Hence on this basis Ma is said to involve primarily Gf variance.

Perceptual speed tasks, although they require little by way of capacity to perceive complexity of relations among stimulus arrays, do, however, require that the subject maintain a vigilant awareness of a broad pattern of the stimuli in the immediate situation. The ability to maintain this kind of awareness is here regarded as a central aspect of Gf function and, hence, P, even though it involves very little of the other functions which characterize Gf, is expected to show some correlation with Gf by virtue of its being a measure of this kind of anlage.

The factor labeled Sc is intended to identify variance on simple speed of arm movement and manual dexterity functions, such as have been described in researches like those of Fleishman (1953; 1954; 1956). It is believed that there is little anlage function in this. It requires merely that the subject write (or print, as the case might be) a short sentence involving familiar words ("The sky is deep blue") over and over again as rapidly as possible for a short period of time. Thus the task does bring in the crystallized skills of writing and printing, but presumably these are so thoroughly over-learned by most older children and adults in our society that there is no appreciable Gc variance on the task when it is used in this kind of sample. However, it might be that some of the fluency performances, as they are measured with paper-and-pencil tests under timed conditions, involve this simple "speed-of-arm-movement" variance.

Writing flexibility is a kind of control variable, the control being for a function which at the negative pole has been described as a neurasthentic "incompetence" or "inability to utilize the abilities one has, but...not synonymous with low intelligence itself." (Scheier, et al, 1961). The factor is not said to be <u>the</u> measure of neuroticism, but a prominent component of this syndrome. Here the factor is scored in the non-neurotic or "high-mobilization" (i.e. flexible) direction.

The factors listed as variables 24 through 31 are all measured with devices which putatively contain no intellectual variance, although several of these factors have in previous research been defined in part by various kinds of speeded performance, some of which could be the speediness involved in intellectual tasks. If some intellectual speediness stems from one of these factors, then the ability tests involving this should be found to have part of their variance in common with the apparently non-intellectual markers for these factors. Also, as noted before, there was some reason to suppose that several of these non-intellectual factors, along with some ability measures, might define a fairly broad non-intellectual speed factor at the second order.

The other hypotheses represented in these non-intellectual factors may be briefly listed as follows:

a. UI-36 Self Sentiment. Cattell and Horn (1963,1965) have argued that this represents in part the extent to which the person has adopted the values of the dominant culture, and has organized his self-image to achieve in accordance with these values. It would thus be related to Gc throughout development. It might also be related to conformity with instructions and test-taking effort (W) in the immediate testing situation. If this latter were true, the factor might load with speeded measures in the second order, this indicating that the speediness variance stemmed partly from differences in motivation in the testing situation.

b. Early Risks. This scale is based largely on the work of Torrence and Ziller (1957), who found that "willingness to take a risk" was a fairly reliable measure over a wide range of questionnaire risk-taking items, and partly on the suggestion from Winterbottom's (1958) work that individuals who are allowed to, and do, try somewhat risky things relatively early in life tend to adopt an attitude of willingness to take a risk.

Torrence and Ziller found a significant ($r = .34$) correlation between their Risks scale and a measure of "willingness to guess on a test in spite of strong threats against guessing." On these grounds it can be reasoned that the Early Risks measure should correlate (negatively) with Carefulness and therefore might, together with some speeded neasures and the Adventurousness and/or the Experimenting questionnaires, define a factor accounting for some of the variance in intellectual tests.

c. UI-24 Unbound Anxiety. Several investigations have suggested that anxiety may bear a negative relationship to intellectual performance, particularly if the ability tests are speeded (e.g., Cattell and Scheier, 1961; Kuhlen, 1959; Sarason and Mandler, 1952). There is perhaps some suggestion (from this last-mentioned work, particularly) that this relationship is slightly curvilinear, but even in this event the linear component would appear to account for the major portion of this relationship, which is the assumption made in using the variable in this study.

d. In recent higher order factoring among the subscales of the 16PF, MPI and somewhat similar questionnaires, Horn (1963; 1964c) has found two very broad group factors at the top of a hierarchical solution. One of these, involving the factors in Anxiety (with negative signs) as well as several of the factors in Extraversion (in particular H-Adventurousness) and in the moral-ethical area (e.g., G-Superego), he interpreted as a positive self-image dimension. It is this factor which is referred to in Table 16 as PSI.

D. Procedures and Results

1. Sampling Subjects

The tests listed in Table 15 were administered to 339 persons at the Stateville, Pontiac and Dwight State Prisons in Illinois, the Illinois Soldiers' and Sailors' Children's School, Canon City Penitentiary in Colorado and to persons on the unemployment rolls at the Colorado State Unemployment office in Denver. All subjects were volunteers. They were offered information about their performances as an inducement for volunteering and for doing their best. The tests were administered in two sessions, each lasting approximately 2½ hours, one in the morning and one in the afternoon. All subjects did the tests in the same order, although the break points between the morning and afternoon sessions were not precisely the same for all groups. The same person administered the tests and the same stop watch was used throughout. Every effort was made to keep the conditions of administration as nearly the same for all groups as was possible.

For one reason or another (usually because they failed to start one of the testing sessions on time) 42 subjects failed to complete two or more tests. These subjects were eliminated from the analyses reported in this section, thus leaving a sample of 297 subjects. In the few cases where one of these subjects failed to complete one (but no more than one) test, the test mean for the group was assigned as the subject's score. Of the 297 subjects, 215 were males.

The age range was 14 to 61 years. However, there was only one fourteen-year-old, two persons aged 61, one aged 56, one 55 and one 52, the bulk of the sample thus being between 15 and 51 years of age. The distribution was not symmetrical within this range, however, as can be seen from the following summary:

Age Range	14-19	20-24	25-34	35-44	45-61
N	71	95	44	62	25

The mean for age was 27.6 years. The standard deviation was 10.6 years.

The amount of formal education received by a person was estimated by adding the scores obtained from two questions, one asking him to circle the highest grade completed in school before his 18th birthday, the other asking him to circle the highest grade completed up to the time of testing. The mean for this variable was 21.6, indicating that the average number of years of formal schooling for the group was about 11; the range of the variable was from 14 to 33, this corresponding to a range from about a 7th grade education to college graduate.

Forty-six of the subjects were classified as belonging to a "minority group"--i.e., either Negro, Spanish-American or Asian.

This sample, although far from ideal in several respects and almost certainly not representative of the adult population in this (or any other) country, is presumably heterogeneous with respect to the influences which, according to hypotheses, are supposed to produce a distinction between Gf and Gc, and is therefore deemed to be adequate to cast some light on the issues in question.

2. The Correlations

The 31 factor variables listed in Table 16 were intercorrelated using the product-moment formula. The results are shown in Table 17. The variables were also correlated with age, the schooling variable and the dichotomy male-vs-female.

With this size sample a correlation of about .11 or .12 is significantly different from zero at the .05 level, one of .15 is similarly significant at the .01 level. Using Hotelling's (1940) test, a difference of about .15 between two correlations would generally be significant at about the .01 level.[2]

Before attempting to interpret the Table 17 correlations

TABLE 17

Intercorrelations of Ability & Personality Factors
(communalities in diagonal)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1 I	64																														
2 SP	39	39																													
3 C	12	-10	48																												
44 L	53	36	30	57																											
5 CFR	67	39	21	53	75																										
6 R	42	11	21	36	36	36																									
7 DFT	40	24	13	34	46	27	35																								
8 S	46	31	03	25	49	19	39	53																							
9 Vz	45	22	11	36	54	32	44	47	58																						
10 Ma	37	28	10	35	46	20	26	26	32	38																					
11 CMR	48	18	22	49	47	42	35	21	42	34	73																				
12 V	31	09	27	40	25	39	27	10	35	20	76	78																			
13 Mk	34	05	07	18	27	38	32	30	41	12	46	45	62																		
14 Rs	45	21	20	39	45	36	29	15	26	33	60	55	30	51																	
15 EMS	21	12	06	19	17	21	15	14	13	14	32	44	20	35	32																
16 Fa	08	05	04	12	13	12	11	-04	19	24	35	42	13	25	23	57															
17 Fi	24	19	-01	24	25	13	23	13	21	26	36	34	21	28	24	53	46														
18 N	45	29	13	44	33	32	33	17	32	35	45	44	30	35	30	27	36	53													
19 Cs	42	33	05	38	55	18	32	42	42	42	33	23	16	31	21	25	26	28	52												
20 Cf	46	20	16	36	47	25	37	38	55	34	35	28	33	31	19	11	23	32	48	47											
21 Sc	22	23	01	21	22	05	19	18	22	30	17	18	03	19	25	25	41	39	29	24	58										
22 Wf	06	25	00	03	19	-07	12	14	12	17	-02	-03	-15	01	13	19	26	13	29	11	49	46									
23 P	37	40	00	37	36	15	18	36	30	26	23	22	05	22	32	16	30	52	43	27	47	32	62								
24 U16	-03	-02	11	07	-08	03	02	-12	-11	-12	09	19	-02	04	10	16	03	-06	01	-02	-02	-04	03	37							
25 U21	14	19	-02	13	22	-06	18	11	23	16	18	14	04	10	05	22	21	21	31	16	23	26	28	16	35						
26 U36	14	08	08	14	03	09	12	06	09	05	26	32	24	21	24	21	09	18	10	02	05	11	06	17	05	25					
27 ER	18	16	03	10	32	08	15	28	23	20	12	04	22	20	10	06	10	06	29	15	06	10	22	-10	26	-02	79				
28 U24	-14	-05	-04	-18	-09	-18	-19	-11	-20	-05	-37	-39	-33	-24	-14	-15	-17	-14	-10	-14	-09	15	-04	-12	-05	-15	04	50			
29 H	07	13	-05	07	08	02	07	05	07	15	20	18	14	11	09	17	15	21	16	04	20	06	16	21	25	-01	10	-49	80		
30 Q1	11	-03	22	19	13	22	19	08	17	04	32	42	35	23	20	21	18	17	06	20	06	-11	06	26	09	19	12	-35	21	39	
31 Ip	-10	01	11	08	-04	-07	-08	-19	-05	-02	06	14	-27	01	06	22	07	-03	05	-02	01	12	03	22	11	12	-17	14	-08	02	42

in terms of the theory stated in previous sections, it will be helpful to first use them to provide a description of the sample which will help to put this in clearer perspective than could be supplied by the information of the previous section alone.

The amount of variance introduced by sex differences in the sample is greater than was anticipated (see Table 18). Of course it was expected, on the basis of common sense and previous results (e.g., Bennett and Cruikshank, 1942; Wesman, 1949), that Mk would show correlation with "maleness," but even in this case the largeness of the correlation was not anticipated. Previous results have also shown that males tend to out-perform females on spatial-visualization tasks, R and reasoning tasks, generally (but particularly when they involve figural and other culture-fair content) (e.g., Bennett and Cruikshank, 1942; Macmeeken, 1939; McNemar, 1942; Paterson, 1930; Terman and Tyler, 1954; Wesman, 1949), and females have generally been found to report more anxiety and neurotic symptoms (Cattell and Scheier, 1961). But again, the largeness of these correlations in the present sample was not expected. Moreover, contrary to past findings (e.g., Havighurst and Breese, 1947; Hobson, 1947; Herzberg and Lapkin, 1954; La Brant, 1933; McCarthy, 1953; 1954; McNemar, 1942; Terman and Tyler, 1954) females scored lower than (instead of higher than or equal to) males on the verbal-educational factors V, Rs, and

TABLE 18

Intellectual and Personality Factors Which Correlated Significantly With the Male-vs-Female Dichotomy

Factor		r with "Maleness"
MK	Mechanical Information	64
R	General Reasoning	30
Vz	Visualization	30
Q_1	Experimenting	30
H	Adventurousness	26
S	Spatial Orientation	25
Cf	Flexibility of Closure	23
I	Induction	21
V	Verbal Comprehension	21
ER	Early Risks	20
DFT	Adaptive Flexibility	18
N	Number	18
Rs	Syllogistic Reasoning	16
CFR	Figural Relations	15
UI-36	Self Sentiment	14

Factor		r with "Femaleness"
UI-24	Anxiety	-32
Ip	Sensitivity	-29
Wf	Writing Flexibility	-25

N, and the frequently observed female superiority in fluency is not here in evidence. Of course, many of the studies noted above have been based on younger samples of subjects than was drawn here, so the possibility exists that the apparent discrepancy between these results and those of previous studies is not that at all, and instead the difference indicates a somewhat later developmental peak and generally superior adult performance for males. Perhaps a more parsimonious interpretation (and certainly one that is more in the spirit of the widely accepted democratic belief in the equality of the sexes) is that the present samples are by no means representative of the male and female populations. The particular sampling bias introduced by drawing male and female subjects in the manner previously described apparently tends to result in one's obtaining a somewhat superior group of males relative to females. In other words, it would seem that males in prison and/or on unemployment rolls tend to be somewhat brighter and less anxious and neurotic relative to the general population of males than are females in these circumstances relative to the general population of females.

The significant correlations between Age and Formal Schooling and the various intellectual and personality factors are presented in Table 19.

In this sample, where there is a significant

TABLE 19

Intellectual & Personality Factors Arranged in Order

of Their Correlations (significant) With Age & Formal Schooling*

Factor		with Age
Positively Related		
V	Verbal Comprehension	54
Q_1	Experimenting	34
EMS	Experimental Evaluation	29
MK	Mechanical Knowledge	26
UI-16	Assertive Ego	24
CMR	Semantic Relations	22
UI-36	Self Sentiment	21
N	Number	20
Fa	Fluency & Association	15
C	Carefulness	14
Rs	Syllogistic Reasoning	12
H	Adventurous	11
I	Sensitive	10
Negatively Related		
Wf	Writing Flexibility	-10
I	Induction	-12
Sp	Intellectual Speed	-13
S	Spatial Orientation	-14
Ma	Associative Memory	-16
ER	Early Risks	-16
Cs	Speed of Closure	-18
CFR	Figural Relations	-29
UI-24	Anxiety	-29

TABLE 19 (Cont'd)

Intellectual & Personality Factors Arranged In Order

Of Their Correlations (significant) With Age & Formal Schooling*

Factor Positively Related		with Schooling
V	Verbal Comprehension	53
CMR	Semantic Relations	42
N	Number	42
L	Intellectual Level	38
Rs	Syllogistic Reasoning	34
P	Perceptual Speed	32
I	Induction	27
EMS	Experiential Evaluation	27
UI-21	Exuberance	26
Sc	Speed of Copying	26
Mk	Mechanical Information	25
Fi	Ideational Fluency	24
Cf	Flexibility of Closure	24
DFT	Adaptive Flexibility	22
Fa	Fluency of Association	22
Vz	Visualization	21
R	General Reasoning	20
SP	Intellectual Speed	20
H	Adventurous	19
CFR	Figural Relations	19
C	Carefulness	16
Q1	Experimenting	16
UI-36	Self Sentiment	14
Ip	Sensitive	14
Cs	Speed of Closure	14
Wf	Writing Flexibility	12
Negatively Related		
ER	Early Risks	-10
UI-24	Anxiety	-23

*The Correlation between Age & Schooling was .39.

correlation (.39) between Age and Schooling it is difficult to ascribe any clear-cut interpretations to the patterns of correlations which these variables have with the personality factors. If Age itself were regarded as a factor (i.e., a functional unity in some sense), it would appear to be characterized at the positive pole by knowledge, the ability to reason in problems requiring knowledge, and various non-intellectual traits suggesting self-control, personality integration and confidence, whereas at the negative pole it seems to be characterized by some breakdown in the anlage functions involved in speeded reasoning tasks based on novel fundaments, spatial visualization and immediate memory. Looking at Schooling in somewhat the same way, it can be seen as characterized by knowledge, the ability to reason in all kinds of tasks, speededness of performance in both complex reasoning and simple clerical tasks, and the various non-intellectual traits suggesting personality integration. Thus, if only the intellectual variables were considered and one were to put a factor through Schooling, a dimension very much like what is usually interpreted as general intelligence would be defined. Theoretically, however, and as suggested here, this is a conglomerate not only in terms of intellectual factors but also in terms of non-intellectual factors.

Turning back now to Table 17, it will be noted that the correlations among the ability factors are quite generally positive and frequently significantly so. The correlation of -.10 between Intellectual Speed and Carefulness approaches significance and that of -.15 between Mk and Writing Flexibility would appear to be significant. But, other than these two, all other relationships are either essentially zero or positive.

In general, however, Carefulness, Writing Flexibility and Speed of Copying have low-to-zero correlations with the intellectual variables and, relative to the former, somewhat higher correlations with non-intellectual variables, this suggesting that fairly high proportions of their variances stem from non-intellectual traits or states.

Although the correlation ($r = .30$) between Intellectual Level and Carefulness is almost certainly indicative of a non-zero relationship between these two, it is equally clear from the patterns of correlations for these factors that they measure somewhat independent functions. The hypothesized negative correlation between Carefulness and Early Risks did not materialize, but the significant, or borderline significant, correlations of Carefulness with Q_1-Experimenting, Ip-Sensitive and UI-16 Assertive Ego are interesting. These latter have previously been found (Horn, 1961) to characterize an upwardly mobile, college-student sample in contrast to a sample of young Air Force enlisted men and and a sample of young state prison convicts. Thus again the suggestion would be that Carefulness is largely a non-intellectual factor which, however, may have relevance for understanding academic work. It will be recalled that it correlated .14 with age and .16 with the schooling variable.

Of interest here, also, is the fact of generally high correlations for CFR and L-Intellectual Level factors with all other intellectual measures. CFR involves speededness variance as well as sheer relation-perceiving, so its high communality can result from its relations to two, perhaps somewhat different, kinds of function. But the L measure is presumably speed-free. Yet its pattern of correlations with other variables is very similar to that for CFR. Both show about the same substantial correlation with the seemingly simple Perceptual Speed (P) factor, and both show relatively low correlations with the so-called "creativity"[3] (i.e., fluency) measures and with age-related, Schooling-related measures of knowledge, per se (e.g., Mk, EMS and perhaps V). Thus the pattern of correlations overall is reasonably consistent with the suggestion from previous research and theory that factors like CFR and L definitely do involve a high degree of what is usually regarded as intelligence and yet are, relative to other measures of this attribute, somewhat more independent of the influences of schooling and acculturation.

