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The terms 'intelligence' and 'mental ability', are open concepts that comprise all aspects of brain activity that result in some form of information processing, including attention, stimulus apprehension, perception, encoding, discrimination, generalization, learning, short-term and long-term memory, thinking, problem solving, relation education, inference, and language, to name a few.

Two main aspects of these functions call for investigation: (1) the basic neural design features and operating principles of the brain that make these functions possible, and (2) the cause of individual biologically normal variation in the proficiency of performing these cognitive functions.

From an evolutionary viewpoint it seems most likely that all modern humans, except those afflicted by brain damage or genetic developmental defects, are virtually the same with respect to n. 1.

The cognitive processing functions could, in principle, be studied with a single subject ($N = 1$). As for n. 2, it seems likely that the causal basis of reliable individual variation in the operations of these cognitive functions is attributable to other conditions, both genetic and non-genetic, which have quantitative effects on the speed and efficiency of the various forms of information processing made possible by the neural design features of the brain (n. 1). Discovering the physical basis of individual variation will probably be considerably easier than discovering the operating principles and neural circuitry involved in the many aspects of mental ability *per se*.

The first historical milestone in the psychometric understanding of variation in abilities was the development of a wide variety of single item-based tests for reliably assessing (i.e., ordinal ranking) individual differences on many phenotypically different cognitive abilities.

The second important milestone was the discovery that test scores on virtually all cognitive abilities are positively correlated with one another to various degrees, and that factor analysis reveals that a much smaller number of factors (latent variables) than the number of different tests can account for most of the reliable variance in all of the test scores. The factors display a hierarchical structure in terms of their generality (i.e., number of different tests in which they are substantially loaded). At the apex of the factor hierarchy is the single most general factor (g), which is common to all tests involving any type of information

processing (Carroll, 1993; Jensen, 1998). This factorial structure of abilities, called the "three-stratum theory" (Carroll, 1993), is now so thoroughly substantiated as to no longer be regarded as a subject worthy of serious controversy. Scientifically speaking, that is the end of the story as far as the conventional psychometrics of item-based tests is concerned.

The frontier of present-day research is aimed at discovering the physical basis of the factors or latent variables underlying test scores. The g factor, being the most highly loaded in all those types of tests generally considered to represent 'higher mental functions', is presently the main target of interest. The fact that psychometric g has a higher heritability coefficient than any other factor indicates that it is the most likely to have a physical basis. There are two main research designs on this front: Within-subjects and between-subjects.

Within-subjects (WS) research uses brain imaging technology to locate the areas of the cortex that are most highly activated while a person is taking highly g-loaded tests as contrasted with the level of activation while taking lesser g-loaded tests. An exemplary study using PET scan showed that activation evoked by the more g-loaded tests is quite specifically localized in the lateral frontal cortex (Duncan et al., 2000).

Between-subjects (BS) research looks for reliable correlations of individual differences in psychometric measures (particularly g) with various nonpsychometric variables – genetic, anatomical, or physiological. An exemplary study combining both the WS and BS methodologies used fMRI on groups of monozygotic and dizygotic twins. It showed that not only did psychometric g have high heritability, as indicated by the correlation within-twin pairs, but the volume of the most g-activated cortical areas (frontal gray matter) also showed substantial heritability.

Moreover, the volume of gray matter in the frontal lobes was significantly correlated ($r \sim .40$) with g (Thompson et al., 2001).

Jensen (1998) has used the "method of correlated vectors" (MCV) as a statistical tool to search for nonpsychometric and physical correlates of psychometric g that might afford a nexus of clues that, in combination, may point to the functional sources (not just the brain localization) of individual differences in g. The MCV consists of two steps: (1) obtaining by factor analysis the vector of g loadings of ten or more diverse

psychometric tests (e.g., the 11 subtests of the Wechsler scales), and (2) obtaining the vector of each test's correlation with some external (nonpsychometric) variable (e.g., head size).

A significant rank correlation between vectors 1 and 2 indicates a relationship between the external variable and *g*. The MCV has found such a relationship for a number of variables, including (with the typical vector correlations in parentheses): genetic heritability of test scores (0.70), assortative mating correlation between spouses test scores (0.95), inbreeding depression of test scores in offspring of cousin matings, heterosis – outbreeding elevation of test scores in the offspring of interracial mating (0.50), head size (0.65), habituation of the amplitude of brain evoked potentials (0.80), brain intracellular pH level (0.63), cortical glucose metabolic rate during mental activity (–0.79), and reaction time (RT) on various elementary cognitive tasks (–0.80) (Jensen, 2000).

The mean RT from a number of elementary cognitive tasks (ECTs) with RTs in the range of 200 to 2000 ms shows higher correlations with psychometric *g* than with any of the lower-order factors independent of *g*. Applying analytic techniques such as canonical correlation and structural equation models to study the relationship between psychometric and chronometric tests can separate the general factor of the two types of test batteries from their residual variance (i.e., all the

lower-order factors plus test specificity and measurement error), thus revealing that the general factor of a psychometric battery (*gp*) and the general factor of chronometric battery (*gc*) are virtually one and the same factor (*g*). Chronometrics is a far more suitable and powerful analytic tool for basic research on human mental ability than are conventional tests in which separate items are crudely scored pass/fail, however practical such ordinal-scale tests have proved to be in applied psychology (Jensen, in press).

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