

THE ORGANIZATION OF HUMAN ABILITIES AND INTELLIGENCE (1971)

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The Greeks had a word for it but the Romans had a word with better survival properties. And as long ago as 2,000 years before the advent of attempts to measure intelligence, there seems to have been recognition of the fact that individuals differ in intellectual ability.

The earlier attempts at measuring were based on either of two quite distinct conceptions: the Galton-Cattell idea that intellectual ability manifests itself in simple discrimination functioning and the Binet notion that cognitive ability reflects itself in more complex functioning. The Binet concept proved to be more fruitful and by 1925 there was on the market, in addition to various versions of the Binet scale, a flood of group tests of so-called general intelligence.

A few words about definition may be in order. The fact that tests of general intelligence based on differing definitions tend to intercorrelate about as highly as their respective reliabilities permit indicates that, despite the diversity of definitions, the same function or process is being measured—definitions can be more confusing than enlightening. That confusion might have been anticipated is evident from a reexamination of the problem of the definition by Miles (1957). This British gentleman found himself struggling with the fact that the word “definition” itself has 12 definitions. Perhaps the resolution of this problem should be assigned to a division of philosophical psychology or maybe as McNemar (1964) states “the problem should be forgotten since psychologists seem to have lost the concept of general intelligence.”

If you believe that the concept of general intelligence has outlived its usefulness, you may choose from among several differential or multiple aptitude batteries which provide measures of the “primary mental abilities.” The great stress on general intelligence, along with other arguments such as something innate being measured by IQ tests, that IQ tests reflect middle-class values and that IQ standing fostered undesirable expectations regarding school achievement; the idea that IQ differences are incompatible with democracy and lead to educational determinism, seem to be causing us to ignore other possible abilities.

These points lead right into the problem of factor analysis. Historically, factor analysis was developed by psychologists as a method for investigating structure, pattern or organization in the complex network of human abilities and is not uncommonly viewed as a classificatory method.

Factor analysis is a multivariate statistical method with applications in many areas of inquiry.

Spearman and Thurstone (1938) were the major influences constructing tests to measure “primaries.” It was found that their “primaries” were themselves intercorrelated when they had been hoped to be independent. The Thurstones (1941) readily admitted that a general factor was needed to explain the interrelatedness of the primaries. This eventually led to the idea of oblique axes, which axes were regarded as representing the primaries as first-order factors, whereas the general factor pervading the primaries was dubbed a second-order factor. Anything called “second-order” could not be regarded as of much importance. Furthermore, it could always be said that in the ability domain, it is less difficult to attribute psychological meaningfulness to first-order than to second-order factors so why pay much attention to the latter. Thus it was easy for most American factorists to drop the concept of general intelligence and to advocate the tests thereof, despite their proven usefulness over the years, should be replaced by tests of the primaries. Hence the emergence of differential aptitude batteries.

In the period under review, a number of authors have pursued a quest for the meaning of factors and their relevance for a theory of behavior. What theory of the organization of human ability do the data of factor analysis tend to confirm or deny? What contribution can factor analysis make to the development of a comprehensive theory of behavior? Such questions as these are not new. Spearman raised them in the first place and provided his own answers to them. As the technical problems of factor analysis attain solution, it is appropriate that interest should focus on an inquiry into the meaning of the data of factor analysis for psychology as a whole.

The view is now widely accepted that factors can be fractioned and proliferated almost without end. This implies that a much more general model is required than the simple dimensional one which views first-order factors as primary. Humphreys (1962), although finding much merit in a hierarchical model, agrees that this model is insufficiently general and advocates facet theory. Facet theory is a matrix-type model for the definition of a universe of possible tests. A facet is a logical dimension of the model and its elements are the presence or absence of logically defined parts of that dimension. They must be manipulatable by the test conductor. They are not even very psychological as defined. Thus item content might be considered a facet and words, numbers, figures and photographs would be its elements. A facet and its elements do not necessarily extend to all kinds of psychological tests. There is no necessity to strive for all embracing categories. They may be restricted to a single domain such as achievement tests. A pragmatic test is applied to their definition but this test does not refer to the behavior of examinees. They should be useful to the test constructor; they do not need to make a behavioral difference in all populations or even in a single

population. In general, they should be selected so that they are potentially able to make a difference in behavior but whether they do may depend upon finding the right people who have the right genetic or environmental background. Thus they may or may not define factors. Facet theory is used to define tests. The product of all elements of all facets defines a hypothetical universe of tests and makes possible the extension of content validity standards to the aptitude area. The test constructor uses this model as a guide in test construction. Humphrey's view is that when a set of tests at all levels of homogeneity is factored, as defined by facet theory, simple structure will tend to disappear and simplex and circumflex patterns will more frequently be found.