As was anticipated (although not necessarily hoped for), Speed of Copying and Writing Flexibility show significant correlations with several of the putative measures of intelligence, with the fluency measures and with UI-21 Exuberance (measured exclusively through devices where speed of performance was not involved). Particularly noteworthy are the rather high correlations which these variables show with the fluency factors. The suggestion is (although this need not be the interpretation) that in samples as heterogeneous with respect to age and educational level as is this one, the measurement of intelligence and "creativity" includes some variance on crystallized skills of a rather elementary kind. Speed of copying correlates -.26 with Schooling and not at all with age, whereas these correlations for Writing Flexibility are .12 and -.10 respectively; Wf shows a correlation of -.25 with the male-vs-female dichotomy (i.e., females were less flexible). Although DFT and Wf correlate at a borderline-significance level, there is little indication in these data that the "flexibilities" referred to in the title for these two factors are the same.

Anxiety shows the expected negative correlation with ability measures--particularly the hypothesized crystallized skills--but contrary to Kuhlen's (1959) hypothesis, the older individuals in this sample do not evince more anxiety than the younger. Rather, the negative correlation ($r = -.29$) between Age and Anxiety is significant, and the other factors said to indicate positive self-image--viz., UI-36 Self-Sentiment and H-Adventurous--likewise suggest that in the range of ages studied here there is no general tendency for older persons to show greater insecurity than younger persons, and, in fact, the opposite seems to be the case.

The Early Risks measure shows significant or borderline significant relations with many of the factors and rather noteworthy high correlation with CFR, S, Gs, Vz, Mk, P, Ma, UI-21 Exuberance and maleness. And it correlates negatively with age ($r = -.16$). These correlations would seem to reflect in part the male-female sampling bias previously alluded to. It is interesting to note that Risks correlates substantially with some factors which do not contain problems of the multiple-choice type (e.e., Vz, Sp), and where guessing, therefore, would presumably not produce variance in the scores. Thus, somewhat in contrast to the interpretation Torrence and Ziller offer, the common variance of "willingness to take a risk" and intellectual performance is apparently not simply "willingness to guess".

3. The Factors

a. Initial Factoring

Unity was inserted in each element of the main diagonal in the matrix of Table 17 and the 31 latent roots were calculated. The roots are listed in the far right column of Table 20. It will be noted that the 9th root is 1.00 whereas the 10th is 0.83. Accordingly, using the so-called (by Horn, 1965) Guttman-Kaiser-Dickman rationale[4] for determining the number of factors, the decision was made to estimate 9 common factors. The principal factor calculations were repeated 25 times, each time replacing the diagonal element for a variable with that variable's communality estimate obtained from the previous calculation. The communalities determined on the 25th iteration differed from those determined on the 24th iteration by only trivial amounts in the third and fourth decimal places. These communalities, rounded to two places, are presented in the main diagonal cells of Table 17 and to the right of the factors in Table 20 and 21. The roots determined in the reduced space are presented at the foot of Table 20. The trace is 16, indicatint that common variance is 16/31 of the total variance. The proportion of this common variance in each principal axes factor is indicated in the last row of Table 20.

TABLE 20

Principal Axis Factors

		I	II	III	IV	V	VI	VII	VIII	IX	h^2	Roots For Unity h^2
1.	I	70	-15	-27	-09	-02	18	-09	02	12	64	7.84
2.	SP	42	-33	06	01	01	19	-15	-04	21	39	2.75
3.	C	22	21	-12	-30	30	01	05	-03	-43	48	2.31
4.	L	63	00	-09	-24	16	25	-10	02	-04	57	1.66
5.	CF	73	-29	-25	-08	20	02	02	16	02	75	1.33
6.	R	47	20	-26	-11	-06	06	-06	01	-07	36	1.20
7.	DFT	54	-05	-16	04	01	01	18	-04	01	35	1.10
8.	S	49	-32	-29	16	-02	-01	13	-21	08	53	1.03
9.	Vz	63	-12	-22	06	-01	-10	31	-01	02	58	1.00
10.	Ma	52	-22	03	-05	-01	01	-05	21	-04	38	0.83
11.	CMR	74	38	-03	-09	00	-02	-05	18	07	73	0.79
12.	V	65	56	11	-13	-06	-08	-04	-03	01	78	0.77
13.	Mk	49	32	-33	26	-22	-17	07	-11	01	62	0.74
14.	Rs	61	21	-04	-13	00	-05	-22	15	01	51	0.68
15.	EMS	41	15	17	-08	-14	-07	-15	-22	01	32	0.64
16.	Fa	38	21	47	-07	-07	-30	11	19	10	57	0.59
17.	Fi	48	01	36	-01	-22	-15	08	13	01	46	0.58
18.	N	63	00	14	-07	-24	15	-14	-03	-11	53	0.51
19.	Cs	61	-30	06	01	17	-06	09	01	13	52	0.50
20.	Cf	59	-13	-17	-03	03	-02	27	-04	-04	47	0.49
21.	Sc	43	-27	43	02	-24	06	07	-08	-24	58	0.45
22.	Wf	21	-45	42	-06	-03	-08	13	-03	-14	47	0.44
23.	P	55	-34	27	-02	-08	13	-19	-25	-04	62	0.43
24.	U16	04	32	27	00	34	09	04	-24	09	37	0.40
25.	U21	32	-15	32	21	26	-07	05	-01	06	35	0.35
26.	U36	24	29	06	-09	-02	-05	-06	-21	21	25	0.32
27.	ER	31	-26	-14	32	25	-53	-38	-04	-10	79	0.31
28.	U24	-33	-41	-10	-40	03	-21	-09	-05	00	50	0.30
29.	H	27	16	34	65	19	30	-04	15	-06	80	0.25
30.	Q_1	34	43	01	14	12	-07	07	-18	-13	39	0.23
31.	I_p	-01	09	37	-39	28	-03	11	-02	14	41	0.16
Com. Var.		7.39	2.29	1.83	1.25	0.82	0.80	0.62	0.52	0.50		
Pct. Var.		46.1	14.3	11.4	7.8	5.1	5.0	3.9	3.3	3.1		

The "solidness" of the positive manifold suggested by the table of intercorrelations is made very evident in the first principal axis factor. Only anxiety shows a noteworthy negative loading and this of course simply reflects the fact that it was scored in the "wrong" (i.e., negative self-image) direction. If this first principal axis factor were interpreted as intelligence, as its counterpart in other studies often is, then it is evident that the concept of intelligence relates to a conglomerate of measures and, by the interpretation preferred here, results from a conglomerate of influences. To be sure, the most highly loaded variables in this factor involve noegenesis, abstracting, reasoning and knowledge measured under both speeded and unspeeded conditions, but the only non-intellectual variables which fail to show noteworthy loadings are UI-16-Assertive Ego and Ip-Sensitivity. It would seem that quite contrary to the eloquent paeans of people like Waldo Emerson on Mother Nature's equitable plan of compensation, the "good things" (in terms of human attributes) tend to be found together (at least by adulthood). Which is the "chicken" and which the "egg" in this relationship between non-intellectual and intellectual attributes is an intriguing but probably unanswerable question.

If one were to take a Burt-like attitude towards factoring and attempt to interpret the so-called "unrotated" principal axis factors,[5] he would note here that P-II[6] contrasts the verbal-experiential-positive self-image variables and those involving flexibility-visualization-anlage functions; that P-III puts simple speediness-fluency-flexibility-exuberance-adventurousness against many of the reasoning factors (CMR and Rs notably excluded); that P-IV contrasts positive-self-image-Mechanical with (in this largely male sample) Sensitiveness-carefulness; that P-V is mainly a compound of Exuberance, Assertive Ego, Carefulness, Early Risks and Sensitivity; that P-VI opposes Early Risks-Anxiety-Fluency and Adventurousness-Intellectual Level and the remaining three factors are characterized by visualization, confident-exuberance and carefulness in that order. However, further interpretation along these lines will not be attempted here.

b. Rotated Solutions

The principal axis factors of Table 20 were first rotated in accordance with the Varimax criterion (Kaiser, 1958), this producing the results shown in Table 21. Just below the factor coefficients in this table the common-factor variance contributions and the percentages of total common-factor variance are listed. Below these two rows are two more indicating the hyperplane counts and the

TABLE 21

Varimax Factors

		I	II	III	IV	V	VI	VII	VIII	IX	h^2
1.	I	54	23	10	52	01	-04	-10	00	01	64
2.	SP	27	02	28	42	04	-09	06	06	-22	39
3.	C	11	12	-03	-09	-04	-01	12	00	66	48
4.	L	35	24	13	54	05	-02	10	-05	25	57
5.	CFR	67	02	11	48	01	10	-01	17	14	75
6.	R	28	36	-06	26	02	02	-15	-04	27	36
7.	DFT	53	18	10	13	08	04	-03	00	07	35
8.	S	64	07	16	09	01	-19	-12	13	-10	53
9.	Vz	71	17	12	06	05	13	-07	04	06	58
10.	Ma	32	02	26	38	04	21	-07	09	06	38
11.	CMR	32	55	-02	38	19	35	01	-04	16	73
12.	V	17	74	04	18	17	29	10	-04	21	78
13.	Mk	42	53	-12	-08	18	05	-32	09	01	62
14.	Rs	21	43	03	43	06	24	-04	12	16	51
15.	EMS	05	48	27	12	00	03	05	07	01	32
16.	Fa	04	31	25	-01	08	59	21	05	-04	57
17.	Fi	16	26	40	08	08	43	00	01	-06	46
18.	N	20	37	41	36	10	09	-14	-08	07	53
19.	Cs	53	04	29	27	06	12	17	18	-05	52
20.	Cf	62	14	16	11	03	07	-02	-01	14	47
21.	Sc	13	08	72	07	09	13	-06	-05	04	58
22.	Wf	13	-19	60	00	-07	15	12	07	-02	47
23.	P	21	18	62	33	03	-14	06	11	-08	62
24.	U16	09	22	-02	-06	23	-08	49	-02	08	37
25.	U21	19	-03	28	06	27	13	28	24	-07	35
26.	U36	05	45	-03	05	-01	01	18	-02	-08	25
27.	ER	22	04	08	07	02	01	-12	84	02	79
28.	U24	-14	-32	07	-01	-58	-06	09	12	02	50
29.	H	-02	01	17	10	86	06	04	09	05	80
30.	Q_1	14	45	-03	-11	29	02	09	08	25	39
31.	I_p	-11	03	06	04	-15	18	56	-10	08	41
Com. Var.		3.63	2.82	2.23	1.98	1.48	1.08	1.02	0.96	0.85	16.06
Pct. Var.		22.6	17.6	13.9	12.3	9.2	6.8	6.3	6.0	5.3	100.00
Hyp. Ct.		5	10	11	15	22	17	18	22	20	140
Pct. Ct.		16	32	35	48	71	55	58	71	65	50

percentages of variables in each factor in the arbitrary ±10 hyperplane range here adopted.

It will be noted that about half of the variance of the first principal axis factor was distributed through other factors by the Varimax rotation, but that the first factor still remains a rather general group factor: the hyperplane count is quite low, indicating that there is no simple structure on this factor. The counts for the other factors are somewhat better, but still are hardly adequate by usual standards. These are typical of the characteristics frequently noted in Varimax solutions.

Cattell (1952), Cattell and Gorsuch (1963) and Thurstone (1947) have pointed out that the best simple structure for a set of factors often cannot be found if the factors are required to remain orthogonal during the rotations. The most important deduction from Thurstone's statement of the principle of simple structure is that the scientific clarity and stability (invariance) of factors is a direct function of the adequacy of the simple structure obtained among them. The validity and generality of this principle is still, of course, very much an issue in the field today, although it would seem that many are (sometimes rather grudgingly) coming around to the view that Thurstone was basically correct: factors with a "good" simple structure are usually found to be more interpretable --to make better scientific sense--and would seem to be more replictable than so-called unrotated factors or factors showing poor simple structure. Although evidence on the matter is still far from unequivocal, studies like those of Thurstone (1947) on boxes, Cattell & Dickman (1962) on balls, Cattell and Sullivan (1962) on cups of coffee, Cattell & Gorsuch (1963) comparing random and "relatively non-random" variables, Cureton (1962) on physiological variables, & Sokal (1956) on insect behavior (not to mention studies on abilities in humans) have certainly established a basis for regarding Thurstone's principle as widely applicable and generally useful.

Horn (1963b) compared the solutions achieved with several of the better-known and more frequently used rotation methods, including Varimax, Oblimax, Binormamin and the method of visual rotation. He concluded that the various methods will probably often lead to very similar conclusions in a study--particularly if the differences between loadings for salient markers are not (implicitly) treated as if they were significant and noteworthy for interpretations--but that oblique, visual rotation will in most cases give the best simple structure. Similar conclusions were reached earlier by Coan (1959) and, on the last point, more recently by Cattell and Gorsuch (1963).

Granted, then, that the principle of simple structure has scientific utility if not unequivocal validity, it follows that in the present study, particularly in view of the poor simple structure achieved on the first factor in the Varimax solution, there is need for oblique visual rotations to provide a firm basis for interpretation of, and generalization from the results implicit in the data. Accordingly, beginning with the Varimax solution, 13 blind, graphic rotations, based on two-dimensional plots of the factors, were carried out. The results from these transformations are presented in Table 22.

c. Basis for Interpretation of Factors

The statistical significance of a factor and of a factor loading are still somewhat in the nature of moot questions. However, it is rather generally agreed that factor loadings above about .30 are usually statistically, if not scientifically noteworthy, and that loadings above .50 are frequently both. These beliefs are probably based on implicit assumptions that the factor solution is not "guided" or "forced" (Cf. Horn, 1963d) and that sample size is sufficient to conform with the assumptions of the factor analytic model. In the present study these latter assumptions have been made explicit and care was taken to see that the data and the procedures were in accordance with the dictates here implied. Accordingly, it seems reasonable

TABLE 22

Oblique Structure

		I Gv	II Gc	III Gs	IV Gf	V PSI	VI F	VII PRM	VIII Er2	IX C2	h^2
1.	I	28	12	-03	50	-02	-09	-06	-05	-06	64
2.	Sp	11	-07	10	40	05	-08	07	-02	-21	39
3.	C	03	07	07	08	-05	-14	12	06	62	48
4.	L	14	12	04	51	03	-11	12	-07	18	57
5.	CFR	43	-08	-07	46	00	01	01	08	09	75
6.	R	12	30	-04	23	-04	-03	-12	-02	13	36
7.	DFT	40	09	03	08	00	00	-01	-05	03	35
8.	S	50	-04	08	06	-07	-20	-07	04	-09	53
9.	Vz	58	07	02	00	-05	-08	-04	-04	01	58
10.	Ma	13	-02	10	32	05	15	-09	04	02	38
11.	CMR	11	50	-13	33	07	29	02	-01	02	73
12.	V	-02	69	00	10	00	26	10	-02	09	78
13.	Mk	25	48	-08	-12	00	04	-28	08	-07	62
14.	Rs	-01	40	-06	34	00	19	-04	12	05	51
15.	EMS	-10	43	23	04	-11	05	04	08	-02	32
16.	Fa	-02	35	08	-09	01	60	16	02	-10	57
17.	Fi	03	25	25	-02	01	42	-04	-03	-10	46
18.	N	-04	29	34	24	04	04	-15	-07	03	53
19.	Cs	38	-05	06	21	01	10	17	07	-06	52
20.	Cf	48	03	03	05	-05	02	01	-08	10	47
21.	Sc	-02	00	63	-04	06	09	-10	-07	08	58
22.	Wf	08	-23	46	-09	-05	14	07	01	06	47
23.	P	02	06	48	20	00	-14	04	06	-03	62
24.	U16	-04	18	-05	05	15	07	48	-04	08	37
25.	U21	13	-08	10	00	23	12	24	15	-04	35
26.	U36	00	43	-06	03	-12	06	20	-02	-13	25
27.	ER	01	06	-02	00	-01	00	-14	81	05	79
28.	U24	-06	-26	06	00	-47	-01	09	14	03	50
29.	H	-10	-06	07	06	82	00	-01	02	-03	80
30.	Q_1	06	39	02	-14	14	-01	09	08	20	39
31.	Ip	02	04	-04	05	-15	20	54	-12	07	41
Hyp. ct.		17	15	24	18	23	18	19	26	25	185
Pct. ct.		55	48	77	58	74	58	61	84	81	66

Transformation Matrix

92	-14	-13	11	-07	14	01	03	-03
-18	97	07	24	-03	-06	-07	-06	-10
-14	-09	91	01	07	02	-14	01	12
04	08	04	95	-04	-06	00	-08	00
-16	04	18	-04	99	-08	-03	06	-02
15	-06	09	-02	-03	98	06	02	-06
-21	04	-18	-14	00	00	98	07	-08
00	-14	18	00	-06	-02	05	97	11
-08	-04	21	-03	03	-10	-02	20	98

to adopt the common practice of treating a loading above .30 as significant. Occasionally, in order to amplify an interpretation suggested by higher loadings, a loading below .30 will be mentioned in interpretation. In no case, however, will a variable with loading less than .20 be used in interpretation except when it is referred to as being in the hyperplane.

Kaiser (1960) and Dickman (1960) have pointed out that there is a relationship between the concepts of variance contribution for a factor and the reliability of the measure of the attribute represented by the factor. The suggestion from this work is that when the variance contribution of a factor is less than unity (i.e., the arbitrary variance assigned to the variables among which the factor is found) the internal consistency relaibility of the factor is no greater than, and probably less than, one or more of the components which enter into the weighted linear composite which measures the factor. Actually, Kaiser shows that the alpha reliability of the factor becomes zero at this point, but his conclusion is based on the assumption that one would use all variables in the battery to estimate factor scores. If only the salient markers were used, the reliability would probably be non-zero, although less than the reliability of the most salient marker. In other words, when a factor shows less than unity variance, there is no justification for interpreting _it_ as a factor; rather the variable which is most salient in the factor should be regarded as the more unitary influence. This is a particularly important point to note in the present study because the variables themselves are, as determined in previous research, factors on their own count. Hence, when a second-order factor, such as IX, is found to have less than unity variance, the conclusion to be drawn is that a first-order factor is appearing again at the second order.[7]

The variances for the oblique factors were not determined in this study. There is enough similarity between the Varimax and the oblique solutions, to indicate that, for the factors which would come into question in terms of the above criteria, the variance contributions of the latter are quite similar to those for the former. Hence, it can be assumed that in both solutions factors VIII and IX are probably best-regarded as outcroppings of first-order factors at the second-order.

d. Interpretations and Discussion of Factors

As concerns the theory being developed in this monograph, the Varimax factors present partial confirmations which are much clarified by the visual rotations. For example, the first and very broad Varimax factor involves spatial visualization to a considerable extent, and yet it is not clearly a confirmation of the hypothesis of a Gv dimension because it also contains several high-loaded factors (e.g., CMR, L, Rs) which seemingly involve little or no use of visualizing processes. Of course, if the term "visualization" were interpreted to mean ability to imagine how things "might be", then the factor could perhaps be given this label. But this is a bastardization of the Gv hypothesis.

