FACTOR ANALYSIS AND HUMAN ABILITIES

BY B. KUPPUSWAMY, M.A.
(Department of Psychology)

I. The Primary Object of Factor Analysis

In everyday life innumerable words are used to describe human personality and human ability. The man in the street as well as the philosopher and the psychologist have been attempting to classify these innumerable traits. Faculty psychology, for example, sought to look upon mind as having a limited number of distinct and unitary powers. Probably long before this, the Hindu thinkers attempted to describe individual differences on the basis of the doctrine of three ‘gunas’, the ‘satva’, ‘rajas’ and ‘tamas’. The Bhagavad Gita attempts to give the cognitive and oretic characteristics of the four Varnas on the basis of the different combinations of ‘satva’, ‘rajas’ and ‘tamas’. This search for the fundamental variables or dimensions of human ability has thus been going on ever since man reflected about his behaviour.

The latest branch of human knowledge, Factor Analysis, is continuing the search from a new angle. Armed with new statistical instruments, the psychologist is now trying to discover the fundamental unitary abilities. From out of the intricate web of mental life, Factor Analysis tries to isolate the fundamental variables of personality.

Factorial Analysis begins with the test results and its problem is to isolate the fundamental abilities involved in the test performance. As Thomson\(^1\) puts it comprehensively, “Factorial analysis attempts to arrive at an analysis of mind based on the mathematical treatment of experimental data obtained from tests of intelligence and other qualities and to improve vocational and scholastic advice and prediction by making use of this analysis in individual cases.”

II. Factors and Abilities

Spearman discovered that the coefficients of correlation between the different mental tests tend to fall into “hierarchical order”. He explained this by the hypothesis that all the correlations were due to one common factor. Thus according to his famous two-factor theory the performance in each

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\(^1\) Thomson, The Factorial Analysis of Human Ability, University of London Press, 1939, p. 3.
test was due on the one hand to a general factor ‘g’ that was common to all the tests and a specific factor ‘s’ that was peculiar to the particular test. This ‘g’ he identified with ‘general ability’ or ‘general intelligence’. The inter-correlations are thus explained on the basis of the factor that is common to all the tests.

This is referred to as the test’s “communality”. In so far as it fails to correlate with the other tests it is measuring the component which is specific to it—its ‘specificity’. Thus the two factors together determine the test score.

The matter would have been quite simple if ‘g’ were the only common factor. Before long it was found that over and above ‘g’ or besides ‘g’ there were other common factors. A factor was found common to all the verbal tests (v), another to all the number tests (n) and so on. Thus the test score could not be explained on the basis of two factors ‘g’ and ‘s’. The additional factors, the ‘group factors’ as they were called, or the ‘s-overlap’ also determined the magnitude of the score. Spearman employs the original two-factor method to determine the various factorial components of every test. The complex matrix of correlations are looked upon as being due to the superposition of sub-hierarchies on the top of the g-hierarchy. Thus the test performance is looked upon as being due to, or as being composed of, the g-factor, one or more group factors and the s-factor, in other words as composed of the factor common to all tests, the factors common to a few and the factor unique to the test concerned.

Since the theory of two factors, in its original form, could not explain the test performance without bringing in the new group factors, other workers tried to work out a method of multiple-factor analysis, whereby any matrix of test correlations could be analysed directly into its component factors. Thurstone\(^2\) gave as many as 57 tests and found on analysis that 12 factors were operating in the performance of the different tests.

Now the point of immediate concern to us as psychologists is what is the status of these ‘factors’? What do they stand for and how do they help us to understand and explain human behaviour? As we have seen above the factors are analysed on the basis of the communality among the different tests. The inter-correlations between the tests are explained by postulating appropriate common factors. As Burt puts it—a factor “is primarily a principle of classification and nothing more: it is expressed in quantitative form simply because the items whose characteristic pattern constitutes the

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\(^2\) Thurstone, Primary Mental Abilities, University of Chicago Press, 1938.
distinguishing mark of the class described by it, vary continuously and in degree rather than discontinuously and in kind”. Now the same set of correlations can be factorised in a number of ways since the scores are looked upon as lines. Spearman, Thomson, and Thurstone, to refer only to three workers in the field, have each selected a different way of factorising. So our problem is to find out the relationship between these factors and abilities of mind.

Every Factorial study starts with certain psychological assumptions. In order to make the factor analysis tests have to be selected. In the selection and construction of tests each worker starts with certain psychological considerations. He assembles certain tests because by preliminary psychological analysis he believes that certain abilities may be involved in the test performance. He then takes up the scores and analyses the interrelationships among the tests. The factors may be defined mathematically on the basis of the relationship between the test scores. But the problem of the identification of the factors in terms of abilities is the crucial thing. The common ability can be decided only on the basis of the study of the different tests which reveal the relationship. If it is not possible to identify any common feature among the different tests then the factorial analysis will have no psychological significance whatever. In Thurstone’s work, for example, we find that five out of the twelve factors discovered do not have any psychological meaning. Consequently mere factor analysis without psychological significance is of no value whatever. As Thomson⁴ writes “It becomes increasingly clear that the whole process is one by which a definition of the primary factors is arrived at by satisfying simultaneously certain mathematical principles and certain psychological intuitions. When these two sides of the process click into agreement, the worker has a sense of having made a definite step forward”. The factorial methods ought to be looked upon not as establishing the fundamental human abilities but rather as methods to test psychological hypotheses. A mere isolation of a factor is of no significance whatever. A factor will be of significance when it is identified with some psychological ability.