From the facet point of view there are no "pure" tests. One obtains better and better measures of an element by adding together as many elements of other facets as possible. A model of the organization of human abilities classified by facet theory, first, included three facets creating 96 combinations of elements.

In 1965 Guilford brought the model for intelligence up to date and defined it as follows: an operational model for problem solving in general. Since most behavior readily involves a bit of problem solving activity, the model could also have applications over wide areas of behavior.

The typical, traditional model for problem solving, since John Dewey in 1910, has been a linear time series with steps such as: seeing the problem, analyzing or structuring the problem, generating solutions and judging and selecting one of the solutions. Things look more complicated now with respect to intelligence. Cybernetics and the computer-simulator people have seen to that.

The occasions for a problem solving episode begins with a certain input, mostly through the sense avenues, of course, represented at Input I in the model. The E and S stand for environmental and somatic sources of input respectively. The somatic source may include both motivational and emotional components from within the brain as well as from internal receptors. A filtering step determines which input goes further and has any appreciable consequences in behavior. "Filtering" is a new and more operational name for "attention." Evaluation is another operation that has to be taken into account at all steps along the way, for the organism is perpetually self-checking and self-correcting. Evaluation is not left to the final stage of problem solving as commonly supposed in traditional models.

Awareness that a problem exists and identification of structuring of the problem are cognitive operations. During these operations there is a dependence upon memory storage and there is evaluation of cognized information. In the effort to cognize the problem, there may be a seeking for

new input information, as at Input II in the model. Filtering of this input also occurs, as well as evaluation.

With the problems reasonably well structured, there is a search for answers or for information from which answers can be constructed, in memory storage, with the ubiquitous interplay with evaluation. If a solution is accepted, there is an exit from this problem solving episode at Exit III. Exit I would be a dodging of the problem. Exit II would be a giving up or perhaps result from a distraction before the productive operation got started.

If no good solutions are found to the problem and if there are doubts about its proper interpretation, a new major cycle begins as shown at the second cognition block. For reinterpretation of the problem, new input may be sought with steps similar to those already outlined. A number of these major cycles may go on, in what has often been described as trial and error behavior. Within each major cycle there are subsidiary loops in the flow of events, each of which might be followed by a number of similar loops. The looping phenomena follow cybernetic principles, with feedback information involved and evaluation.

It should be said that the 1965 model is a very general or generic one and not designed to fit necessarily any particular episode of problem solving. But the basic kinds of operations are there. Modifications would be needed to suit the particular case.

Along the lines of the general intelligence theory (but using the factor analytic approach) Cattell (1963) published the results of an investigation designed to test certain ideas concerning the nature of intelligence. It questioned the belief that the conglomerates measured by combining subscores from collections of intellectual tests is the best estimate of intelligence. But the theory also questions the contention that it is theoretically and practically most worthwhile to “splinter” the intellectual domain into a very large number of narrow, slightly distinct abilities.

Cattell argues for not one general ability, as did Spearman but for a number of general abilities. Of these, two, called fluid and crystallized intelligence, are viewed as of major importance. Crystallized intelligence is more highly involved in cognitive tasks in which skilled habits have become “crystallized” so to speak, as the result of earlier learning. Fluid intelligence is more involved in tasks which require adaption to new situations where crystallized skills resulting from prior learning are of no great advantage. Fluid intelligence is thought to have more of a hereditary basis than crystallized intelligence and to depend more on physiological efficiency, whereas crystallized intelligence depends more on environmental factors and is subject to fluctuation as a function of recent exercise and interest. Fluid

intelligence reaches its maximum level at 14 to 15 years, whereas crystallized intelligence may increase to 25 or 30 years of age.

Differences exist in the variation of these two forms of intelligence, crystallized intelligence tending to be less variable in cultures with educational systems such as our own. General brain damage will tend to have a more pronounced effect of fluid intelligence, whereas local brain damage will affect particular crystallized abilities.

The evidence for Cattell's theory is claimed to depend, in part, on the second-order factor analysis of psychological tests. Results based on 44 variables are presented to show that a number of second-order factors emerge. Two appear to be clearly more important than the others. The first of importance is identified as fluid intelligence with high loadings on a number of culture-fair tests, published by the Institute for Personality and Ability Testing. These tests are classification, topology, matrices and series. The second factor, labeled crystallized intelligence has high loadings on Thurstone's primary factor variables, more particularly verbal, reasoning and numbers.