What could be wrong here? Why has Varimax thrown up this general factor?

It will be noted that Varimax factor I is also similar in some respects to the hypothesized Gf. It is identical to this factor except that it involves visualization variables and, crucially (because this gives the clue), Mk. Now visualization and Mk functions have previously been shown to be among those which rather clearly distinguish between males and females; and it has been noted that in the present study, presumably by virtue of sampling bias, the males of the sample out-performed the females in many factors involving intelligence. It would appear, therefore, that factor I probably represents a confounding of a male-vs-female sampling bias and general visualization. (This is what Thurstone (1947) and Thomson (1948) have carefully considered under the heading of "the effects of univariate and multivariate selection of subjects".). In other words if one had only the Varimax he should probably conclude that the first factor is Gv--which in fact (i.e., in the population) correlates with masculinity (at least in this society)--but that here it "pulls in" various factors which in *this particular sample* correlate with masculinity by virtue of the fact that the samples from the populations of the two sexes were not representative or biased in the same ways.

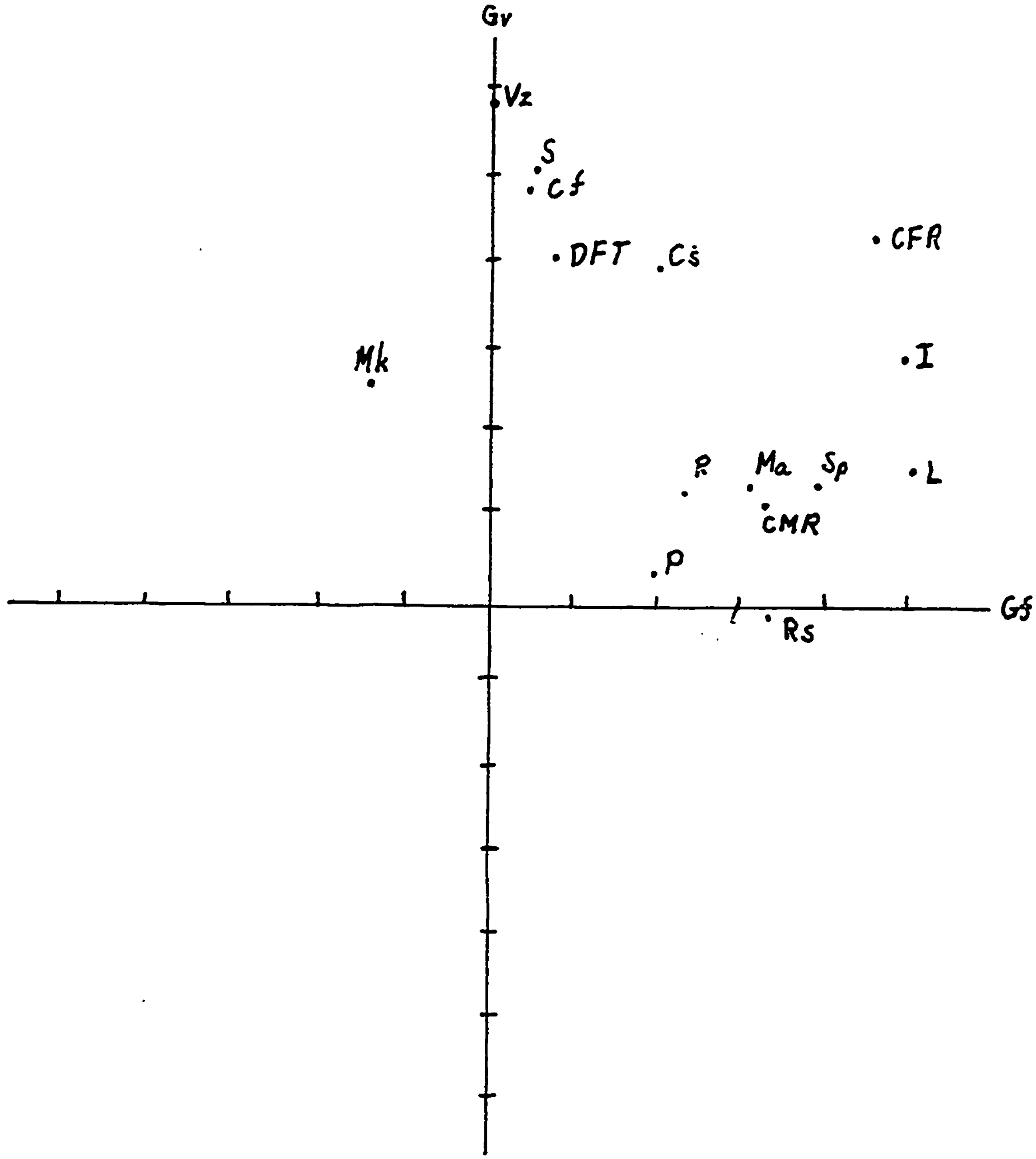
The fascinating sequel to this interpretation is that when the rotations to the more nearly adequate oblique simple structure are carried out, the ambiguities occasioned by the Varimax solution largely disappear, just as Thurstone argued they should. This would thus appear to be a minor confirmation of Thurstone's hypothesis that simple structure factors are invariant with univariate selection of subjects. More pertinent to the present study, however, the oblique solution gives quite definite support for the hypothesis of a general visualization dimension spanning the facets of Vz, S, Cf, Cs and DFT and dipping into measures of Gf when these involve Figural content. The only apparent anemalies in this O-I factor--and they seem to be only apparent, not crucial--are the still remaining low loadings on Mk and I. It seems likely that these probably represent some residual of the sampling bias effect noted above, together with the fact that Mk and I do perhaps involve slight amounts of the visualization function. Actually, although the oblique rotation gives a much better simple structure than the Varimax, there is still room for improvement in it. It seems, in fact, as will be shown at a later point, that the visual rotations should have been carried a bit further to achieve the truly "best" simple structure and a truly "clean" separation of Gv and Gf.

The factor numbered IV in both the Varimax and oblique solutions is in striking agreement with what was hypothesized for Gf. It contains figural reasoning tasks (CFR), symbolic reasoning tasks (I, L, SP) and semantic reasoning tasks (CMR, Rs, R). Intellectual Level (L), presumably involving little or no speed variance, is the most salient marker, but factors involving intellectual speed, as represented by SP, also load quite prominently. The hypothesized anlage functions represented by Ma and P are present with loadings that are consistent with their measure of these functions. Perhaps most important, the high-loaded variables can all be seen to be relatively culture-fair measures when they are made on a sample of adults and the variables which most obviously reflect intensive acculturation are in the hyperplane, as, incidentally, are the non-intellectual factors. Some of the primaries can be seen to present possibilities for the operation of alternative mechanisms, fluid or crystallized intelligence, as discussed before. Thus, variables like R, Rs, CMR and N allow that if one has developed the particular specialized skills of algebra, the "calculus of syllogisms," the "tricks" of numerical analysis, and the vocabulary implicitly required in some verbal analogies, then these can be used to solve the problems of these factors; but if such specialized skills have not been learned, some of the problems in each of these factors can be solved by just "thinking them through" with the help of aids that can (if one is able) be learned more or less incidentally through experiences that virtually everyone in this society would have had, and had repeatedly, by the time they reach adult age. Thus, over-all, factor IV can be rather confidently identified as Gf.

A bi-variate plot of the loadings for Gv and Gf is given in Figure 4 to help the reader visualize the similarities and differences between the two functions. This plot indicates, too, that there are still possibly some shifts

Figure 4

Bivariate Plot of Gv and Gf



which should be made: I on IV plus to bring the IV axis counter-clockwise some 10 to 15 degrees, and IV on I negative to bring the axis of I about 5 degrees clockwise.

Just as factor IV agrees with expectations for a Gf dimension at the second order, so, too, factor II is quite consistent with what was predicted for Gc, particularly Gc_1. Of the various primary factors in this battery which putatively would be said to involve intelligence to any considerable degree, practically everyone which would be expected to be improved by intensive acculturation loads prominently in this dimension. The salients are, just as expected, Verbal Comprehension, Semantic Relations, Mechanical Knowledge, Experiential Evaluation, Number, etc. In accordance with the theory that some primaries allow for use of alternative mechanisms--Gf or Gc intelligence--the factors R, CMR, Rs and N split their variances between this factor and the Gf functions.[8] The fluency variables are involved with low loadings, but the bulk of the factor does not indicate merely a glibness in spouting concept labels: there is indication of understanding and being able to use cultural concepts and aids.

The only loadings which might seem anomalous in factor II are those on the non-intellectual factors; Self-Sentiment, Q_1-Experimenting and Anxiety (negatively).

Actually, the same kind of alignment of the self-sentiment and Q_1 with a crystallized intellectual function has been found in a previous study on an entirely different sample (Horn, 1961), as can be seen in Table 23. There it was pointed out that theoretically (see e.g., McDougall, 1932; Cattell, 1950; 1960), the development of the self-sentiment and the intellect are closely entertwined in mutually supportive interaction. One's capacities for comprehending complexities initially determine the adequacy with which he adapts to the demands which are placed on him by the circumstances of his physical and social environment; and his perception of his adequacy in coping with these demands, determined and reinforced by the feedback which he inevitably (although perhaps subtly) gets from both the physical and social environment, determines in part his adjustment,[9] his self-regard and the motivation, personality integration, etc., which stem from more and less accepting and realistic perceptions of self. This development of self-sentiment, in turn, determines in part the extent to which an individual can take advantage of acculturational opportunities such as those which enable him to build up crystallized intelligence. Hence, although theoretically and in measurement the self-sentiment and crystallized intelligence are somewhat distinct--the former is measured

TABLE 23

The Factor Interpreted As a Crystallized Intellective Self-Sentiment (Abstracted from Horn, 1961)

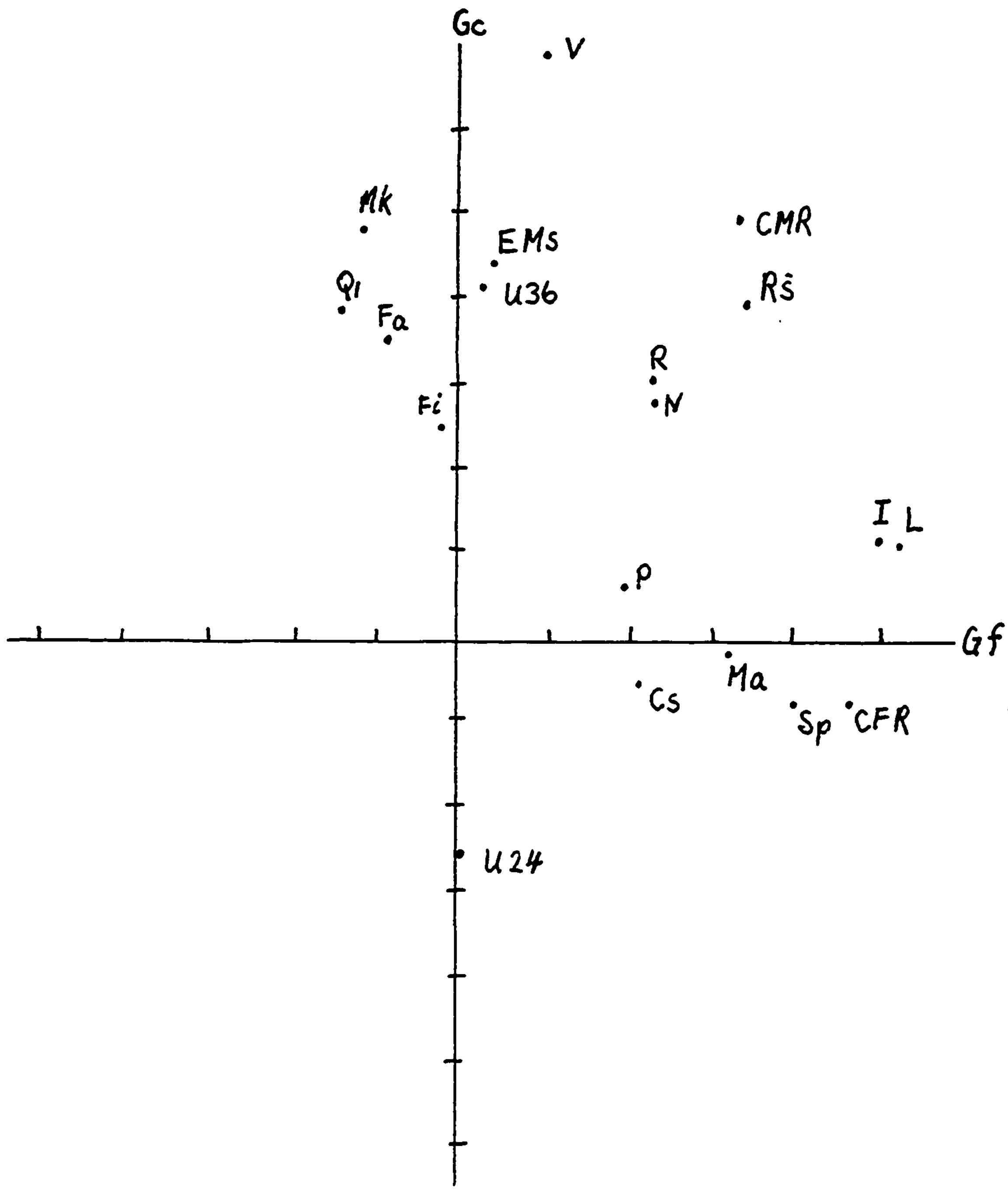
Variable	Factor Loading
PMA Verbal Ability (V)	69
MAT General Information	47
16PF Analogies (CMR)	46
Attitude: I want to discover and create: Utilities Device	42
Attitude: I want to test myself: Utilities Device	39
Self-Sentiment: Utilities Device	39
Life Goals Distant in Time	38
Q_1 Experimenting	33
Q_2 Self Sufficiency	32
Self-Sentiment: Word Association Device	28
Self-Sentiment: Autism Device	27

among attitude variables which do not involve intellectualization, as such (Cf. Cattell, Horn, Radcliffe and Sweney, 1964), whereas the latter is measured among ability tests calling for noegenesis, abstracting, etc.--they are developmentally correlated and constitute a functional unity at a general level. The present factor, because of its many salient loadings on purely intellectual factors, is best identified as crystallized intelligence, but it must be recognized as somewhat confounded with the Self-Sentiment, since this latter was not separately identified at the second order.

Figure 5 presents a plot illustrating the relationship between, and the distinctiveness of, the two major intellectual functions, Gf and Gc. Here it is clearly seen that in performances like CMR, N and R either one or the other function may be used, and that these primaries are not truly characteristic of either function, although they load on both. In other studies (Horn, 1965b) it is shown that when the analogies problems of CMR are separated into two sets, one set involving relations among very common words, the other involving relations among abstruse words, the former set loads mainly on Gf whereas the latter set loads almost exclusively on Gc. It would seem that if the arithmetical reasoning problems of R were likewise split into one set

Figure 5

Bivariate Plot of Gf and Gc



requiring rather abstruse aids and another set requiring "everyday" reasoning, the latter would show greater variance in Gf, while the former would load mainly Gc.

In both the Varimax and the oblique solution, factor III brings together all of the simple speeded tasks with high loadings. However, the Varimax factor (which has a rather poor simple structure) also includes (with low loadings) some variables which appear to involve an intellectual speed component,[10] as represented most notably by SP. This would thus suggest a very broad speediness function, spanning temperament or motivation and intellect. But in the oblique rotations the relation-perceiving speediness component drops out, leaving a very good simple structure on only the simple tasks. Thus the suggestion is that factor III represents either a rather simple intellectual speed function or an aspect of temperament or motivation.

One might ask at this point: "What happened to the intellectual speed component in the oblique rotations?" The answer to this is to be found in Table 24, where the correlations between the oblique factors have been presented. Here it can be seen that the speediness of factor III is indeed correlated with Gf (as well as with several other second-order functions, notably Gv). Thus in a sense the intellectual speed component which the orthogonal Varimax

TABLE 24

Intercorrelations Among Second-Order Factors

Primary Factor Number

	Gv I	Gc II	Gs III	Gf IV	PSI V	F VI	PRM VII	ER2 VIII	C2 IX	Roots for Unity h^2
I										2.24
II	36									1.42
III	37	10								1.29
IV	34	16	39							1.07
V	25	33	16	00						0.86
VI	09	-12	22	21	06					0.75
VII	-11	-01	22	00	10	04				0.53
VIII	34	-01	27	17	14	06	12			0.46
IX	-02	12	-26	06	-03	22	-09	-19		0.38

Re-arranged to Show Approximation to Hierachical Order

	Gs	Gv	ER2	Gf	PSI	Gc	PRM	F	C2(-)
Gs									
Gv	37								
ER2	27	34							
Gf	39	34	17						
PSI	16	25	14	00					
Gc	10	36	-01	16	33				
PRM	22	-11	12	00	10	-01			
F	22	09	06	20	06	-12	04		
C2(-)	26	-02	19	-06	03	-12	09	-22	
Sums	1.99	1.62	1.28	1.20	1.07	0.69	0.45	0.33	0.15

factor III contains is simply an indication of a correlation between Gs and Gf. Or looked at another way, Varimax factor III indicates which particular primaries in Gf mainly involve the Gs function.[11]

But whether one looks primarily at the oblique Gs and the correlations which it has with other factors or at the Varimax Gs, with its low loadings in intellectual tasks, the correct interpretation of factor III does not come readily to hand. Speed of copying suggests that it could be a state-like function of effortfulness in the immediate testing situation. That is, there is at least a suggestion that this is a dimension of individual differences in a kind of test-taking motivation which can be largely independent of the abilities represented by the other factors isolated in this study. Introspectively it makes good sense that there is such variance--that is, one is aware that his performance on a simple writing task can be improved by just "trying especially hard ". The main objection to this interpretation is that this study employed no methods which would provide an operational distinction between such a state-like function and a stable trait (Cf. Cattell, 1957; Horn, 1963a). As a result there is no firm evidence here that would support the hypothesis. And other possible hypotheses are in no better shape. The link-up with UI-21 Exuberance in the

Varimax solution may be an important clue, but in fact the interpretation of UI-21 itself is still in doubt (Cf. Hundleby, Pawlik and Cattell, 1965). Hence for the present, at least, about the most that can be said is that a simple speediness function can be identified at the second-order and that this is related to performance on complex intellectual tasks, such as some of those which define Gf.

