



## Obituary

John Bissell Carroll (1916–2003): grandmaster of quantitative cognitive science.

John (“Jack”) B. Carroll was an impressively distinguished scientist of legendary intellect, erudition, and authority. He died of complications of diabetes and pancreatic cancer on July 1, 2003, at age 87, in Fairbanks, Alaska. His name and reputation, and his scientific contributions, will long be known in our field. A consistently productive researcher for over 60 years, his major contributions, especially those in the latter half of his career, are immensely germane to psychometrics and the taxonomy and correlational structure of human cognitive abilities. Although he probably was not as generally well known in the broad field of psychology as he deserves, because he typically worked at a highly technical level, wrote no undergraduate textbooks, and remained aloof from professional politics, he is truly famous and unreservedly admired among all advanced workers in his areas of endeavor.

Jack was born June 5, 1916, in Hartford, Connecticut, the son of an English father in the insurance business, whose given name was William James. A precocious child, Jack began piano lessons at the age of three and before long he played well enough to become the piano accompanist to an amateur quartet in which his father sang. Jack kept up his piano practice and evidently became quite good at it, being able to perform even Beethoven’s formidable *Emperor* concerto with a semiprofessional orchestra. He also composed some piano music. A story he told with some amusement was that while he was a student at the University of Minnesota, he presented the score of what he considered his best piano composition to the noted orchestra conductor and piano virtuoso Dmitri Mitropoulos (then the conductor of the Minneapolis Symphony), who immediately sat at his piano and played it, but complained that it was entirely too derivative of the style of Schumann to be taken seriously as an original composition. (The same criticism was made of Max Planck’s efforts as an aspiring composer, before he turned to physics.)

Jack graduated with highest honors from Wesleyan University in 1937, with a major in classics, including Sanskrit. (I’m struck here by the similarities in talents and proclivities between Jack Carroll and Cyril Burt: both became surprisingly good pianists, in university both majored in classics, both were incredibly encyclopedic, both were excellent and prolific writers, both had exceptionally distinguished careers in psychology spanning more than 60 years, and both made major contributions to psychometrics, factor analysis, and the theory of intelligence. But there the similarity ends; their personalities were notably different.)

As a teenager, Jack attended a lecture by Benjamin Lee Whorf on the relation of linguistics to cultural differences in the perception and conception of reality. Whorf was a student of Edward Sapir, the father of cultural and linguistic anthropology. Jack was strongly attracted to this field and became personally acquainted with Whorf, who later on encouraged Jack to study linguistics from the standpoint of psychology, as cultural anthropology at that time was not a widely developed field and offered few opportunities for a university position.

So Jack went to the University of Minnesota for graduate study in psychology. His major professor for his PhD research was nominally B.F. Skinner, a zealous Watsonian behaviorist who at that time was interested in verbal behavior strictly from a behaviorist's viewpoint. But Skinner actually had little influence on Jack's dissertation. It was perhaps an auspicious happenstance for Jack's subsequent career that Louis Leon Thurstone (1887–1955), then a professor at the University of Chicago, came to the University of Minnesota as a visiting lecturer. His presentation of factor analysis immediately captured Jack's interest, who saw it as an objective method for studying the taxonomy of language abilities. Skinner, however, had no interest in Thurstone's analytic methods, which focused on latent traits rather than directly observed and experimentally manipulable behavior, so Thurstone himself agreed to become Jack's de facto dissertation advisor. This contact with Thurstone was undoubtedly a crucial influence in Jack's career. His dissertation was a factor analytic study of verbal abilities (published in *Psychometrika*, 1941). Jack was highly impressed by Thurstone personally and also by the potential of factor analysis as a general tool for the study of individual differences. Under the tutelage of Thurstone, then America's foremost quantitative psychologist and the leading expert in factor analysis, Jack became one of the leading experts himself and went on to make original methodological contributions to its mathematical development, including a strictly objective analytic method for approximating the ideal of Thurstone's theoretical criterion for "simple structure" by means of orthogonal (or oblique) rotation of the factor axes. Probably because it was mathematically more complex and, in 1960, not easily computerized, it never gained the same popularity of use (and *overuse*) as the more elegant conceptual simplicity of H.F. Kaiser's computerized procedure known as *varimax* rotation. It is interesting to note the chief difference between Jack Carroll and Henry Kaiser as top-notch factor analysts. Jack's main focus of interest was like that of the famous pioneers of this method (Spearman, Burt, and Thurstone), who invented and developed factor analysis to deal empirically with substantive problems in differential psychology, whereas Henry Kaiser was a pure methodologist in the mathematics of factor analysis (in which he had few if any contemporary peers); his only interest in real psychometric data was simply to illustrate strictly theoretical and mathematical points. In applied factor analysis, however, it is hard to think of anyone, past or present, who used it more extensively or more wisely and effectively to solve important substantive problems in psychometrics than did Jack Carroll. His stature in this respect, generally acknowledged among his contemporaries, is reminiscent of an anecdote about the famous composer Giacomo Puccini when he was asked his opinion of Wagner. Puccini said, "Compared to Wagner, the rest of us opera composers are just a bunch of second-rate guitar pickers."

