APTITUDE TESTING
JOB ANALYSIS
SELECTION TESTS

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GENERAL INTELLIGENCE FACTOR

A general factor common to all cognitive abilities, however tested, was originally hypothesized by Sir Francis Galton in 1869, but Charles E. Spearman made the first objective empirical test of the hypothesis in 1904. The general factor, which Spearman signified as *g*, was the basis of his famous two-factor theory: that every mental test measures only two factors (i.e., independent dimensions of individual differences): a general factor *g*, common to all tests, and a specific factor *s*, peculiar to each test. The method of factor analysis developed by Spearman made it possible to show precisely the degree to which each test among a battery of diverse tests measures the *g* factor common to all the tests in the battery. This is a test's factor loading on *g*, or simply its *g* loading; it can be thought of as the correlation between scores on the particular test and the *g* factor, if a hypothetical test could measure *g* and nothing else. Spearman's principle of "the indifference of the indicator" meant that *g* could be measured by an infinite variety of possible tests, regardless of the sensory modality, specific knowledge content, or particular skills required to perform the test. The *g* factor will be manifested to the extent that the test, whatever its specific item contents may be, calls for relatively complex mental operations, particularly the "eduction of relations and correlates" and abstraction. Because tests that involve seeing relationships and grasping concepts, abstract reasoning, and solving novel problems are the most highly *g*-loaded and discriminate most clearly between persons ordinarily judged to be of high or low intelligence, *g* is considered practically synonymous with general intelligence. A large *g* loading is the *sine qua non* of all intelligence tests.

At the level of analysis represented by factor analysis, there is no doubt of the existence of *g* in the cognitive abilities domain. The demonstration of a large *g* factor is merely a consequence of the more fundamental fact that all cognitive tests, however diverse, show positive intercorrelations in representative samples of the general population. But it became apparent, not long after Spearman proposed his two-factor theory, that other factors besides *g* are necessary to account for all the intercorrelations among tests. These additional factors—not common to all tests (as is *g*), but common only to certain groups of tests—are termed *group factors*.

The method of multiple factor analysis developed by Louis L. Thurstone, with rotation (transformation) of the factors to approximate a criterion of "simple structure," most clearly revealed the group factors, which Thurstone termed *primary mental abilities*. The most clearly established primary factors are reasoning, verbal comprehension, verbal fluency, number, spatial visualization, perceptual speed, and associative memory. But the mathematical nature of Thurstone's method of factor analysis precluded the emergence of Spearman's *g* factor, which becomes submerged among the primary factors. For a time, this seeming disappearance of Spearman's *g* in the work of Thurstone and his followers was a point of great theoretical dispute, until it became apparent that it was a mathematical artifact of the particular method of factor analysis. Thurstone himself finally pointed out that if the primary factor axes are rotated to the best possible simple structure solution, they are oblique (correlated), and a factor analysis of the intercorrelations among the primary factors yields a *second-order factor* that is the same as Spearman's *g*. This type of *hierarchical* factor analysis, in which *g* emerges as a second-order (or higher order) factor, is now the most generally preferred method for extracting the *g* factor. Other widely used methods, usually yielding only slightly different results, are the first unrotated principal component of the correlation matrix, and the first unrotated principal factor in a common factor analysis. Orthogonally rotated principal components or principal factors (such as varimax rotation) by their mathematical nature obscure the *g* factor and can reveal only the primary or group factors.

Raymond B. Cattell (1971) has distinguished two facets of *g* by means of factor analysis, *fluid* (g_f) and *crystallized* (g_c). The former, g_f, is the ability available for new learning and novel problem solving, and is best measured by figural analogies, block designs, memory span, and tests of relation eduction. The latter, g_c is the product of the investment of g_f in certain content areas and skills, such as vocabulary, general information, arithmetic skill, and scholastic achievement. The distinction between abstract reasoning ability on the one hand, and specific knowledge and acquired skills on the other, roughly corresponds to the difference between g_f and g_c

It has proved impossible to devise tests that are factor-pure measures of the primary mental abilities. Tests of primary mental abilities are always substantially intercorrelated, a fact accounted for by the *g* factor in all cognitive tests. Thus the "purest" tests that can be devised measure a single primary ability plus *g*, with *g* usually accounting for the larger proportion of the total variance (individual differences) in the test scores.

There is as yet no generally accepted theory of the fundamental nature of *g*, and certainly we are still far from understanding the brain mechanisms that would explain *g*. Spearman wrote that *g* could be defined "by site rather than by nature," meaning that one can note the properties of tests that are most highly loaded on *g* but cannot say what *g* itself is. It clearly cannot be identified with any particular type of test content, knowledge, or learned skills. David Wechsler (1958) has remarked: "Unlike all other factors [*g*] cannot be associated with any unique or single ability; *g* is involved in many different types of ability; it is in essence not an ability at all, but a property of the mind." Spearman conceived of *g* as "mental energy" that could be applied to any cognitive task, with tasks differing in the amount of such energy they require for solution. Edward L. Thorndike (1927) thought of *g* as the sum total of stimulus–response connections or "bonds" acquired through learning and experience. Sir Godfrey Thomson (1937) explained *g* in terms of the sampling by different tests of elements from a large pool of unspecified neural elements; more complex tests sample more of these elements, increasing the probability that some of the same elements are sampled by different tests, hence the higher correlations (and higher *g* loadings) among more cognitively complex tests. Sir Cyril Burt (1940) speculated that *g* reflects the general character of the individual's brain tissue, such as the degree of systematic complexity in the neural architecture. Other speculative hypotheses of the nature of *g* have been suggested: the number and extent of branching of brain cells, synaptic conductivity between cells, thresholds of activation of neural elements, the production of neurochemical transmitters, the richness of the capillary network supplying blood to the brain, and neural connections acquired through experience.

Although *g* is not yet well understood theoretically, it is unquestionably the single largest source of individual differences in all cognitive activities that involve some degree of mental complexity and that eventuate in some form of behavior assessable in terms of an objective standard of performance.

ABSTRACT INTELLIGENCE
CONCEPTUAL LEARNING AND DEVELOPMENT
HUMAN INTELLIGENCE
PRIMITIVE MENTALITY

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GENERAL SYSTEMS

General systems theory attempts to find models applicable across disciplines. If the same model (or analogy) can be applied to metallurgy, agriculture, business, and music, we have a "general system." Mathematical operations