III. “Independence” of Factors

An essential aim of factor analysis is to see that the factors are orthogonal, independent, uncorrelated with one another. No purpose is gained if the factors are overlapping. That will only lead to confusion since neither individuals, nor tests can be described with accuracy in terms of the

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⁴ Thomson, Factorial Analysis of Human Abilities, p. 247.
factors. Criticising factorial analysis Allport writes\(^5\) “Another ground of disagreement lies in the assumption that independent factors are the desideratum of any theory of elements. Not only all men are supposed to have precisely the same basic elements in their personalities, but in each life these elements are to be regarded as independent of all other elements.” The confusion here lies in the meaning of the word “independent”. By independent is meant that the factor is uncorrelated with another. Most tests of mental ability exhibit some degree of positive correlation. Consequently the notion of separate and unitary powers which operated in an isolated manner must be discarded. What the factorist means is that one factor, for example, the verbal factor, is something which is uncorrelated with another factor ‘g’, something which a person with low ‘g’ is as likely to have as another with high ‘g’. It is asserted that there is no covariance between the two.

IV. Negative Saturations

The great majority of correlation coefficients reported in psychological work are positive. Even the tests of physical, sensory and other non-intellectual functions correlate positively with one another though the coefficients are generally very low. But occasionally negative correlations arise. Particularly in the work on personality traits negative values occur. Negative values also arise in some methods of factor analysis. In the work on multiple-analysis it has been found that there is a need for weighting the factors. As Spearman writes, “The lost determinateness can, however, be more or less regained by stipulating that the weights of the respective factors should be heaped up in order of calculation. Some such determination has been employed by Hotelling, Kelley and Burt. The trouble this time is not so much statistical but psychological; the procedure generates a large and regular number of negative values which contradict all experience.”\(^6\)

All the statisticians, except Burt, employ certain methods to overcome these negative factor loadings. Thurstone, for example, by his method of rotation, gets rid of the negative entries in the factorial matrix. The fundamental assumption is that if the mental abilities are present they must act positively. If a particular ability is not operating in any given performance then there will be no influence whatever, there will be zero entries in the factorial matrix.

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Burt, on the other hand, accepts the negative loadings just as they are. His argument is based on the phenomena of reciprocal inhibition and interference established in the experimental work upon learning. As we have already seen the problem has no statistical importance since by suitable methods we can get rid of the negative saturations in the factors. Further these negative loadings do not occur in certain methods of factor analysis, as for example, in Spearman’s Two-factor method. Finally as Vernon writes “Occasional negative correlations might arise, but they are not likely to be statistically significant, and so may be ascribed to errors of sampling.” So the crucial question is psychological: can abilities vary inversely? Or in other words can an ability hinder a person from turning out a certain work? Negative correlations may arise if a certain ability is present which hinders him in doing a particular task. So its function is to “disable” him. This is what Spearman calls a contradiction. Either an ability is present or not. If it is present then it influences some performance to a certain extent—to a greater or less degree. If it is absent then it has no influence whatever. On this hypothesis the entires in the factorial matrix will either be positive or zero. As Thurstone writes “By psychological considerations the hypothesis can be entertained that the primary factors act positively unless they are absent from a performance. If this assumption is correct then the projections of the test vectors on the co-ordinate axes should be either positive or zero.” As regards Burt’s contention based on the phenomena of inhibition and interference it might be stated that such phenomena clearly indicate that these new factors affect the ability in question by diminishing the output. Consequently the “disability” turns out to be low output. Since it is the task that is measured we will notice that the task is affected by being performed to a less extent than more. So the decrease or increase in the output remains a positive quantity. Consequently any factor that contributes to such operations will contribute in a more or less way.

Burt considers that the negative loadings are quite natural since factors may be looked upon as bipolar. A number of personality traits are bipolar according to the extent analyses. They have their opposite characters. But this is really a matter for experimental work. To take but one illustration, McDougall in his work on expressiveness found that the amount of alcohol needed to bring about a certain degree of expressiveness varied among the Introvert-extroverts. It is possible that the so-called bipolar factors turn out to be mere differences in degree and not any difference in kind though

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8 Thurstone, *Primary Mental Abilities*, p. 71.
for descriptive purposes we look upon them as differences in kind. Unless more work is done in this field one is not justified in asserting that personality traits are bipolar involving negative factor loadings necessarily.