It will be recalled that some of the previous work in this area, particularly that of Botzum, had suggested that there might be two Gc-like functions at a second-order level of analysis. This hypothesis is seemingly confirmed in the present study by the finding of the previously mentioned factor II and factor VI, now to be discussed.

This latter is defined primarily by the fluency factors: Fa, which has little variance in the Gs component and Fi, which had some of its variance taken up with simple speediness. Both of these factors also have some of their variance in the Gc-reasoning factor II. In addition to sheer fluency, factor VI also brings in some variance on CMR. Hence, in accordance with the hypothesis that was adumbrated in the earlier discussion of Botzum's work, it would appear that factor VI represents a dimension of individual differences in familiarity with concepts and/or concept labels of the culture and a facility in getting these elements of long-term memory out to the immediate-awareness "drum," whence they can be spouted or otherwise used.

It was supposed in the earlier discussion that this dimension would be a component of a general Gc factor at the third-order. This supposition is not borne out in the present study, however. As can be seen in Table 24, it would seem, rather, that this fluency dimension is largely independent of the Gc, factor II, dimension. That is, it would appear that crystallized intelligence involves fluency, to be sure, as represented by the loadings of Fa and Fi in factor II, but that the fluency factors, particularly, and V and CMR to a lesser extent, may measure a kind of glibness function which, although it might at first be confused with crystallized intelligence, is in fact independent of Gc. Hence here it is labeled F to indicate general fluency, rather than Gc2.

The remaining factors V, VII, VIII and IX are of less relevance for the main hypotheses of this study, although some of them are quite intriguing.

Factor IX, for example, suggests that the carefulness factor, measured among intellectual tests, stands virtually alone at the second order in this rather broad sampling of both intellectual and non-intellectual primaries. The pattern of loadings on IX is virtually identical to the pattern of correlations which carefulness showed with other factors in Table 17. The suggestion is, therefore, that carefulness is, in the space of these variables, both a first order and a second-order dimension.

Thus if instead of attempting to interpret factor IX, which shows only one loading meeting our criterion for significance, the factor C itself is interpreted from its pattern of correlations with other "primaries," it may be seen that carefulness enters to a small extent into the performances of General Reasoning, Intellectual Level and Verbal Comprehension and that it correlates slightly negatively with Intellectual Speed (or Speediness), but not at all with general speediness. Also, whatever it is it seems to relate to the rather academic kinds of values expressed in Q_1-Experimenting.[12] It is unfortunate that factors in the sub-area of superego functions were not included in the present analysis, for although it is apparent that the acceptance of intellectual values implied here is not the same, in terms of content, as superego, it may be related to the sort of intellectualized moral-ethical system which McDougall recognized as the substitute for superego in the "rational" man. In any case it would appear that carefulness involves non-intellectual traits and it seems likely that these are to be found among the dimensions of moral and ethical beliefs.

Factor V is defined exclusively by non-intellectual factors. The variables which mark it most prominently (H and UI-24(-)) are those in which the person expresses himself as being rather bold in social situations--able to come forward and speak in a group, not embarrassed when the focus of attention in a group, able to speak to strangers, at ease at social gatherings, etc.--and lacking in the physical and psychological ailments which denote anxiety. The dimension appears to match rather closely the positive self-image factor which Horn (1963b; 1964) found at the uppermost level in a hierarchial pattern of factors in the 16PF, MMPI and other questionnaires.

Factor VII is defined essentially by three variables: Ip-Sensitivity, UI-16 Assertive Ego, and Mk (-). The values expressed in the first two factors are those of preferring what might be called the "good and delicate things in life"--i.e., "good" books, "good" art, "good" music, "good" food, etc. The "sensitivity" is that of a person who prefers English to mathematics, "imaginative novels" to "realistic accounts of military or political battles," brandy to beer, ballet to burlesque, etc. In Mk, on the other hand, the person shows himself (and the _Him_ is appropriate here) to know the difference between a U-bolt and a yoke, a timing gear and a crankshaft, a key-hole saw and a rip saw, etc. The dimension is thus obviously one of interests. Cattell's term "Premsia" has a certain ring about it which seems to capture the essence of the "sensitiveness" represented by this dimension. The dimension is probably that labeled "sensitivity" at the second-order in questionnaire studies (Horn, 1963b, 1964; Gorsuch and Cattell, 1965).

Factor VIII is a specific loaded only by Early Risks. This factor was discussed in the previous section dealing with the intercorrelations of the primaries. There would appear to be no need to amplify that discussion on account of the second-order findings.

e. The Correlations Between Second-Order Factors

The table 24 intercorrelations between second-order dimensions was introduced in the previous section. There the reader may have noted that a positive manifold existed among the first five dimensions. Allowing that there would be considerable sampling error in the correlations and thus that the small negative correlation of O-VI with O-I and O-II would be essentially zero (or perhaps slightly positive) in the population, it might be reasoned that the positive manifold would also include factor IV. Carefulness has already been shown to exist in the positive manifold of primary factors except for its slight negative correlation with speediness functions, and it seems that the second-order C, somewhat similarly, shows mainly zero-to-low positive correlation with the general functions except for Gs, where the correlation is negative. Thus it would appear the main general factors isolated in this study are not completely independent, and that a more general integrating principle operates among them. According to the theory stated in this monograph, this general integrating principle is to be understood in terms of the interaction in development between various intellectual and non-intellectual traits and it is to be understood, also, in terms of the lack of independence in operation of the external environmental conditions which tend to promote or inhibit these various developments.

To note the positive manifold in Table 24 is not to say that a single factor will explain the covariance there represented. Hierarchical order is not by any means evident in the matrix. It is questionable whether such an order should be found, both on general theoretical grounds and, in the present instance, on technical grounds.

As concerns the theoretical issues, consider the fact that the positive manifold in Table 24 (and earlier in Table 17) includes the positive self-image dimension. Now it is reasonable that this should be correlated with Gf and Gc, surely, and it is not unreasonable that it should be correlated with Gv and Gs, but it does not necessarily follow that it should fall into a hierarchical order defining a single unitary function. Hierarchical order is a considerably more stringent requirement than is positive manifold. It implies one and, most importantly, _only_ one influence or attribute in a set of observations; positive manifold indicates one influence, but not necessarily only one. While it is reasonable to argue that positive self-image stems from some of the same influences as Gc, Gf, etc., it is not so reasonable to argue that these various functions involve only one thing in common. The implication is that a multifactor theory is called for among these dimensions at the third order.

However, the technical issue alluded to above introduces difficulties which make it awkward, at least, and perhaps impossible, to adequately explore possible multifactor hypotheses at the third order in the present study. It was pointed out above that Thurstone (1947) presented convincing statistical and logical arguments for the contention that simple structure factors would be relatively invariant with univariate and multivariate bias in the selection of subjects (and the results in the present study appear to be consistent with his deductions). But by these same arguments he suggested, also, that the correlations between factors will not be invariant and in fact will reflect the sampling bias.[12] Thus in the present instance, where it seems evident that there is some (perhaps gross) sampling bias, the table of intercorrelations between second-order dimensions is possibly quite ambiguous as concerns the third-order factors. For example, according to the arguments presented earlier, the correlation of Gv with Gf (and also with Gc and Gs) represents in part at least, sampling bias in drawing male and female subsamples. Perhaps Thurstone's arguments for the invariance of simple structure factors will apply equally well to the analysis of factors among correlations between simple structure factors, but we should probably be cautious about assuming this without proof.

A related technical issue concerns the error of correlations like those in Table 24. It is certain that more than sampling error is involved. Of course this is always true even of zero-order correlation coefficients. The experimenter introduces some error by virtue of the way he administers tests. Some of this is bias in the sense that it raises the consistency reliability of his variable and raises the correlation between two related variables. Some of it is random in the sense that it attenuates these correlations, etc. But intuitively it seems that what the experimenter does in rotating factors introduces error of a higher order of magnitude than that involved in merely obtaining his basic measurements. For one thing, unless he rotates for years, he will always find that he can improve the simple structure of the last rotation by "just one more" shift. The implication is that he never quite gets to the point where he can compute the correlations between his dimensions. This is the feeling in the present analysis, for example.

In general, then, the above considerations imply that while the general trends in correlations between dimensions are possibly indicated in Table 24, the <u>differences</u> between correlations should probably be interpreted only when they (i.e., the differences) are quite substantial and even then very cautiously. The implication is, too, that results obtained at the third-or higher order should be regarded gingerly.

f. Higher-Order Analysis

Realizing, then, that higher order analysis might be more misleading than revealing, the correlations in Table 24 were nevertheless factored, this yielding four third-order factors, and the correlations between these were factored to give two fourth-order dimensions. In each case the procedures were like those described above: the root-one criterion was used (rather blindly it would seem in retrospect) to determine the number of factors and a number of iterations of the principal axis procedure was carried out to stabilize communality estimates, after which the factors were rotated in accordance with the Varimax criterion. The four third-order factors were also rotated by visual means. The results from these analyses are presented in Table 25.

Factor A at the third order brings together Gs with Gv, F and ER. It thus seems to be a compound of a general speediness function, involving both intellectual

TABLE 25

Third-Order Factors

		Principal Axis				Varimax				Oblique				
		A	B	C	D	A	B	C	D	A	B	C	D	h^2
	I	69	23	-07	-19	56	46	03	-22	56	35	00	-21	58
	II	42	44	-43	23	02	78	07	-05	01	76	10	04	61
	III	67	-30	16	-01	70	10	-12	22	69	-02	-14	16	57
	IV	48	07	25	-12	52	10	17	-06	52	00	12	-07	31
Primary	V	34	08	-20	19	13	41	-03	12	12	38	-01	15	20
Factor	VI	20	06	49	04	34	-15	38	08	34	-21	35	07	29
Number	VII	15	-40	08	61	07	04	-04	75	05	03	02	73	57
	VIII	40	-20	01	-09	41	08	-17	05	40	00	-19	02	21
	IX	-13	66	38	23	-17	10	78	-10	-15	13	79	00	66
Com.	Var.	170	100	071	058	142	104	083	070					
Pct.	Var.	426	250	179	145	356	260	209	175					

Third-Order Transformation

	A	B	C	D
A	98	-05	02	10
B	00	99	02	-09
C	18	-07	99	07
D	01	-08	04	98

Intercorrelations Among Third-Order Factors

	A	B	C	D	Roots For Unity h^2
A	12				1.20
B	18	34			1.18
C	03	-03	04		0.93
D	-08	-10	-18	69	0.68

Fourth-Order Factors

Alpha	Beta
09	33
-09	58
-21	-03
82	-04

and non-intellectual speeded measures, and the male-female sampling bias.

Factor B is a general crystallized intelligence and positive self-image component. Perhaps this could be termed an intellectual self-sentiment function.

The variance for factor C is less than one, thus, suggesting that carefulness (which has the principle loading here) remains independent even to the third order. There is perhaps some suggestion that the dimension involves variance on the fluency factor. This might be a clue to a fuller interpretation of earefulness, for it suggests a tie-up with a factor Horn (1961) interpreted as intellectual superego and which contained fluency measures with various objective and self-evaluational indicants of rigid superego.

Just as Early Risks was independent of other primaries at the second order, so, too, it is largely independent of second-order factors at the third order. It is likewise independent in factor alpha at the fourth order.

Factor Beta at the fourth order gives indication of a big G factor, accounting for the general positive manifold noted in the original correlations.

Horn (1963b) found that transformation of higher

TABLE 26

Schmid-Leinan Transformation Factors

		Alpha	Beta	B	C	D	I	II	III	IV	V	VI	VII	VIII	IX	Res.	h^2
1	I	42	30	20	00	–14	26	08	–02	46	–02	–08	–04	–05	–04	–11	64
2	SP	40	16	00	–19	08	11	–05	08	36	05	–07	05	–02	–14	00	41
3	C	05	09	15	50	–06	03	05	06	07	–05	–13	08	06	41	04	48
4	L	33	26	20	22	–02	13	09	03	47	03	–10	–08	–07	12	01	33
5	CFR	53	28	12	13	–13	38	–06	–06	41	00	01	00	08	06	–09	74
6	R	13	24	26	18	–18	10	22	–03	22	–04	–03	–09	–02	08	–09	34
7	DFT	32	27	22	06	–10	32	06	02	09	00	00	–01	–05	02	–06	35
8	S	39	26	15	–19	–12	41	–03	06	06	–07	–18	–05	04	–06	–12	53
9	Vz	41	31	22	05	–14	46	05	01	02	–05	08	–03	–04	00	–10	59
10	Ma	44	17	02	09	–05	12	–02	09	29	05	14	–06	04	01	–05	37
11	CMR	26	36	39	26	–08	09	36	–10	30	07	27	01	–01	01	00	74
12	V	14	37	46	28	01	–02	50	01	10	–00	24	07	–02	06	07	79
13	Mk	10	35	43	00	–26	21	36	–06	–11	00	05	–19	08	–05	–15	64
14	Rs	26	27	26	20	–07	–12	29	–05	35	00	18	–03	12	03	–02	51
15	EMS	20	23	23	00	09	–08	31	19	04	–11	05	03	08	–01	06	32
16	Fa	25	16	12	15	17	–02	25	07	–09	–01	56	11	02	–07	13	58
17	Fi	38	20	10	06	07	02	18	21	–02	00	40	–03	–03	–07	04	45
18	N	39	28	20	06	–03	03	21	28	25	04	04	–11	–07	02	–02	48
19	Cs	52	25	08	–02	08	32	–04	05	20	01	09	12	07	–04	02	53
20	Cf	38	28	19	10	–11	40	02	06	06	–05	02	00	–08	07	–07	47
21	Sc	48	16	–01	00	11	–01	ol	52	–04	06	09	–08	–08	06	04	57
22	Wf	44	02	–19	–02	18	06	–17	39	–08	–05	13	05	01	04	08	48
23	P	52	23	06	–14	16	00	04	40	21	00	–13	02	06	–02	06	62
24	U16	11	09	20	08	30	–03	13	–04	–05	15	–06	34	–04	05	23	38
25	U21	33	14	05	–04	22	11	–06	08	00	23	11	17	15	02	13	34
26	U36	00	17	25	–01	10	00	31	–05	02	–12	06	14	–02	08	08	26
27	ER	32	15	05	–11	–04	01	04	–02	00	–01	00	–10	80	04	–06	81
28	U24	00	–26	–37	–04	06	–05	–19	05	00	–47	–01	06	14	02	00	50
29	H	14	19	20	–06	14	–08	–04	06	06	82	–00	–01	03	–02	09	82
30	Q1	–01	26	38	18	02	04	29	02	–14	14	–01	06	08	13	07	41
31	Ip	00	–06	–05	20	31	–02	03	–03	04	–15	19	38	–12	05	24	42

order factors by means of the technique developed by Schmid and Leiman (1957) seemed to be helpful in two ways: first, it reaffirmed, as it were, the simple structure among first order factors--i.e., it produced orthogonal first-order factors which had as good a simple structure as was achieved in the oblique rotations and, second, it gave higher order factors that were defined in terms of the basic variables and were somewhat interpretable. It seems possible that the factorial solution achieved with a Schmid-Leiman transformation in the present instance might be similar to the hierarchial solutions obtained by British psychologists. Insofar as this kind of link can be forged, hitherto unrelated findings from different kinds of factorial studies can be related. The number of factors extracted by the present study is far greater than would have been defined at this order in the British work, but it is still possible that the more general dimensions isolated here would correspond to some of those identified in the British hierarchial solutions. For these reasons, then, it seemed desirable to compute the Schmid-Leiman transformation on the present data. The results from this computation are shown in Table 26.

It can be noted in Table 26 that the previously dis-dussed findings at the second order are here repeated in factors I through IX. In addition, the correlations between the second order dimensions are represented in the factors labeled B, C and D and alpha and beta. The residual factor to the far right in this table probably represents the fact that at least one too many factors was estimated at the higher orders.

Because of their extreme generality and the fact that they probably represent, in part, various kinds of sampling bias inherent in the present study, the interpretations of the general factors at the top in this hierarchial solution are difficult. The first one seems to indicate a very broad speediness and fluid intelligence function, including also, however, UI-21-Exuberance and the boldness implied by Early Risks. Seemingly, too, this factor isolates much of the variance associated with differences between male and female subsamples in this study. The other most general dimension is, by way of contrast, a very broad crystallized intelligence and positive-self image function largely devoid of speediness in either the intelletual or temperament sense. The distinction between factor B at the third order and factor II at the second order is here seen to be very minor. Probably these two factors should be regarded as representing the same set of influences, the repetition being merely an indication that some slight sampling or rotation bias was present and led to an over-estimation of the number of factors at one order or another. This kind of explanation seems called for to account for the slight variations between factors D, VII and what is labeled Res. In general, then, it would seem that no more than about three factors are indicated above the second-order dimensions.

Table 26 is intended to give a schematic summary of these major findings as they relate to the concept of a structure of intellect.