Cattell's theory is an extension of Spearman's theory of a general factor. Spearman argued for a single innate general factor. Cattell extends two factors, the first dependent largely on heredity, the second on prior learning. Spearman based his argument on a factor analysis of tests. Cattell's is based on analysis of the intercorrelations between factors and is much more general than Spearman's original theory. Cattell's neurophysiology is not much different than Spearman's.

Further study in an attempt to refine Cattell's theory of fluid and crystallized intelligence by Cattell and Horn (1966) brought forth the indication that a major proportion of the variance observed in intellectual performances can be understood in terms of six major functions:

- 1) Fluid intelligence, representing processes of perceiving relations, educing correlates, maintaining span of immediate awareness in reasoning and abstracting in both speeded and unspeeded tasks of a relatively culture-fair kind but involving figural, symbolic and semantic content.
- 2) Crystallized intelligence, representing similar processes of perceiving relations, educing correlates, etc., in speeded and unspeeded tasks involving various kinds of content but tasks requiring considerable pretraining to acquire techniques representing the accumulated wisdom of culture.

- 3) General revisualization, representing 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.
- 4) General Speediness, an attribute measured in simple writing and checking tasks requiring little in the way of complex relation-perceiving but an attribute producing variance in the measure of most intellectual factors.
- 5) Facility in the use of concept labels, an ability to quickly bring words (i.e., concept labels) from long-term memory into immediate awareness, a facility which the evidence of this study suggests is largely independent of comprehension of the subtlety of the concepts themselves as indicated in crystallized ability.
- 6) Carefulness, a factor indicating unwillingness to make a mistake, as indicated by few wrong answers but manifested in a wide variety of intellectual tasks.

These general functions are positively related to other variables indication an optimistic view of self, personality integration, independence and upwardly mobile social attitudes. Such positive manifold would thus seem to represent an interdependence between the attributes of the person, the influence of the environment upon the person and the person's affect on the surroundings.

Horn (1965) and Horn and Cattell (1967) reviewed cross-sectional studies and produced new data to show that when putative measures of intelligence are classed as "primarily fluid," "primarily crystallized" and "about evenly mixed with these two," much of the seemingly contradictory evidence on age difference can be seen to be consistent. Younger adults were found to be superior in fluid functions and no systematic age differences were found for primaries and omnibus tests which involved these two factors in about the same degree.

This line of research thus shows promise of integrating previously diverse bits of evidence in the field of human abilities. Perhaps more interesting, it shows some promise of furthering reapproachment among previously separate, if not antagonistic, subfields in which principal concern is with questions about the process of problem solving, perception, etc. But this promise can be realized only if the results obtained heretofore are not specific to either a particular sample of primary factors or a particular sample of subjects.

Guilford (1966) provides a useful discussion of the dimensional, hierarchical and matrix models and extends his discussion to a consideration of the role of factor analysis in relation to psychology generally. He reaches the conclusion that factor psychology, like behaviorism, is a completely objective approach concerned with what goes on between stimulus and response rather than a model emphasizing stimulus-response correlations. Unlike behaviorism, it finds limited use for the concept of association and would substitute the concept of cognition-response sequences for that of stimulus-response associations.

Conclusion

The upshot of this quest for the psychological meaning of factors is far from clear. The conclusion seems to be that this topic has made no singular and clear advance in the period under review. The problems which demand solution have not, it appears, been formulated with the clarity they require. What precisely are the theories which particular factorial and correlational outcomes tend to confirm or deny? Another relevant observation is that a model for the organization of abilities must deal with the developing and changing structure of abilities in the child and must go beyond a descriptive statement of the organization of abilities at a particular point in time. The temporal aspects of structure must be considered.

Lloyd G. Humphreys in his 1967 critique of Cattell's theory of fluid and crystallized intelligence states after examination of the design and the results, he concluded that he lacked confidence in both. "The ideas which led to the research are stimulating, but they deserve a better design and a more objective methodology."

In the study in question, second-order factors, their intercorrelations, third-order factors and their intercorrelations were presented. The factorings on which the conclusions rest are rather far removed from the basic data, the intercorrelations of the variables. The techniques of factor analysis are not sufficiently objective that a reader can accept final rotated matrices without question. This is particularly true of higher-order analysis. It is essential to have test intercorrelations and the first-order factoring at hand in order to interpret adequately, let alone criticize, higher-order factoring.