Commenting on the discussion of this problem in the British Psychological Society Thomson writes, "The debate about the justifiability of negative loadings has been rather inconclusive for two reasons. It has not been fully appreciated, I think, that the objection among certain psychologists to negative loadings is not an objection to one or two such, for a few negatives can be made plausible. It is an objection to having almost exactly half the loadings negative in the factors following the first one and to the artificiality of explaining even a matrix of exclusively positive correlations by numerous negative loadings." 9

V. Limitations of Factor Analysis

As indicated above methods of factor analysis must be looked upon as tools to test psychological hypothesis. Mental tests are constructed with definite purposes in mind. The items in each test are based on the analysis of behaviour and experience. If we presume that certain abilities are operating in certain tasks we can make use of the methods of factor analysis to see whether it is possible to isolate such factors which explain the variance in any task.

Let us consider this problem from the point of view of Spearman's 'G' factor. Spearman postulated this factor on the basis of the psychological interpretation of the test results. The whole programme of intelligence testing assumes that there is a certain general ability which determines or influences the actual performance of an individual in a given set of tasks. By his method of factor analysis he found that it is possible to find out the 'g'-saturation in each task. Though the exact psychological description of this ability may not be approved by other workers in the field tests are devised and standardised to measure it. Thurstone has shown that there is no evidence of 'g' among his 57 tests. But this is demonstrated to be due to the method of analysis. As we have already noted there are innumerable methods of analysing the same data. By reworking the data Spearman and his co-workers have shown that those tests also involve 'g'.

Now what is the status of this 'g' which appears when certain methods of analysis are used—Spearman, Thomson and Kelley—but vanishes when certain other methods of analysis are used—Thurstone? The sole test is its

status as a psychological concept. Does it help us in understanding behaviour and in predicting behaviour? If it does, it can be accepted, otherwise it must be rejected. As Thomson says, “The real defence of ‘g’ is simply that it has proved useful.”\(^{10}\) Or again as Spearman himself writes about the two-factor theory: “Psychologically it is credited with affording the sole base for such useful concepts as those of "general ability" or "I. Q."\(^{11}\)

We must consider another correlated point. Do these factors reveal the constitution of mind? Are they ‘real’ and ‘existential’? Without going into the ontological aspect of these concepts we must here note briefly the status of these factors. Mind is a complex and an integrated whole. The work of Lashley has shown that the problem of localisation of cerebral functions is not as simple as it was thought to be in the last century. When the concrete nervous system itself acts in an integrated way both at the spinal and cortical levels what about mind or behaviour which involves the entire organism? As Thomson points out “There is a feeling that factors may be more enduring entities than the innumerable and changing tests used to find them. It is an easy transition to look upon the factors as actual and real. It is of the nature of man to deify or reify forces and powers behind phenomena—which is, I think, a large part of the explanation of why factors are so acceptable to so many of us”.\(^{12}\) This danger is always there. The factors have only a conceptual status. We should not use any spatial or visual images in understanding them. Factors are merely descriptive mathematical coefficients which enable us to describe the test performance. Of course, it must be borne in mind that factors themselves are described in terms of tests since they are derived from the tests. The fundamental advantage of factors is that we can replace a multitude of tests and verbal descriptions by a description in terms of a few factors. We can describe individuals as well as activities and occupations in terms of a small number of factors. “This, if achieved, would react on social problems somewhat in the same way as the introduction of a coinage influences trade previously carried on by barter. The transaction is facilitated even though the end result is the same. And so perhaps with the “pricing” of each man and each occupation in terms of a few factors”\(^{13}\).

Factors, consequently, ought not to be looked upon as entities of mind with immutable constitutions. They should not be looked upon as elements

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11 Spearman, *ibid.*, p. 79.
the human minds are made of. They are primary categories for classifying mental tests and tasks. Their value lies in the fact that they tell us objectively what mental tasks are correlated, and to what extent they are correlated. It is here that factors are different from faculties and such other subjective conceptions of human traits or abilities.

VI. Vocational Guidance and Two-factor Theory

Thomson, Hull and others have pointed out that the two-factor theory of Spearman makes aptitude testing impossible. If \( g \) were the only general or common factor pervading over the tests and if \( s \) were something specific to the particular task, not involved in any other, then the programme of vocational guidance or selection will be restricted to the measurement of \( g \) and in the detection of the amount of \( g \) needed for success in the different vocations. So the discovery of any aptitudes will be out of question. But Spearman has now shown that there are a number of group factors common not to all tasks, but common to a set of tasks. Thus there is hardly any difference in final detection of communalities as between the two-factor theory and any multiple-factor theory. As a theory postulating only one common factor it was long ago abandoned. So really it is misleading to call Spearman's theory 'Two-factor' since he recognises the various group factors. But as a method of factor analysis it remains 'two-factor' since step by step the communalities and specificities are separated as two factors.

It is not correct to assert that aptitudes are specific factors since by definition a specific factor is peculiar to the task on hand and not common to other tasks. But as the different factors like mechanical aptitude, manual dexterity, etc., have established, aptitudes are really group factors and not specific factors. It is impossible to predict anything on the basis of specific factors since they do not enter into the performance of any other tasks. Thus Spearman's two-factor theory in no way makes occupational analysis on aptitude testing impossible.