TABLE 27

Schematic Representation of a Hierachy of Human Abilities & Non-intellectual Traits Indicated By This Study

Primaries	Second-Order								Third-Order		
	Gf	Gc	Gv	Gs	F	C	PRM	PSI	A	B	G?
L	5					3			3	3	5
I	5		2						4	3	5
CFR	4		3						5	3	5
SP	4								4		4
Ma	3								4		4
CMR	3	4			3	3			3	4	4
Rs	3	3			2				3	3	4
R	2	2				2				2	4
N	2	2							4	3	4
V		5			2	3				4	5
Mk		4					−3			4	3
EMS		3							2	2	3
Vz			5						4	3	3
S			4						4	3	3
Cf			4						4	3	3
DFT			3						3	3	3
Cs	2		3						5	2	3
Sc				5					5		2
Wf				4					4		2
P	2			4					5	2	2
Fi		2		3	4				4	2	2
Fa		2		2	5				2	2	2
C						5					1
U36		4					2				
Q1		4								2	
U24		−3						−5		−2	
U16							5				
Ip							5				
H								5		2	
U21								2	3	2	
ER									3		

E. Summary

Thirty-one primary mental ability and general personality traits were measured in a sample of 297 adults, and the intercorrelation and factors among these traits were studied in detail. Some eight general dimensions were indicated at the second order, viz.,

Gf. Fluid Intelligence. This is a broad dimension of individual differences in the processes of perceiving relations, educing correlates and maintaining span of immediate awareness in reasoning and abstracting. It is measured in relatively culture-fair tasks involving various kinds of fundaments, including those found in figural, symbolic and semantic content. It can be measured in both speeded and unspeeded tasks. However when measured in the former, the performance contains a general speed component, whereas when measured under power conditions alone, the performance may contain a carefulness component, just as when it is measured in figural content alone, the performance contains a general visualization component. Hence, the most valid measure is obtained by spanning the facets of content and those of speededness of test administration.

Gc. Crystallized Intelligence. This likewise is a broad dimension of intellect involving the processes of reasoning and abstracting. However, unlike Gf, this is manifested in tasks which require considerable pre-training in the skills which constitute the collective intelligence of the culture and which are learned under conditions of intensive acculturation. Such acculturation is a result not only of opportunity such as is occasioned by special schooling and continued exposure to the culture in aging, but also of motivation, personality integration and similar non-intellectual traits. These latter are probably related to intellectual function through interaction in development. Gc can be measured in tests measuring awareness of concepts, facility and quickness in the use of concept labels and in various reasoning tasks involving cultural concepts and specialized solution instruments. If measured in fluency tasks alone, performance will contain, besides Gc, substantial variance from the general speed component and a fluency component that is largely independent of Gc. Hence, valid measurement requires the spanning of fluency, speediness, knowledge, etc. facets.

Gv. General Visualization. This involves the processes of imagining the way objects may change as they move in space, maintaining orientation with respect to objects in space, keeping configurations in mind, finding the Gestalt among disparate parts in a visual field and maintaining a flexibility concerning other possible structurings of elements in space.

Gs. General speediness. As identified in this study this could perhaps be an attribute indicating a state of test-taking effortfulness, rather than a stable trait. Actually, it is possible that it indicates a trait that shows considerable function fluctuation. In any case, it is measured most purely in simple writing and checking tasks which require little in the way of complex relation-perceiving. However, as noted above, the function itself produces variance in the measure of most intellectual functions unless care is taken to cancel it out by measuring with both unspeeded and speeded tasks.

F. Facility in the use of concept labels. Here it would seem that the principal process is one of being able to quickly bring words (i.e. concept labels) out of long-term memory and into immediate awareness. This facility is perhaps largely independent of comprehension of the subtlety of the conecpts themselves, as indicated in Gc.

C. Carefulness. This is a primary factor which appears to maintain its independence at the second-order, and is thus perhaps a more general function than was first supposed. Like Gs, it appears to be an attribute which is not intellectual in itself, but which can produce variance on intellectual tasks. It is measured by recording the number of wrong answers given in a wide variety of intellectual tests. As such, it seems to represent an unwillingness to leave a problem until virtually certain that the answer given is correct. It is thus descriptively similar to what is termed persistence and, although evidence on the hypothesis is not presented in this study, it is expected to be closely related to some aspect of superego development.

PRM. Premsia. This is a more general version of the questionnaire factor of the same name. Here it is seen to involve, besides stated preferences for literary, artistic, feminine-type activities, a lack of knowledge about mechanical principles, mechanical tools, and the like.

PSI. Positive Self-image. This is a broad dimension in self-ratings and self-evaluations as these are admitted in questionnaires. The person high in the trait denies having the physical and psychological symptoms of anxiety, claims the sociable, adventurous, outgoing, qualities of extraversion, and the confidence and wide range of experience of UI-21 Exuberance. More generally the trait is one of ascribing characteristics to oneself that are rather widely regarded as socially desirable. Present indications are that this bears a positive relationship to most of the above-mentioned traits of intellect, particularly Gc.

In addition to the above factors, which constitute the principle findings of this study, two higher-order dimensions were suggested among these, one bringing together Gf, Gv, Gs and F, the other involving Gc, Gf, and PSI principally. However, the higher-order factors were not clearly defined due in part to certain biases inherent in the sampling of subjects and in part due to the fact that rotations were not fully adequate to meet the intricate demands of higher-order analysis.

Footnotes-III

[1] Although insofar as rotations have not been based on thoroughly objective procedures--i.e., insofar as "Procustes-like" methods have been employed--the empiricism has not been, according to the position taken in this paper, blind enough. Although the charge will not be documented here, it would seem that rotations have frequently been "guided" by preconceptions about the nature of ability factors.

[2] That is, a blanket statement cannot be made on this since the formula requires use of three correlations (r_{12}, r_{13}, and r_{23}), the combinations of which can vary in numerous ways. The above statements are intended to provide general approximations to help the reader who scans over the entire set of correlations. The significance of difference of any particular set may be determined from Hotelling's

$$Z = (r_{12} - r_{13})\sqrt{\frac{(N-3)\ (1+r_{23})}{2(1 - r_{12}^2 - r_{13}^2 - r_{23}^2 + 2r_{12}\, r_{13}\, r_{23})}}$$

which, for this size example, has an approximately normal distribution.

[3] It can be noted that the correlations of the fluency measures, Fa particularly, with the putative tests of intelligence are in general rather low. Thus if one were to accept the currently popular premise that the former are measures of creativity (Cf. Getzels and Jackson, 1962), then it would follow that, indeed, creativity is relatively independent of intelligence, as the popular argument maintains. However, as Burt (1963) has carefully pointed out, the soundness of the basic premise in this argument is far from well-established.

[4] Actually, according to Horn's arguments this criterion is apt to be biased in the direction of indicating more factors than can be reliably (in both the measurement and sampling sense of this term) determined. However, at the present time the criterion is much more widely and favorably accepted among factorists than is Horn's modification of it. Also, at the time these analyses were carried out Horn's modification did not exist.

5
Actually rotated in accordance with a least-squares criterion which maximizes the variance of each successive factor in turn.

6
In this report the factors obtained in each kind of solution--principal axis, Varimax, obliquely rotated, are numbered with Roman numerals I through IX. The factors with the same number in different solutions are distinguished by a letter abbreviation for the solution--P for principal axis, V for Varimax, O for oblique--which letter precedes the Roman numeral.

7
Possibly because the number of factors was overestimated. At least this is what Horn (1963d; 1965) has argued. If Horn's criterion were applied in the present study, it is likely that 7 rather than 9 factors would have been estimated.

8
Even the low loadings for L and I in the Varimax solution are consistent with the hypothesis of Gf-Gc alternative mechanisms, for these, too, involve differential acculturation (knowing the alphabet) to a low degree.

9
That is, a distinction must be made, as Cattell (1957) makes it, between one's objective adaptation to circumstances and his subjective adjustment, for these, although correlated, are somewhat independent processes. The neurotic millionaire who seeks out the services of a poor clinical psychologist is poorly adjusted but, in a sense at least, well-adapted, whereas the opposite might be true of the psychologist.

10
The presence of Ma in this component might at first seem rather odd. But in fact the tests which were used to measure Ma were in each case administered under what Morrison (1960) has called "paced" conditions; that is, the paired associates which the subject was required to memorize were read by the examiner at a fixed rate. This rate, although not intended to be fast, was no doubt too fast for some subjects to comfortably adapt to. Thus, the administration of the Ma tests introduced some of what Morrison identified as "paced speed" variance.

11
Discussion of the correlations between the general factors has, for the most part, been reserved for a later section, after the factors themselves have been described. But in the case of the Gs dimension it seemed necessary to consider these correlations in order to get the interpretation of the factor itself into a proper perspective.

12
That is, one obtains a high score on this factor by expressiong himself as: 1. trusting logical reasoning more than feelings, 2. preferring to read "essays on science and society" rather than attend movies, 3. in favor of birth control, 4. believing that today's troubles arise through lack of science and thinking rather than through lack of moral and religious idealism, 5. preferring intellectual to athletic games, etc., these being just a few of the values expressed in Q_1.

13
This, incidentally, is perhaps another argument for computing first order factors as was done in this study when going to the second order, rather than determining primaries among tests and going to the second order with the R_1 matrix.

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APPENDICES

A. Scoring Rationale for Furneaux's Speed Factor.

The procedure requires that, in the administration of tests, the subject marks his paper at specified time intervals to indicate the rate at which he is proceeding. In the present study a letter series test was used and the subjects put a circle around the problem they were working on after each of twelve 30-second intervals. The problems were all at about the same, fairly easy but not trivial level of difficulty. Thus the number of answers given in each of twelve 30-second periods could be recovered from the answer sheets. Ideally, one would score only in those intervals where the person got all of the problems correct. Unfortunately, however, some answer sheets could not be scored at all if this procedure were followed, and in other cases a score determined in this manner would be based on very few observations. Thus, Furneaux recommends that one omit from scoring "Any subsection (interval) which contains any incorrect answers, unless it contains also at least two correct solutions for each incorrect one" (Furneaux, 1956). The rate at which problems are worked (solved and failed) within each such interval is then determined and converted to a common-logarithm (log.-item-time). If all the items of an interval are correct, this log.-item-time is the score assigned for each such item. If any of the answers in an interval are wrong, the log.-item-time is assigned for "all save one of the right answers." No score is given for items answered incorrectly. The final score is obtained by adding the log.-item-time scores thus assigned to problems correctly solved.

The rationale for this rather involved scoring procedure is, if anything, even more involved. Furneaux argues that subjects differ in the skew and dispersion (over m items) of the time (t) taken to produce correct answers; since (he says) the slower subjects tend to exhibit greater dispersions and skew, the average response rates for these subjects would be a mean for an erratic, asymmetrical set of subscores while the average for faster subjects would be a mean for a fairly smooth, symmetrical set of scores. In such a situation, he maintains, the use of raw rate scores would need to be based on knowledge about the person distributions. But he argues that "If the observed values of t are converted to logarithms, the distribution for log t for any particular person approximates that defined by a normal curve, the variance of which is the same at all levels of difficulty and for all people...(then) a single number, specifying mean log. t at some standard value of difficulty completely describes a person's problem solving rate at all values of difficulty, and needs to be interpreted only in the light of the single value of dispersion and of slope, both of which are population constants" (Furneaux, 1956).

For a detailed attempt at justification of these various assumptions and procedures the reader must be referred to Furneaux's papers (1956; 1961).

II

Psychometric Information About the Basic Variables, Including First-Order Results

TABLE

gf-gc FACTORIAL STUDY: PSYCHOMETRIC CHARACTERISTICS AND HYPOTHESES FOR VARIABLES

1. Main Analysis Variables:

Matrix Number	Title of Variable	Title Abbrev.	Abbreviations and Hypothesis: First-Order	Second-Order	r_{xx} Estimate	h^2	Number Items	Total Work Time Seconds	Approx. Time Per Item	Mean	Sigma	Index of Skew	Index of Kurtosis	Scoring	Response	Administration	Task Novelty	Guilford's O	Guilford's C	Guilford's P
1	Letter Grouping (Botsum)	LG	I	gf	67	61	24	240	10	9.08	3.17	-.41	.24	R	S	T	N	C	S	C
2	Number Series (Botsum)	NS	R(I)	gf	59*	64	20	244	12	8.37	4.05	.35	-.13	R	P	T	NP	C	S	R
3	Furneaux Speed (Letter Series) A(2)	FSL	I(sp)	gf(sp)	63	48	20	200	10	28.7	12.4	-.12	-.67	1nR*	P	T	N	C	S	R
4	Carefulness Furneaux B(1)	CFB	C	?	57	48	20	200	10	15.4	3.46	-1.2	2.1	20-W	P	T	N	C	S	R
5	Furneaux Level	FL	I	gf	72	58	35	900	26	216	76.6	.11	-.07	%R*	P	T	N	C	S	R
6	Figure Series (Cattell II, III)	FS	I	gf	69	61	24	360	15	15.7	3.21	-.83	1.8	R	S	T	N	C	F	R
7	Topology (Cattell II, III)	T	?	gf	65	44	16	300	19	10.7	3.07	-.65	.11	R	S	T	N	C	F	R
8	Matrices Speed (Cattell II)	MS	?(I)	gf	56	53	12	180	15	8.15	2.28	-.82	.91	R	S	T	N	C	F	R
9	Matrices Power (Cattell III)	MP	?(I)	gf	53	51	13	360	28	5.71	1.79	-.20	-.25	R	S	T	N	C	F	R
10	Figure Classification (Cattell II)	FC	?(Vs)	gf(S_2)	52	43	14	240	17	7.28	1.91	-.09	.74	R	S	T	N	C	F	C
11	Careful Figure Classify (Cattell III)	CFC	C	?	45	32	14	240	17	13.1	2.70	.25	-.68	20-W	S	T	N	C	F	C
12	Arithmetic Reasoning	AR	R	gfgc	70	45	12	600	50	3.66	1.73	.14	1.9	R	P	T	PN	C	M	S
13	Match Arrangements (Guilford)	MA	(?)	gf	69	40	20	420	21	6.37	4.00	.52	-.33	R	P	T	N	D	F	T
14	Cards (Botsum)	C	S	gf(S_2)	86	81	54	240	4.4	23.4	9.12	.27	-.21	R	S	T	N	C	F	S
15	Figures (Botsum)	F	S	gf(S_2)	85	66	52	240	4.6	27.8	10.7	.20	-.60	R	S	T	N	C	F	S
16	Paper Form Board (Thurstone)	PFB	V_2	gf(S_2)	81	60	28	240	8.6	25.3	11.9	.23	-.38	R	P	T	N	C	F	T
17	Cued Nonsense Memory	CNM	Ma	gf	68	52	20	280	14	7.73	3.98	.86	.40	R	P	P	N	M	S	R
18	Cued Meaningful Memory	CMM	Ma	gc	87	32	25	288	11	21.5	4.39	-1.6	2.9	R	S	P	P	M	M	R
19	Common Word Analogies	CWA	V(R)	gfgc	65*	66	30	390	13	14.1	4.04	.09	-.09	R	S	T	NP	C	M	R
20	Abstruse Word Analogies	AWA	V	gc	67*	68	30	390	13	9.06	4.68	1.1	1.3	R	S	T	P	C	M	R
21	Vocabulary	V	V	gc	93	85	50	900	18	23.3	10.4	-.10	-.76	R	S	T	P	C	M	U
22	General Information	GI	V	gc	84	82	28	420	15	13.4	4.88	.45	-.52	R	S	P	P	C	M	U
23	Mechanical Information (AAF)	MI	Mk	gc	71	72	15	150	10	8.37	4.50	-.06	-1.3	R	S	P	P			
24	Tool Identification (AAF)	TI	Mk	gc	72	67	15	150	10	9.25	3.59	-.14	-.81	R	S	P	P			
25	False Premises (Thurstone)	FP	Rs	gcgf	41	40	22	360	16	13.2	3.19	-.01	.08	R	S	T	PN	E	M	R
26	Inferences (Guilford)	IG	Rs	gc	66*	69	14	480	14	6.18	2.58	.14	-.32	R	S	T	P	E	M	R
27	Careful Practical Estimate (Guilford)	CPE	J	gc		27	20	420	21	11.2	2.53	-.17	.42	20-W	S	T	P	E	M	T
28	Social Situations (Guilford)	SS	V	gc	61	39	16	360	22	9.94	2.58	-.88	.48	R	S	T	P	E	M	S
29	Controlled Associations (Thurstone)	C	Fa	gc	73	60		180	13	14.6	6.03	.14	4.7	N	P	P	P	D	M	R
30	Things Round (Taylor)	TR	Fi	gc		60		180	12	15.4	5.93	.87	1.4	N	P	T	P	D	M	U
31	Ideas (Man up Ladder)	I	Fi	gc		57		180	22	8.48	3.91	.96	1.8	N	P	T	P	D	M	U
32	Adding	A	N	gc	71	66	20	60	3.0	7.93	2.56	.39	1.7	R	P	T	P	N	S	I
33	Carefulness Subtracting	CS	C	gc	75	35	20	60	3.0	7.76	1.19	-1.0	1.1	9-W	P	T	P	N	S	I
34	Carefulness Dividing	CD	C	gc	66	50	20	90	4.5	18.1	1.76	-3.4	18	20-W	S	T	P	N	S	I
35	Multiplying	M	N	gc		74	20	90	4.5	7.05	2.77	.44	.33	R	S	R	P	N	S	I
36	Mixed Arithmetic Operations	MAO	N	gc		76	20	150	7.5	9.04	4.38	.21	-.50	R	P	T	P	N	S	I
37	Carefulness Fractions-Decimals	CFD	C	?		47	20	180	9.0	16.0	2.83	-2.2	8.4	20-W	S	T	P	N	S	I
38	Backward Reading (Botsum)	BR	Cs	S_2	89	57	40	165	4.1	30.1	10.3	.14	-.60	R	S	T	N	C	S	U
39	Street Gestalt Completion (Botsum)	SGC	Cs	S_2	73	46	24	210	8.8	35.1	10.7	-.15	.20	R	P	T	N	C	F	U
40	Designs (See Σ) (Botsum)	D	Cf	S_2	85	54		120		32.2	6.94	-.28	-.72	R-W+20	S	T	N	N	P	T
41	Forward Writing (copying)	FW	22(Fe)	W		38		30		34.2	9.24	.84	2.9	R	P	T	N	D	S	S
42	Forward Printing (copying)	FP	22(Fe)	W		54		30		40.6	11.7	.66	1.7	N	P	T	P	D	S	S
43	Novel Writing (Backward and other)	NW	23	W	58	48		120		52.9	15.4	.49	.27	R	P	T	N			
44	Speed Reading	SR	16	Sp	85	47		80		154	58.1	1.6	3.9	N		T	P			
45	Matching Letters and Numbers	MLN	22	Sp	81	62	50	90	1.8	37.1	7.92	-.59	-.12	R		T	P	E	S	U
46	Rapid Cancellation	RC	22	Sp(W)	86	61		90	1.8	47.3	14.6	.63	1.4	R		T	N	E	S	U
47	Agreement With Platitudes	AWP	16	?	75	34	20	120	6.0	31.7	5.40	-.76	.30	K		P				
48	Highbrow Tastes	HT	16	?	71	55	20	180	9.0	19.1	5.91	.31	-.54	K						
49	Critical Hostility	CH	19	?	50	30	20	240	12	45.8	6.70	-.15	.13	K						
50	Experience Claimed in Skills	ECS	22	?	76*	81	20	180	9.0	22.9	6.37	-.22	-.05	K						
51	Confidence in Doing Skills	CDS	21(32)	?	55	54	20	180	9.0	23.1	7.17	.23	-.30	K						
52	Self-Sentiment: Utilities	SSU	36	W(gc)	49	33	16	150	9.4	10.9	2.01	-.38	-.04	K						
53	Self-Sentiment: Opinions	SSO	36	W(gc)	43	31	16	150	9.4	25.0	4.83	-.06	.20	K						
54	Early Risks Claimed	ERC	?	gf(-)	86	63	26	135	5.2	50.9	14.9	-.17	-.39	K						
55	Denial of Brain Damage Symptoms	DBD	?	gf	73	46	20	105	5.2	67.1	9.74	-1.3	2.5	K						
56	Test Anxiety Admitted	TAA	24	?	82	67	30	240	8.0	18.9	11.8	.61	-.44	K						
57	16 PF Q_4: Tension	Q_4	24	?	78	56	26	180	6.9	26.5	7.90	-.15	-.41	K						
58	16 PF H: Adventurousness	H	32	?	73	56	26	180	6.9	24.5	9.93	.08	-.61	K						
59	16 PF Q_1: Experimenting	Q_1	?	?	64	49	20	150	7.5	21.2	5.03	-.02	-.26	K						
60	16 PF I: Sensitivity	I	16(-)	?	57	40	20	150	7.5	19.1	4.64	.09	.02	K						
61	Sex (Female = 1, Male = 2)		Mk, 16(-)			83				1.72	.45	-1.0	-1.0							
62	Years of Education Claimed			gct		63				21.6	4.05	.11	.39	*K						
63	Years of Education Claimed for Parent					42				20.5	6.48	.42	.49	*K						
64	Chronological Age		gf(-),gc(-)			80				27.6	10.6	.78	-.34							
65	Non-minority Group Member					41				1.84	0.36	-1.9	1.6							
66	Height					62				67.9	3.95	-.24	-.52							
67	Fisher-Yates Random 1					30				4.49	2.86	-.04	-1.2							
68	Fisher-Yates Random 2					25				4.16	2.96	.20	-1.2							
69	Fisher-Yates Random 3					71				4.49	2.70	.04	-1.1							
70	Fisher-Yates Random 4					19				4.73	2.79	-.10	-1.2							
71	Dickman Random 1					25				4.52	3.01	-.06	-1.2							
72	Dickman Random 2					23				4.63	2.93	-.04	-1.3							
73	Dickman Random 3					30				4.56	1.00	.18	.01							
74	Dickman Random 4					41				4.29	2.82	.08	-1.1							