The design of Cattell's theory was complex and probably unnecessarily so. Results were presented in Humphrey's critique (1947) which indicated that a simple, straight-forward approach provides a much less ambiguous basis for interpretations. This alternative method of analysis also has the merit that it supports the relationship among the ability variables hypothesized by Cattell.

Cattell structured his analysis of the data as a series of factorings in several orders in order to avoid “distortions from the unreliabilities and imperfect validities of actual scales,” (1963). This is theoretically sound but depends in practice upon an objective factor-analytic methodology. It is useful to look at a simpler approach and to gauge the extent to which unreliability and imperfect validity mask relationships versus the extent to which a simpler design reduces computation and interpretational difficulties.

In practically all areas of psychological research the demonstration of trivially small minutia is doomed to failure because of random errors. “Not so” says McNemar (1964) “if your technique is factor analysis, despite its being based on the correlation coefficient—that slipperiest of all statistical measures. By some magic, hypotheses are tested without significance tests. This happy situation permits me to announce a Principle of Psychological Regress: Use statistical techniques that lack inferential power. This will not inhibit your power of subjective inference and consequently will progress you right back to the good old days when there was no strangling stat or sticky stix to make your insignificant data insignificant.” From the evidence gathered his argument holds true today.

It may be a long time before an ivory tower, strictly scientific resolution of the issue as to whether a scheme involving primary abilities plus a deemphasized general factor is preferable to one involving an emphasized general factor plus group factors. With bigger and better computers we will have bigger, though not necessarily better factor-analytic studies but it seems unlikely that such further studies will, in and of themselves, settle the issue under discussion. Until such time as some genius resolves the broader question of the place, if any, of correlational method in a science that aspires to be experimental, we may have to turn to the criterion of social usefulness as a basis for judging whether it is wise to discard general intelligence.

There have been thousands of researches on the multitudinous variations from organism to organism and the results fill books on individual differences. These studies can be roughly classified into two types. First, those that ascertain the intercorrelations among scaled response products to various stimulus situations, known as tests, have to do with the structure of intellect and whether the resulting factors are anything more than dimensions for describing individual difference; and the second type of study seeks nontest correlates of test performance and whether or not any of the found correlates can be regarded as explaining individual differences. Both types of studies certainly force one to stress the overwhelming diversity exhibited among the organisms.

But these studies of individual differences never come to grips with the process or operation, by which a given organism achieves an intellectual

response. Indeed it is difficult to see how the available difference data can be used as a starting point for generating a theory as to the process nature of general intelligence or of any other specified ability.

Notes

- 1) Cattell, R. B., "Theory of fluid and crystallized intelligence: a critical experiment", *Journal of Educational Psychology*, 54, 1963, pp. 1-23.
- 2) Cattell, R. B., "Refinement and test of the theory of fluid and crystallized intelligence", *Journal of Educational Psychology*, 57, 1966, pp. 253-271.
- 3) Cattell, R. B. and Bolton, L. S., "What pathological dimensions lie beyond the normal dimensions of the 16PF? a comparison of MMPI and 16PF factor domains", *Journal of Consulting Clinical Psychology*, 33, 1969, pp. 18-30.
- 4) Ferguson, G. A., "Human abilities", *Annual Review of Psychology*, 16, 1965, pp. 39-63.
- 5) Guilford, J. P., "Intelligence: 1965 model", *American Psychologist*, 21, 1966, pp. 20-27.
- 6) Horn, J. L., "Organization of abilities and the development of intelligence", *Psychological Review*, 75, 1968, pp. 242-260.
- 7) Horn, J. L. and Bramble, W. J., "Second-order ability structure revealed in rights wrongs scores", *Journal of Educational Psychology*, 58, 1967, pp. 115-122.
- 8) Humphreys, L. G., "The organization of human abilities", *American Psychologist*, 17, 1962, pp. 475-484.
- 9) Humphreys, L. G., "Critique of Cattell's Theory of fluid and crystallized intelligence: a critical experiment", *Journal of Educational Psychology*, 58, 1967, pp. 129-137.
- 10) Mednick, S. A., "The associative basis of the creative process", *Psychological Review*, 69, 1962, pp. 220-233.
- 11) McNemar, Q., "Lost: Our intelligence? Why?" *American Psychologist*, 19, 1964, pp. 871-883.