$*r_{xx} < h^2$

*Rescaled

TABLE
CORRELATIONS : NORMALIZED DATA

	64	1	2	3	4	5	6	7
64	1.0000000							
1	-.2106493	1.0000000						
2	.0012523	.4983789	1.0000000					
3	-.1261633	.3723382	.3033728	1.0000000				
4	-.0331079	.1959938	.2775910	.0795699	1.0000000			
5	.0490755	.3955499	.5150189	.3608290	.4044157	1.0000000		
6	-.2958294	.4705691	.5019042	.3352672	.3257154	.4538746	1.0000000	
7	-.0752486	.3618452	.3990979	.2223704	.2250982	.3759822	.3831354	1.0000000
8	-.2994411	.4189819	.4218543	.2199389	.3585168	.3752086	.4483396	.3788116
9	-.2542696	.4464275	.4363705	.2925115	.2948131	.3907563	.4830067	.4200479
10	-.1219427	.3021962	.3766007	.3070365	.1301460	.2929238	.3563261	.2695578
11	-.0030012	.0817455	.0609704	-.0425028	.3167632	.1795671	.1229713	.0478413
12	.1037889	.3114948	.4226790	.1132993	.2349137	.3634485	.3271349	.3321134
13	.0426869	.2866490	.4053086	.2397743	.1654953	.3434319	.3757701	.3986873
14	-.1109265	.4044732	.3749021	.3045303	.1256331	.2639327	.3930742	.3622094
15	-.1573494	.3895935	.3156633	.2676099	.1002914	.1973420	.3442129	.2890199
16	.0302185	.3416397	.4401334	.2173964	.1467169	.3557617	.4260688	.4029823
17	-.2053876	.2556549	.2567723	.2212241	.0747103	.2235727	.3237374	.2077930
18	-.0385987	.2449294	.2367076	.2222364	.2262499	.3332680	.2101586	.2899131
19	.0687444	.4236045	.5251238	.1732519	.3690264	.5016227	.4639037	.4001316
20	.3070205	.1577752	.2987236	.1257455	.1591939	.3304569	.1939239	.2506716
21	.5660709	.0915989	.3226875	.0301740	.2479097	.3331053	.1254979	.2177774
22	.4423236	.2269591	.3534938	.1388945	.2631694	.4060280	.1580539	.2957825
23	.2513091	.1892361	.3435846	.0553894	.0580500	.1896172	.2421353	.2273501
24	.2352450	.2223107	.3272567	.0389037	.0512318	.1424702	.2310683	.2631278
25	-.0675563	.2480947	.3267425	.2416529	.1381019	.2161218	.2928715	.3412985
26	.2625922	.2951393	.4036900	.0943672	.3367039	.4242719	.3083091	.3058997
27	.1705829	.0627459	.1555190	.0090951	.2201218	.2110147	.0788011	.1759562
28	.2917050	.1826230	.1829265	.1155231	.1002258	.1943788	.1117335	.1752067
29	.1463638	.0244845	.1085917	.0469579	.0649936	.1181558	.1084535	.1387718
30	-.0372144	.1647096	.2345583	.1705088	.0510818	.2048719	.2140014	.2200640
31	.1320339	.1537965	.1713975	.1649227	.1229680	.2039134	.1519867	.1815642
32	.3059362	.2444839	.4051377	.2230860	.1617609	.3701338	.3110158	.2059021
33	.0842813	.0592614	.1334772	-.0550791	.1861039	.1428611	.0681987	.0111224
34	.0729984	-.1028486	.0170934	-.1022868	.2531213	.0692527	-.0231764	.0338810
35	.0674353	.2586405	.3768924	.2597618	.1951515	.3383413	.2768769	.2554249
36	.1380280	.2755324	.4846689	.2795733	.3192212	.4504366	.3086868	.2367488
37	.1963011	-.1929668	-.0473321	-.2133754	.1816082	.0057467	-.0715251	-.0941727
38	-.0124163	.3320391	.3537866	.4059287	.1590756	.3996974	.3762037	.3477261
39	-.2724669	.3267239	.1557975	.1352496	.1988630	.2278721	.3583462	.2486027
40	.0498167	.3835933	.4073467	.2002000	.2321008	.3626870	.3982747	.3027093
41	-.0414201	.1063053	.0849221	.1895119	.1066525	.1105781	.0899158	.1062252
42	.0612406	.2332045	.2044668	.2000752	.2051502	.2404439	.2827910	.1639652
43	-.1088043	.0961749	.0053283	.2529431	.1468531	.0346999	.1838866	.1302875
45	.0265719	.2656818	.3245387	.3567151	.1611495	.3593929	.3341369	.2146910
46	.0470532	.3136183	.2315918	.3509082	.1150965	.3053472	.2962143	.2109688
47	.0166974	-.0547409	-.0800472	-.0378787	-.0441735	-.0573035	-.0886486	-.0708396
48	.3441796	-.0237663	.0684695	-.0004581	.1042256	.1609236	.0210958	.0037194
49	.0283905	-.0588990	.0232582	.0439661	.0025198	-.0420269	.0143744	-.0216453
50	-.0991777	.1201615	.1035057	.2052231	.0674623	.0492585	.1882550	.0263638
51	.0174510	.0847880	.1140500	.1259580	.0873892	.1810079	.1701119	.0768862
52	.2434225	.0827507	.0151064	.0048306	-.0521997	.0295755	-.0408439	.0579819
53	.0713555	.1044673	.1653716	.1113113	.0587991	.1842536	.1204325	.1020479
54	-.1632040	.1431263	.1785107	.1620243	.1003828	.1037208	.2727183	.2027050
55	.2613200	-.0246626	.0726649	-.0130302	.0308273	.0723056	-.0050107	-.0758655
56	-.2111049	-.1129015	-.2809136	-.1618594	-.1000471	-.2821937	-.1703808	-.2130955
57	-.2103370	.0474030	-.1784481	.0301728	.0160826	-.0610288	.0304480	-.0505286
58	.1110062	.0070875	.1167220	.1261799	.0294179	.0730839	.0642715	.0227034
59	.3424764	-.0132757	.1971769	-.0295771	.1272728	.1935867	.1606392	.1184441
60	.1057069	-.0111335	-.1658171	.0064361	.0930319	.0777953	-.0971200	.0325704
61	.0820164	.1055369	.2612309	-.0467210	-.0284551	.0138341	.1345765	.1585284
62	.3893397	.1559096	.3161388	.1992249	.2161402	.3801834	.1578886	.1645363
63	-.1970932	.1353138	.0967820	.1371445	.0145679	.1052407	.2039810	.1201507
65	-.0671618	.1753024	.1559360	.1459729	.0147433	.0828712	.1479082	.0417208
66	.0438948	.1508667	.2716985	.0579696	.0238468	.1610201	.2340924	.1184130

	49	50	51	52	53	54	55	56
49	1.0000000							
50	.0617958	1.0000000						
51	.0796772	.4613113	1.0000000					
52	.0181158	.0347972	-.0359655	1.0000000				
53	.1226651	-.0123746	.1340249	.1328022	1.0000000			
54	.0181188	.2799916	.1577287	-.0056091	-.0198595	1.0000000		
55	-.0371701	-.0219196	-.0172247	.0991568	.1384714	-.2286792	1.0000000	
56	.0227226	-.0926308	-.1953487	-.0158617	-.1744825	-.2090049	-.3394593	1.0000000
57	.0346987	.0953288	-.0663254	.0305262	-.1140136	.0639861	-.3623332	.5384690
58	.0519312	.2670893	.3342548	-.0934465	.0814709	.1041789	.2509389	-.5095549
59	.0179308	-.0232507	.1746927	.1186189	.1628200	.1187858	.1256968	-.4022818
60	-.0123360	.0507932	.1349564	.1084000	.0662796	-.1690831	-.0341777	.1349365
61	.0664154	-.0902366	.0619387	.1059673	.1050943	.1991137	.1391307	-.3658247
62	.0945074	.2167491	.2351153	.0638387	.1473312	-.1002728	.1570408	-.2549864
63	.0764752	.1576195	.0840705	-.0797245	.0682200	.1231402	.0530326	-.1150989
65	-.0393833	.0852664	-.1808837	.0080178	-.0201461	.0673163	.0308141	.0003788
66	.0491058	-.0489560	.0678314	.0279524	.0801360	.2062099	.1269752	-.3321560

	57	58	59	60	61	62	63	65
57	1.0000000							
58	-.4009483	1.0000000						
59	-.3010557	.2138762	1.0000000					
60	.1630592	-.0760285	.0173364	1.0000000				
61	-.2450766	.2566128	.2989450	-.2887483	1.0000000			
62	-.1279871	.1892333	.1640160	.1451635	-.0135694	1.0000000		
63	-.0418805	.1238839	.0232979	-.0819467	.0161684	.2241961	1.0000000	
65	.0151012	-.0443227	-.0772335	-.0685882	-.0353955	.0755095	.1307871	1.0000000
66	-.1599115	.1543667	.2260815	-.2355671	.6498742	.1322905	.1002199	-.0466454

TABLE
CORRELATIONS : NORMALIZED DATA

	8	9	10	11	12	13	14	15
8	1.0000000							
9	.4815054	1.0000000						
10	.3451962	.2925947	1.0000000					
11	.1925827	.1776463	.1299132	1.0000000				
12	.2795570	.1692406	.1753608	.1419534	1.0000000			
13	.2990369	.2794496	.2964968	.0543098	.2667204	1.0000000		
14	.3505258	.3094892	.3429564	.0224720	.2024103	.4051914	1.0000000	
15	.3154458	.2959494	.3028078	-.0466257	.1522631	.3282777	.7521154	1.0000000
16	.3550172	.3307209	.3992035	.0637925	.3196289	.4358508	.4955647	.3794646
17	.2884409	.2739585	.2386907	.0197795	.1977316	.2084416	.2711783	.2269518
18	.2343230	.2169880	.2736840	.1382445	.1224592	.2000301	.1430962	.1235269
19	.4424519	.3621909	.3275712	.2044013	.3914364	.3637162	.2551879	.2443339
20	.1455558	.1276884	.1610541	.1102140	.3190301	.2348664	.1153270	.0715617
21	.1193706	.0618848	.1521438	.1586964	.3513352	.2633501	.1064354	.0523003
22	.1647531	.1245364	.2288009	.0892535	.3749545	.2407840	.0942615	.0892329
23	.1707960	.0655824	.1595679	.0285721	.3702943	.3117884	.2520875	.2559008
24	.1360752	.1165433	.1467302	.0345534	.3337124	.2815427	.2715972	.2559184
25	.2108789	.1879944	.2163272	.0038397	.1655560	.2194897	.1244961	.1429254
26	.2953966	.2224532	.2160199	.1699087	.4144116	.2465550	.0931918	.0907257
27	.1980088	.1255410	.1369352	.1304199	.1416267	.2166123	.1268562	.0439555
28	.1405941	.0920369	.0868478	-.0280566	.2091973	.1480504	.1297322	.1384028
29	.0646079	.0871387	.0522922	.0465660	.1150952	.1092183	.0075946	-.0801014
30	.1870023	.1563255	.1304632	.0091481	.1421240	.2567769	.1922137	.0929762
31	.1242692	.1584698	.0346194	-.0468028	.0784206	.1487994	.0829959	.0431328
32	.1624187	.1475957	.0915937	-.0140330	.3545768	.3730200	.1887114	.1408397
33	.0718344	.0864976	.0248248	.1910711	.1045846	.0937428	.1029107	.0966059
34	.0367950	.0490528	-.0622299	.1702876	-.0011488	-.0154450	-.0954324	-.0342394
35	.2093331	.1227776	.1421488	-.0348123	.2155618	.2197153	.1792191	.1147134
36	.2424871	.1380592	.1772733	-.0156060	.2598875	.2630879	.1263160	.0961380
37	-.0957338	-.0180715	-.1831905	.1613269	.0838942	-.0671292	-.1109383	-.1388866
38	.3022798	.2850888	.3121758	-.0351124	.1734927	.2934041	.3887727	.2922203
39	.3886742	.3578989	.2392015	.0845444	.1220351	.2265689	.3210279	.2763372
40	.3603537	.3234543	.2981632	.0709773	.2518480	.3703469	.4217322	.2985562
41	.1142807	.0937567	.0605334	-.0363983	-.0227124	.1263563	.1335618	.1018306
42	.1699825	.1798461	.0778627	-.0391784	.1072785	.1847104	.2054668	.1360487
43	.1485759	.1926940	.0378002	-.0483762	-.0731723	.1197344	.1671301	.0995917
45	.2353561	.1683577	.2099945	-.0702517	.1369174	.1188774	.2904552	.2373118
46	.2330001	.1856428	.1731101	-.0083058	.1307704	.1968336	.4004965	.2879560
47	-.1015814	-.0457888	-.1592483	.0110734	-.0590260	-.0727077	-.0478534	-.0756680
48	.0357947	-.0136896	-.0228708	.0530679	.0980872	.0965665	-.0757386	-.1351208
49	-.0525488	.0455516	-.0690722	-.0141036	.0103041	-.0347023	-.0689738	-.0355303
50	.1499747	.1359267	.2206227	-.0131825	-.1086369	.1674119	.1577021	.1083563
51	.1595079	.0627941	.1609508	.0215317	.0116677	.1397238	.0946189	-.0170307
52	-.0543674	-.1199266	-.0810633	-.0022639	.0379484	.0518867	.0862023	.0438216
53	.0592471	.0459350	.0725753	.0492525	.1025862	.1252191	.0455680	.0091503
54	.2308451	.2364866	.2098019	-.0676448	.0751843	.1491221	.2471032	.2705352
55	-.0483469	-.1050925	.0176840	.0401736	.0450348	.0931837	.0268478	.0566287
56	-.1561823	-.0859459	-.2608481	-.0199864	-.2461525	-.2400095	-.2201036	-.1339703
57	.0001854	.0187958	-.1241591	-.0290530	-.1275840	-.1152660	-.0351885	-.0108166
58	.0703064	.0143955	.1250592	-.0172882	.0253794	.0716969	.0416087	.0479737
59	.0621262	.0474354	.0639534	.0708572	.2230577	.1889693	.1326082	.0177794
60	.0350392	-.0030158	-.1297503	.0545172	-.0748322	-.0858606	-.1472401	-.2043124
61	.1413929	-.0241798	.1238977	-.0154229	.3049656	.1823978	.2275635	.2431199
62	.0911578	.1014254	.1562402	.0947822	.2047878	.2158295	.0422471	.0191254
63	.0983529	.1545967	.0832188	.0091267	.0924295	.1021068	.0314797	.0974606
65	.1079575	.0841734	.0492193	-.0265649	.1592280	.1203408	.1130291	.1444817
66	.1050608	.0637578	.1487487	.0650163	.2822733	.1788368	.1695967	.2252669

	16	17	18	19	20	21	22	23
16	1.0000000							
17	.3102376	1.0000000						
18	.1916359	.2223254	1.0000000					
19	.4117695	.2252250	.3253736	1.0000000				
20	.3076684	.1618138	.1934868	.4567329	1.0000000			
21	.3051493	.0186978	.2347733	.5452933	.6780790	1.0000000		
22	.3426531	.0451690	.2859774	.5625154	.6532601	.7405138	1.0000000	
23	.3839134	.1864349	.0360736	.3106044	.4057022	.3725542	.3914936	1.0000000
24	.3650262	.1065540	.0252079	.3006398	.4134013	.3827314	.4033044	.6933216
25	.1667339	.1599476	.2713249	.3269452	.2942638	.2459097	.2321686	.2082523
26	.2579309	.1075930	.3155693	.5788206	.4808378	.5934092	.6003022	.2639080
27	.2046010	.0987349	.1302423	.2331782	.1362387	.2860815	.2411483	.1328887
28	.1329377	.0933829	.1291278	.3011138	.2455818	.4236989	.3887450	.2031690
29	.1904309	.1663828	.2091273	.2620976	.3389623	.3988532	.3764629	.1109028
30	.2176166	.2723111	.1647119	.2806406	.2360221	.2448492	.2489916	.2328252
31	.1518653	.1286534	.1309391	.2711662	.2863598	.3197341	.2859000	.1114888
32	.2839562	.3000749	.1644532	.3265295	.3727633	.4251396	.4320485	.3294695
33	.1022168	-.0884440	-.0196045	.0896423	.0077341	.1392621	.0598614	.0569667
34	-.0509928	.0315949	.0497004	.1219085	-.1054939	.0442060	.0433403	.0116506
35	.2940098	.2943304	.2637126	.3080218	.2482684	.2659197	.3115000	.1590848
36	.2701060	.2227389	.1980389	.3897207	.3459491	.3256718	.3988309	.2293730
37	-.0974359	-.1439697	.0112613	-.0009504	-.0498735	.0815468	.0072668	-.0357273
38	.3806597	.2757708	.2613880	.3130524	.2315402	.2591136	.2835239	.1465676
39	.3030713	.3520869	.1894368	.2304696	.1423564	.0557563	.1010130	.0572785
40	.5500194	.2870835	.2523452	.3586304	.2364992	.2732018	.2585652	.3039717
41	.1044098	.1324436	.1417688	.0751936	.0225684	.0327485	.0771182	-.0140718
42	.2659398	.3125241	.1859454	.2528446	.1461203	.1994075	.2379143	.1056018
43	.1221041	.2086198	.0512218	.0358631	-.0679067	-.0445924	-.0186315	-.1594036
45	.2233233	.3013057	.2023066	.2192642	.1813392	.1657870	.2158057	.0174841
46	.3084474	.2965985	.1939296	.1802110	.1061637	.1604839	.1744057	.0836763
47	-.1983631	-.1199187	-.1055383	-.1495828	-.0925885	-.0527818	-.1148561	-.1107622
48	.0358216	-.0514286	.0087766	.1464238	.3112052	.3437609	.3389699	.0405589
49	-.0203615	-.0223052	-.0133591	-.0535182	.0688444	.0510011	.0962132	.0870149
50	.1766933	.1145184	.0932797	.0675259	.0978764	.0039681	.0728769	.0407446
51	.2121771	.1075062	.1039381	.1632111	.2105457	.1906677	.1730652	-.0087810
52	.0556567	-.0410551	-.0115094	.0688337	.0792827	.2103562	.1007427	.1495363
53	.0818380	.0632241	.1025589	.2489755	.2826516	.3384433	.2618834	.1679194
54	.2332022	.2303393	.0799047	.1301312	.0706294	-.0083127	.0874688	.2023953
55	.0578325	-.0449487	.0139495	.1810889	.2226394	.2625838	.2182421	.2059036
56	-.2916359	-.1444126	-.1085845	-.3073278	-.3898121	-.4020663	-.3953527	-.3445936
57	-.1146392	.0284833	-.0092135	-.1473041	-.2460946	-.2551838	-.1840952	-.1839185
58	.0685021	.1898149	.0354474	.1286432	.2216211	.1227052	.2129400	.1153668
59	.1699252	.0451690	.0256382	.2279797	.3154588	.4445936	.3333877	.3238218
60	-.0539279	-.0776816	.0418006	.0397790	.0680342	.1144900	.1504951	-.2498117
61	.2959465	.1787917	-.1421905	.2111941	.3250422	.2250092	.1757527	.6168186
62	.2084947	.0089822	.1161473	.3337398	.3896944	.4744053	.5078998	.2173226
63	.0544186	.0984507	.0745094	.1246440	.1735600	.0464730	.1151642	.0199326
65	.1273217	.1086993	-.0303371	.0781437	.0389404	-.0526830	.0687972	.2274648
66	.2859313	.1630401	-.0183085	.2542722	.3040876	.2439177	.1980315	.4869380

TABLE
CORRELATIONS: NORMALIZED DATA

	24	25	26	27	28	29	30	31
24	1.0000000							
25	.1798663	1.0000000						
26	.2487081	.3200248	1.0000000					
27	.1686268	.0460642	.2380821	1.0000000				
28	.1633402	.1856942	.3799801	.0711509	1.0000000			
29	.1214873	.1474292	.2628606	.0384606	.2333014	1.0000000		
30	.2038648	.2228020	.1576105	.0475865	.1368475	.4975725	1.0000000	
31	.1246165	.1462792	.2591007	.0492085	.2837451	.4226528	.5106268	1.0000000
32	.3122606	.1695969	.3387387	.1050157	.2852577	.2979926	.3068370	.2853471
33	.0110124	-.0949057	.0758763	.0783349	-.0147636	-.0294008	-.0757905	-.1385358
34	-.0080606	.0105982	.1180432	.1729724	.0128476	.0286143	.0175901	.0136337
35	.1959948	.1747630	.2578080	.0456279	.2433563	.2471350	.3047456	.2545357
36	.2103116	.1466470	.3911763	.1123847	.2451319	.1674479	.2158815	.2685509
37	-.0726683	-.0868699	.1237176	.1043671	.0507796	-.0303152	-.0933188	-.0724372
38	.1223958	.2121197	.2448111	.0524354	.2558124	.2433367	.2591581	.1557087
39	.1585618	.1890803	.1816488	.1465518	.0904325	.1601906	.2124395	.1020994
40	.3053388	.1981943	.3085123	.2321948	.1907552	.1109493	.1709265	.2226104
41	-.0596332	.0848896	.0480175	-.0399064	.1391320	.1145578	.2392879	.3073534
42	.0724914	.1478068	.2329630	.1106215	.2811512	.2957285	.2740797	.3603840
43	-.1111888	.0022200	.0152273	-.0370839	.1303687	.1866969	.1995327	.2603167
45	.0008171	.0889011	.2556919	-.0168326	.2762987	.1336341	.1608872	.2753556
46	.0709894	.0909463	.1849812	.0429954	.2889395	.1561253	.2048945	.2955693
47	-.0997828	-.1009768	-.0878445	-.0979920	-.0030852	.0595082	-.0549465	-.0818573
48	.1002112	.0272635	.2560480	.1709314	.1549726	.1719354	.0525055	.1515735
49	.0847171	-.0533059	-.0585639	-.0341730	-.0412336	.1046038	.0690924	-.0220326
50	.0730836	.0870609	.0080851	-.0707416	.0162602	.1459479	.1343104	.1468484
51	.0360901	.0406568	.1321537	.0489141	.0765310	.2247795	.1800697	.1660566
52	.1641066	.0810678	.0756866	.0882194	.1467916	.0610722	.0534935	.0011958
53	.1696702	.0600066	.2872882	.1273833	.2138085	.2536103	.0899186	.0946695
54	.1944122	.2201799	.1102066	.0479463	.1028379	.0636208	.1200422	.0520538
55	.1870690	.0634562	.1536403	.0463290	.0799091	.0737254	.0162133	.0885370
56	-.3113209	-.2022597	-.2703920	-.1765241	-.2255829	-.1966157	-.2567537	-.1699433
57	-.1822083	-.0499473	-.1583983	-.0779779	-.0228080	-.0691633	-.1019850	-.0504618
58	.1390027	.0455251	.1324694	-.0025175	.0943097	.1694374	.1308521	.1263026
59	.3244112	.0962710	.2750346	.1902217	.2047519	.2074473	.1396776	.1734772
60	-.2408129	-.0716350	.0894423	.0666857	.0595581	.2150755	.0248862	.0997221
61	.5666467	.1588370	.0978872	.1137613	.1039611	-.0241956	.1494083	-.0347202
62	.2390342	.1675076	.3910479	.0873661	.2708100	.2182068	.1240067	.2998172
63	.0885548	.1868779	.0282593	-.0334871	.0127134	.0462864	.0691452	.0712627
65	.1508541	.1373442	-.0066071	-.0129169	.0196974	.0097373	.1476455	.1259329
66	.4711745	.2004792	.1711818	.0746057	.1151145	-.0172141	.1188107	.0123729

	32	33	34	35	36	37	38	39
32	1.0000000							
33	.0696396	1.0000000						
34	.0469109	.0688804	1.0000000					
35	.6163789	.0426095	.1427214	1.0000000				
36	.6289244	.0362975	.1245416	.6567744	1.0000000			
37	-.0116678	.1870890	.2491393	-.1167833	-.0595195	1.0000000		
38	.3248191	.0389179	-.1287182	.3117223	.2857215	-.1818967	1.0000000	
39	.1038167	-.0066457	.0126008	.1112405	.0509650	-.0541535	.3290990	1.0000000
40	.2882200	.0861917	-.0226658	.2653212	.2859047	-.0639943	.4278052	.3531469
41	.2368810	-.0361264	-.0657308	.2671940	.2157492	-.0549527	.1068813	.0855163
42	.3530071	-.0879781	.0198514	.3151427	.3126623	-.0168528	.3650852	.2286616
43	.1160827	-.0826839	.0014475	.1738664	.0615046	-.0035177	.2560906	.2149061
45	.3901512	.0552064	-.0980493	.4938222	.4570740	-.0293345	.4598816	.1613666
46	.3535149	.0292130	-.1168354	.3510834	.3407428	-.0433355	.4456858	.1844039
47	-.2035431	.0439689	.0303859	-.1593499	-.1819059	.0698100	-.0369857	.0296075
48	.1450792	.0423718	.0167437	.0517227	.1237214	.1355856	.0833928	-.0430297
49	.0665049	.0175492	.0318263	.1370500	.0988750	-.0499737	.1194082	-.0185553
50	.0850333	-.0470358	-.0230677	.2121889	.0492436	-.0337769	.2895087	.1951854
51	.1481735	.0005454	-.1024023	.2266142	.2121618	-.0448760	.2879193	.1015506
52	.1438974	-.0330462	.0909037	.0290907	.0110803	.0546279	.0795340	-.0092549
53	.1691599	.0472409	.0003784	.1639217	.1899127	-.0414951	.1776340	.0088556
54	.0967185	.0319175	.0016271	.0700753	.0022927	-.0143632	.2221640	.2411793
55	.0755142	-.1036328	.0277135	-.0372891	.0501245	.0219105	.0145073	-.0433060
56	-.2611660	.0414162	-.0202033	-.1379299	-.2178837	.0582668	-.2748900	-.1892973
57	-.0892091	.0571375	.0069859	.0412202	-.0913817	.0148269	-.0125059	.0712335
58	.2040467	-.1576874	.0182888	.1334558	.2039412	-.0540368	.1202844	.1434738
59	.1960981	.0835495	.1188141	.0922948	.1574511	.1328198	.0544761	.0380881
60	-.0358745	-.0169002	.0633547	-.0128583	-.0372206	.1176343	.0871821	-.0112451
61	.2142359	.0078283	.0049641	.1012872	.1654756	-.1063321	.0304202	.0868603
62	.4179687	.0615535	-.0013239	.3119248	.3785724	.0591711	.2447395	-.0072444
63	.1280272	-.0295936	-.0186593	.1691029	.1009185	-.1165934	.1403632	.0392686
65	.1566994	.0101367	-.0540045	.1009050	.1237817	-.0309354	.0053487	.0007233
66	.1950111	.0226885	-.0375499	.1085567	.1954647	-.1314477	.1458868	.1071022

	40	41	42	43	45	46	47	48
40	1.0000000							
41	.1284773	1.0000000						
42	.2727012	.3960630	1.0000000					
43	.1140620	.3533117	.4702366	1.0000000				
45	.2012267	.2833594	.3775703	.2425718	1.0000000			
46	.2811084	.3166782	.4105248	.3288942	.5725547	1.0000000		
47	-.1456108	-.0882263	-.0756315	-.0419475	-.0341433	-.0362031	1.0000000	
48	.1116638	-.0212759	.1335143	-.0170489	.0749566	.0835960	.0853535	1.0000000
49	-.0362221	-.0414712	.0511268	.0091588	.0686629	.0899309	.0815283	.0550062
50	.0918751	.1799743	.1585622	.2546546	.2026957	.2130524	-.0159909	.1015094
51	.1865865	.1101984	.2157265	.1904439	.1998216	.2409371	.0381597	.2848576
52	.0236537	-.1082171	.0747863	-.0921535	-.0671115	.0205601	.1033785	.0255892
53	.0082489	.0883680	.0670533	-.0764790	.1575356	.0491959	.0906570	.1656469
54	.1480672	.0406579	.0655216	.0991650	.1415269	.2402631	-.0075995	-.1435893
55	.0354597	-.0229402	.0681318	-.1176048	.0038127	-.0494081	-.0493455	.1414442
56	-.2619301	-.0518354	-.1435125	.0795156	-.1429541	-.1354237	.0306752	-.2077906
57	-.0369964	-.0614314	-.0538481	.1545130	.0063232	.0257786	.0285904	-.1787262
58	.0427569	.1384486	.1934230	.0605044	.1617557	.1229799	.0672457	.2382779
59	.1951887	-.0263869	.1273727	-.1109100	.0316492	.0768861	-.0239898	.4016017
60	-.0193821	-.0346547	.0540279	.1241266	.0188285	.0305249	.0341458	.2902772
61	.2331707	-.0977198	-.0233539	-.2516643	-.0625657	-.0325548	-.0786036	-.0039155
62	.2377073	.1247867	.3117603	.1164968	.2837277	.2760255	-.1267731	.3888920
63	.0140810	.0457587	.1221917	.0216301	.1456347	.1274824	-.1413349	.1230688
65	.0260398	.1252307	.1147143	.0524460	.1547124	.0045256	-.1021227	-.0675805
66	.2885535	-.0677619	.0116288	-.1594485	.0309771	.0978207	-.1247344	.0204179

Horn gf-gc study

VARIMAX: NORMALIZED VARIABLES ANALYSIS

VARIABLE	gf	P?	R?	V?	S	M?	gc	MK(w)	Rs	?	Fl	N	C	?	?	UI-16	UI-21	UI-22	?	UI-19	UI-36	h^2
1 Letter Grouping	.6582	.0085	.1453	-.1242	.1350	-.0173	.0755	.0704	-.0141	-.0404	-.0144	.1620	-.1288	.0494	.0838	.0039	.0304	.0849	-.0880	-.0981	.1076	.5904
2 Number Series	.6348	.0013	.0545	.0447	.0301	-.1505	.1824	.2014	-.0065	-.0174	.0707	.3188	-.0169	-.0193	.0129	-.1291	.0105	-.0232	.0968	.1357	.0552	.6613
3 Furneaux Speed	.3720	.3612	.0627	.0424	.1226	-.0821	-.0112	-.0914	.1077	.0961	.0252	.2375	-.1179	.0519	-.0618	-.0384	.1055	.1717	-.1450	.0485	.0405	.4703
4 Careful Letter Series	.3747	.0380	-.0607	-.0902	-.0197	-.0288	.1655	-.0369	.0739	.0456	-.0199	.0677	.4454	.0011	.0210	.0625	-.0047	.1624	.2575	-.0022	-.1161	.5050
5 Furneaux Power	.5609	.2528	-.0357	.0766	-.0070	-.0209	.2569	-.0321	.0932	.0034	.0545	.3017	.1052	-.0107	.0451	.0795	-.0400	.0173	.1566	.0695	.0113	.6068
6 Figure Series	.6637	.0061	.0106	.0271	.0546	.0982	-.0007	.1654	.2686	-.0241	.0668	.1334	-.0012	-.0217	.0033	-.0334	.0829	.1288	.0926	-.0096	.0883	.6177
7 Topology	.5619	.0107	.0176	.1575	.0699	.0230	.1814	.0587	.0245	.0530	.0652	.0511	.0059	.0553	-.1710	.0493	-.1041	.0979	-.0995	.0078	-.0610	.4618
8 Matrices Speed	.6598	-.0694	.0341	-.1191	.0684	.1018	.0167	.0456	.0154	-.0650	.0182	.0569	.0995	.1207	-.0832	.1125	.0757	.0894	.0621	.0045	-.1215	.5573
9 Matrices Power	.6655	-.0425	.0468	-.0102	.0662	-.0135	-.0178	-.0572	.0913	.1008	.1074	-.0306	.0715	-.0341	-.1105	-.0056	.0043	.1070	.0782	.0007	.0234	.5228
10 Figure Classify	.4906	.1687	-.0508	.0419	.1047	.0496	.0843	.0300	-.0235	-.0677	-.0132	.0385	-.1018	.0602	-.0489	-.1867	.1958	-.0452	.0131	.1514	-.1721	.4461
11 Careful Fig. Classify	.2038	.0398	-.0199	-.0425	-.1015	.0390	.0938	-.0070	.0397	.0214	-.0010	-.1311	.2580	.0950	.1551	-.0245	.0428	-.0440	.3529	-.0182	-.0682	.3188
12 Arithmetical Reason	.3756	-.1003	.1265	.0818	-.0520	.0675	.2940	.2529	.0536	-.0174	-.0088	.1889	-.0091	.0067	-.0177	.0014	-.1911	-.0539	.1475	.0414	.0387	.4352
13 Match Problems	.4360	-.0136	.0184	.4230	.1629	-.0342	.1324	.1544	.0400	-.0415	.0939	.1107	-.0289	.0057	.0219	.0021	.0967	.0793	.0055	.0727	-.0270	.4860
14 Card Rotations	.4497	.1099	.0372	.1592	.6081	.1049	-.0478	.1737	-.1046	-.0706	.0022	.0629	-.1420	.0450	-.0504	.0188	.0498	.1570	.1152	.0684	.0252	.7450
15 Figures	.3663	-.0023	.0472	-.0113	.8978	.0171	-.0112	.1605	.0560	.0113	-.0584	.0405	-.0123	-.0192	-.0410	-.1189	-.0035	.0728	-.0272	.0024	-.0016	.9995
16 Paper Form Board	.4927	.0349	.0186	.2099	.1714	.1736	.1589	.2918	-.1779	.0167	.0693	.0824	-.1506	-.0041	.0077	.0408	.1394	.1191	.1147	.0696	-.2366	.6336
17 Cued Nonsense Memory	.3194	.0091	-.0026	.0498	.0454	.4137	-.0781	.1144	.0904	-.0492	.1372	.2397	.0057	.0468	-.0879	-.0715	.0170	.1767	-.0721	.0477	-.0588	.4413
18 Cued Meaningful Memory	.3269	.1337	-.0926	.0957	.0083	.1479	.2419	-.1938	.0180	-.0537	.1339	.1016	.0970	.0740	-.0254	-.2005	.0373	.0257	-.0262	-.0011	-.1234	.3657
19 Common Word Analogies	.5514	-.0422	-.0320	-.0404	.0435	.0112	.4633	.1364	.0655	-.0977	.1347	.1101	.1436	.1456	.1311	-.0402	.0102	.0349	.0391	.0472	-.0797	.6599
20 Abstract Word Analogies	.1603	-.0363	-.0032	.0219	.0133	.0778	.6109	.2382	.1851	.1049	.2068	.1041	-.0929	.1028	.0186	.0980	.0384	-.0754	-.0214	.1718	-.1308	.6447
21 Vocabulary	.0914	.0493	-.1112	.0976	.0313	-.0012	.8240	.1933	-.0303	-.0025	.2008	.0917	.0284	.1332	.0847	.0514	-.0183	.0172	.1513	.1063	-.0227	.8634
22 General Information	.2029	.0333	.0670	-.0062	.0171	-.0136	.7812	.0937	-.0086	.1743	.1275	.1549	.0413	.0765	-.0119	.0838	.0290	.0092	-.0086	.1366	-.1641	.7984
23 Mechanical Information	.1542	.0128	.2829	.1479	.0755	.0185	.2845	.6933	-.0468	.0914	.0765	.0509	.0198	.0360	-.0151	-.1153	.0433	-.0331	.0223	.0824	.0003	.7379
24 Tool Identification	.1862	-.0486	.2189	.1283	.0972	-.0018	.3108	.6420	-.0231	.1860	.0499	.0025	.0028	-.0165	.0148	-.0336	.0751	-.0368	-.0590	.0829	-.0100	.6763
25 False Premises	.3295	.1302	.0329	.0405	-.0132	-.0300	.2524	.1158	.2112	-.1475	.1343	.0064	.0334	.0071	-.1303	-.1445	.0276	-.0083	-.2615	-.0235	-.0149	.3998
26 Inferences	.3778	-.0495	-.0760	-.0651	-.0553	.0434	.6580	.0396	.0266	-.1241	.0303	.1223	.1569	-.0007	.0177	-.0251	-.0463	.0457	.0331	.0671	.0460	.6641
27 Careful Estimates	.1901	.0793	-.0618	.2289	.0047	.0729	.1961	.0968	-.0901	-.0578	-.0387	-.0453	.2441	.1068	-.0032	.1411	-.0790	.0154	.0673	.0453	-.1122	.2834
28 Social Situations	.1060	.0222	.0133	-.0802	.0715	.0323	.4640	.0815	-.0928	-.1265	.0363	.1648	.0076	.0234	-.0926	.0196	-.0293	.2253	-.0849	.0016	.1758	.3987
29 Control Associations	.0527	-.0676	-.0461	.0330	-.0656	.1734	.3247	-.0562	-.0324	.1479	.6137	.0523	-.0019	.0815	.0049	.0418	.1030	.1240	-.0221	.0517	.0885	.6012
30 Things Round	.1846	.0392	.0697	.0588	.0234	.0272	.0710	.1230	.0040	.0174	.6943	.1131	.0014	.0394	-.0318	-.0145	.0503	.1605	-.0634	.0649	-.0329	.6010
31 Ideas (Man up ladder)	.0938	.0337	.0734	-.0858	.0232	-.1225	.2521	-.0044	.0236	-.1051	.5391	.1367	-.0034	-.0786	.0049	.1091	.0452	.3362	-.0854	.0405	-.0471	.5671
32 Adding	.1554	-.0822	.1098	.2083	.0348	.0815	.2998	.2014	.0592	.0580	.1702	.6586	.0219	-.0834	.0385	.0045	.0197	.1536	.0230	.0368	-.0058	.7290
33 Careful Subtracting	.0873	-.0094	-.0107	.0259	.0778	-.0661	.0608	.0200	-.0479	.0368	-.0603	.0618	.0483	-.0027	-.0425	.0181	-.0176	-.0992	.4927	-.0998	.0177	.3017
34 Careful Dividing	-.0055	-.0253	-.0043	.0212	-.0064	-.0013	-.0031	-.0055	-.0760	.0118	.0324	.0819	.6230	.0019	-.0161	.0035	-.0267	-.0599	.0262	.0168	.0374	.4100
35 Multiplying	.1959	-.0311	.0218	.0326	.0152	.0386	.1565	.0780	-.0092	.0857	.1575	.6942	.0832	.0794	-.0120	-.0330	.1400	.1682	-.0660	-.0511	-.1296	.6725
36 Mixed Arithmetic	.2525	.0384	-.0226	-.0299	-.0311	-.1144	.2266	.1202	.0103	.0725	.0489	.7191	.1341	.0559	.0755	.0205	-.0006	.1173	-.0292	.0824	-.1297	.7368
37 Careful Fractions	-.1289	-.0817	.0550	.0677	-.0675	.0420	.1462	-.0839	-.0171	-.1254	-.1026	-.0638	.3487	-.1354	-.0514	.0795	-.0100	.0317	.3386	-.0028	.1440	.3816
38 Backward Reading	.4269	.2978	-.1362	.0374	.1429	.2271	.1899	.0113	-.0199	.1799	.0892	.1997	-.2036	-.0448	-.0195	.0661	.1627	.1908	-.0718	.0211	.0991	.6061
39 Street Gestalt	.4500	-.0223	-.0556	-.0503	.1129	.3823	-.0233	.0454	-.0034	.0468	.1138	-.0823	.1040	-.0455	-.0822	.0276	.0778	.1458	-.0753	.0327	.0007	.4465
40 Designs (See Signs)	.4996	.0881	-.0817	.0795	.1115	.1365	.1524	.2619	-.1761	-.0820	.0791	.0979	-.0472	-.1707	.0642	.0945	.0748	.1600	.0464	.0147	-.1282	.5412
41 Forward Writing	.0433	.0160	.0655	.0048	.0607	-.1107	-.0117	-.0926	.0168	-.0789	.1437	.1865	-.0484	.0953	-.0535	-.0780	.0569	.5177	-.0073	.0944	-.1171	.4074
42 Forward Printing	.1659	.0306	.0209	.0304	.0306	.1644	.1603	.0120	.0413	.0141	.1503	.1975	.0599	-.0143	.1034	.0486	.0548	.6519	-.0900	.0530	.0421	.6046
43 Novel Writing	.1364	-.0398	-.0266	.0408	.0433	.0611	-.0740	-.1841	.0023	.0834	.1225	.0069	-.0059	-.0832	-.0671	.0384	.1348	.6303	-.0685	-.0920	-.0286	.5330
45 Speed Matching	.2131	.2199	.0598	-.1492	.0952	.1677	.1458	-.1161	.0949	.0037	.0069	.5182	-.1719	.0271	-.1248	.0033	.0886	.3108	.1065	.0116	.0610	.6392
46 Speed Cancellation	.2088	.2431	-.0343	-.0592	.1805	.1282	.1073	.0096	.0083	-.0166	.0707	.3448	-.1741	-.0543	-.1249	.0512	.1327	.4629	.1302	-.0043	.1073	.6041
47 Agree with Platitudes	-.0668	-.0311	-.0763	-.0466	.0042	-.0195	-.0458	-.0902	-.0862	.1549	-.0031	-.1401	.0177	.0704	-.0449	.0412	-.0083	-.0437	.0438	.0501	.4298	.2744
48 Highbrow Tastes	-.0301	-.0381	-.0951	.0896	-.0799	-.0776	.3543	-.0176	.1653	-.0078	.0333	.0524	.0222	-.0459	.0791	.4513	.1372	.0185	[illegible]	.2025	.1077	.4820
49 Critical Hostility	-.0548	.0223	-.0589	-.0148	-.0165	.0000	.0197	.0755	.0640	.4408	.0343	.0889	-.0019	.0393	-.0132	-.0013	.0408	.0188	.0399	-.0404	.0881	.2355
50 Experience Claimed	.1104	.0541	.0725	-.0074	.0718	.0495	.0203	-.0630	.0901	.0584	.0614	.0326	.0022	-.0271	-.0846	-.0094	.7543	.1435	-.0443	.0127	-.0103	.6485
51 Confidence Claimed	.1188	-.0447	-.3854	.0353	-.0604	-.0048	.0925	.0322	.0683	.0479	.1051	.1467	-.1081	.0723	-.0480	.2032	.5326	.1360	.0469	.1323	.0135	.6011
52 Self Sentiment (UT)	-.0595	.1135	.0781	.1778	.0626	.0359	.1459	.1579	-.1718	-.0787	.0407	.0301	.0911	.1447	.1097	.0870	.0482	-.0583	-.1290	-.1528	.2842	.3191
53 Self Sentiment (OP)	.0773	.0222	-.0184	.0327	-.0030	-.0068	.2783	.0383	.0601	.1214	.0859	.1113	-.0322	.4232	.0691	.0174	.0136	-.0135	.0115	.0698	.1860	.3501
54 Risks Claimed	.2319	.0756	.0082	-.0164	.1139	.1274	-.0108	.2104	.0826	-.0112	.0295	-.0158	.0450	-.0430	-.5296	-.1301	.1932	.0433	-.0350	.0106	.0671	.4879
55 Dewy Brain Damage	-.0687	.0678	.1153	-.0005	.0991	.0612	.2379	.0882	.0414	-.0698	-.0168	-.0529	.0422	.0280	.4618	-.0270	.0030	-.0322	-.0791	.3686	.0454	.4720
56 Test Anxiety	-.1853	-.1862	.0165	-.0359	-.0423	-.0826	-.2566	-.2550	-.0015	.0195	-.1214	-.0582	-.0159	.0014	.0631	-.0587	-.0445	.0231	.0632	-.6779	-.0032	.7024
57 16 PF Q_4 Tension	-.0009	.0397	.0012	-.0751	.0224	.0903	-.1506	-.1252	-.0091	.0451	-.0418	.0190	.0533	-.0609	-.1277	.0591	.0855	.0256	-.0283	-.6805	.0355	.5579
58 16 PF H Adventurous	.0132	-.1010	-.0941	-.0759	-.0053	.0998	.0722	.0801	.0917	.0897	.0373	.1575	.0611	-.0123	-.0162	.0288	.2641	.0971	-.1845	.6317	.0588	.6099
59 16 PF Q_1 Experimenting	.0422	-.0433	-.0802	.1589	.0149	-.0424	.3043	.3099	.0384	-.1125	.1520	.0134	.1167	.0186	-.1130	.2530	-.0027	-.0111	.1617	.3089	.1492	.4981
60 16 PF I Sensitive	-.0149	.0537	-.0685	-.0147	-.0862	.0505	.1871	-.3126	-.0749	.0274	.0867	-.0370	.0763	.0590	.0796	.4960	.0525	.0112	-.0228	-.1866	-.0029	.4659
61 Sex (Fem 1, Male 2)	.0771	-.0923	-.0763	-.0278	.0990	.0478	.0465	.8201	-.0435	-.0236	-.0004	.0686	-.0024	.1222	-.0706	.0067	-.0715	-.1237	-.0708	.1958	-.0340	.7959
62 Years Education	.1310	.1494	.0772	.0382	-.0351	-.1828	.5029	.0391	.1520	.0953	.0143	.2426	.0106	-.2083	.2075	.1491	.2021	.1748	.0450	.0836	-.0353	.6177
63 Years Parents Schooling	.1280	.0166	.0886	-.0050	.0001	.0154	.0538	.0313	.4778	.0771	-.0061	.0727	-.0759	.0219	-.0181	.0219	.1008	.0443	-.0570	.0534	-.0859	.3008
64 Chronological Age	-.3557	.0570	.0306	.2488	-.0142	-.1127	.6086	.0886	-.3149	-.0056	-.0479	.1415	.0279	-.1941	.0810	.0922	-.0226	.0037	.1275	.1507	.0921	.8068
65 Non-minority Race	.1178	.0050	.5584	.0042	.0434	-.0197	-.0435	.0489	.0957	-.0580	.0729	.0889	-.0301	-.0075	.0123	-.0330	-.0132	.0684	.0091	-.0291	-.0510	.3686
66 Height (inches)	.1610	.1237	-.1698	-.0759	.0469	.0291	.1117	-.7014	.1363	-.0081	-.0128	.0627	-.0477	-.0806	.0245	-.0700	-.0495	-.0733	-.0079	.0986	-.0574	.6412

Vita, 1964

Name: John Leonard Horn

Address: 196 South Corona Street; Denver 9, Colorado

Citizenship: U. S. A.

Date of Birth: September 7, 1929

Place of Birth: St. Joseph, Missouri

Marital Status: Married; four children

Military Service: U.S. Army, November, 1950 to October, 1952
Honorable discharge.

Present Position: Assistant Professor, Department of Psychology
University of Denver.

Education: Denver Public Schools: 1934-1947
University of Denver: Jan., 1953-June, 1956. B.A. degree
undergraduate major: Psychology (50 hours)
undergraduate minor: split mathematics (30 hours)
and chemistry (30 hours)
University of Melbourne; Melbourne, Australia
Sept., 1956 - Nov., 1957
Social Psychology and Personality
University of Illinois: Feb., 1958-present.
M.A. degree awarded Jan., 1961.
Graduate major: Personality
Graduate minor: Measurement
Languages: German and Russian

Professional Experience:

Undergraduate teaching assistant, University of Denver 1954-1956. Mainly paper grading. Some individual tutoring in algebra, trigonometry and geometry.

Research assistant to S.B. Hammond, Senior Lecturer, University of Melbourne, Australia during the year 1956-1957 while on a Fulbright Fellowship. Projects: (1) scaling and pattern analysis, (2) prediction of academic success. Reports of these studies were circulated locally but never through formal media.

Research assistant to R. B. Cattell, Research Professor, University of Illinois during the period from 1958-1961 while on an NIMH Fellowship. Projects: (1) neuroticism factor measurement and diagnosis, (2) standard errors for newly developed statistics, (3) test construction and analysis for multivariate studies of motivation, temperament and ability.

Assistant Professor, University of Denver since 1961.

Projects: (1) estimation of factor scores, (2) random models for behavioral problems, (3) structure and change of abilities, (4) structure among questionnaire variables and social desirability.

Teaching: statistics, test construction and scaling, multivariate analysis, individual differences.

Academic and Research Interests:

Teaching with opportunities for research in the following areas in order of preference)

Personality measurement and change, including test construction and analysis of structure and change of abilities, motives and stylistic traits.
Methodology and design, with emphasis on multivariate methods
Psychometrics and statistics
Psycholinguistics
History and systems in psychology
Social Psychology
Dynamics of leadership in small groups

Publications: (Listed in chronological order of acceptance by publisher)

Scheier, I. H., Cattell, R. B. and Horn, J. L. Objective test factor U.-I. 23: its measurement and its relation to clinically-judged neuroticism. J. Clin. Psychol., 1960, 16, 135-145.

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*Horn, J. L. Significance tests for use with rp and related profile statistics. Educ. Psychol. Measmt., 1961, 21, 363-370.

*Cattell, R. B. and Horn, J. L. The Handbook for the Motivational Analysis test (MAT). Champaign, Illinois: Institute for Personality and Ability Testing. 1962 Revised, 1964.

Cattell, R. B., Horn, J. and Butcher, J. The dynamic structure os attitudes in adults, Brit. J. Psychol., 1962, 53, 57-69.

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*Horn, J. L. Second-order factors in questionnaire data. Educ. Psychol. Measmt., 1963, 23, 117-134.

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*Horn, J. L. A note on the estimation of factor scores. Educ. Psychol. Measmt., 1964, 24, 525-527.

Horn, J. L. Geometric interpretation and computation of correlation. J. Psychol. Studies, 1965 (in press).

Elkind, D., Horn, J., and Schneider, G. Studies in perception IV. Decentration and word recognition. J. Genet. Psychol. 1965, (in press).

Adams, D. K. and Horn, J. L. Non-overlapping keys for the MMPI scales. J. Consult. Psychol., 1964 (in press).

Horn, J. L. A rationale and test for the number of factor in factor analysis. Psychometrika, 1965 (in press).

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Horn, J. L. Concepts and issues in the multivariate measurement of motivation. Ch. 21 in the Handbook of Multivariate Experimental Psychology, Rand-McNally, 1965 (in press).

Horn, J. L. and Morrison, W. L. Dimension of Teacher Attitudes J. Educ. Psychol., 1965 (in press).

Papers read at meetings of professional societies

Horn, J. L. Spearman revisited: disjunctive concept attainment and its relation to the general ability factor. Annual meeting of the Rocky Mountain Psychological Association, 1963.

*Horn, J. L. Social desirability, evaluation and a hierarchial model for the organization of questionnaire response. Annual meeting of the Rocky Mountain Psychological Association, 1964.

Spilka, B., Horn, J. and Langenderfer, L. Social desirabilities among measures of social desirability. Annual meeting of the Rocky Mountain Psychological Association, 1964.

* copies available on request

Membership in professional societies

American Association of University Professors. (since 1962)
American Psychological Association (since 1962)
Psychometric Society (since 1961)
Society of Multivariate Experimental Psychologists (since 1961)

Honors, recognitions, awards, etc.

American Men of Science. Listing
Fulbright Student Fellow, 1956-1957.
National Institute of Mental Health Fellow, 1958-1961.
Phi Beta Kappa, 1955.
Phi Delta Theta. Honorary mathematics, 1956.
Phi Kappa Phi. Honorary, 1961.
Psi Chi. Honorary Psychology. 1956.
Sigma Xi. 1962.
Who's Who in the West. Listing in next edition.
National Aeronautics and Space Administration Research Grant, 1964-65, to study short-term changes in abilities.