The same year that he received his PhD, 1941, Jack married Mary Searle, his wife for 61 years; they had one child, a daughter. Then a 4-year period of teaching in the psychology departments of Mt. Holyoke College and later at Indiana University was interrupted by World War II, during which he served in the U.S. Naval Reserve as a research aviation psychologist and then as a U.S. Army personnel research psychologist at the Pentagon in Washington, DC.

In 1949, Jack joined the faculty of the Graduate School of Education at Harvard University, quickly advancing from assistant professor to Roy E. Larson Professor of Educational Psychology, a position he held until 1966. During this period the psychology of language dominated his research interests and produced many articles and books long esteemed by students of psycholinguistics, such as his influential *The Study of Language: A Survey of Linguistic and Related Disciplines in America* (1953). He also developed a number of foreign language aptitude tests, the Modern Language Aptitude Test being the most widely used in schools and government agencies. The most salient characteristic of Jack's research style in the language field was his keen ability to objectify and quantify psycholinguistic phenomena that

previously were dealt with only subjectively, descriptively, or anecdotally. His study of individual differences in pitch discrimination and absolute pitch was definitive, as were his studies of the distribution of word frequencies in the language and their close relation to their differing response latencies in verbal recall.

It was probably to capitalize on Jack's exceptional talent for quantification, analysis, and systematizing that the Educational Testing Service in Princeton lured Jack away from his distinguished professorship at Harvard to join its psychometric research division in 1966, where he worked until 1974. It was during this period that Jack introduced the psychometrically reductive idea of *elementary cognitive tasks* (ECTS) as an approach to objectifying and quantifying the measurement of the fundamental processes involved in variation in human cognitive abilities. He later on developed an elaborate systematic, albeit theoretical and tentative, taxonomy of ECTs. The use of ECTs has since become a major feature of research on cognitive abilities. The dependent variable is typically a measure of response time (RT) to these very simple, clearly defined ECTs, each one designed to reflect the one or very few hypothetical cognitive processes essential for performing the task. However, Jack did not carry out empirical studies of ECTs of research during his 8 years at ETS, which apparently showed little interest in it at the time. His major monograph on the subject did not appear until after he left ETS.

After his professorship at the University of Chicago, Thurstone spent the last 3 years of his life (1952–1955) doing research at the Psychometric Laboratory in the University of North Carolina at Chapel Hill. After his death, the Lab was named the L.L. Thurstone Psychometric Laboratory. It seemed most fitting that the University of North Carolina, in 1974, recruited Jack Carroll for both a distinguished professorship in psychology and as Director of the Thurstone Psychometric Laboratory, a position he held until his official retirement in 1982, although he remained active in the Lab until the death of his wife in 2001, when he moved to Fairbanks, Alaska, to live with his daughter and son-in-law. His years at the Thurstone Lab were the most importantly productive for his contributions to the psychometric study of intelligence, and culminated in his magnum opus, which I will mention later on. His other books and journal publications total nearly 500 titles contributed over a period of 60 years.

Jack served as a referee for many linguistic and psychological journals and was a member of the editorial board of *Intelligence* since 1981. Although he was a hard critic, he was always so objective, fair, helpful, and technically correct that it was a real privilege to have one's article critiqued by him. In this role, he perfectly personified the meaning of competence.

Many honors and awards were bestowed on Jack, including the Edward L. Thorndike Award (APA, 1970), the Diamond Jubilee Medal of the Institute of Linguistics (London, 1971), The Educational Testing Service award for Distinguished Service to Measurement (1980), an honorary Doctor of Science degree from the University of Minnesota (1986), the Charles Spearman Lecture given at the first Spearman Seminar (University of Plymouth, England, 1993), and the American Psychological Foundation's Life Achievement Gold Medal (2002). He was also elected President of the Psychometric Society (1960) and the APA's Division of Educational Psychology (1966).

Jack Carroll's crowning achievement, *Human Cognitive Abilities: A Survey of Factor Analytic Studies* (1993), is a truly monumental work. It was a fulfillment of something that most of us would agree needed to be done, but it seemed too vast an undertaking to imagine how it could ever be done effectively and adequately. If there was ever anything a team or committee or any multiauthored effort could never accomplish, it was this work that Jack took on himself. If such an undertaking could even have been imagined before it was actually done, and if anyone had asked me who could possibly do it, Jack Carroll would be the first and the only name that would have come to mind. Fortunately, he did do

it. It took him 12 years of postretirement labor, between ages 65 and 77 to complete this Herculean feat, although during the same period he kept up nearly his usual pace of writing journal articles and contributed chapters to many edited books. On my first reading this tome, in 1993, I was reminded of the conductor Hans von Bülow's exclamation on first reading the full orchestral score of Wagner's *Die Meistersinger*, "It's impossible, but there it is!"

Jack's aim was to summarize the most defensible conclusions warranted from a synthesis of all of the correlational and factor analytic studies that had ever been done on individual differences in measurable cognitive abilities of any kind, regardless of the original authors' conclusions. This required assembling every correlation matrix of cognitive abilities that could be found anywhere—in published articles, dissertations, archives—as far back as the existence of the correlation coefficient itself, invented by Karl Pearson in 1896. In some cases, Carroll had to request the correlations or all the original data from those researchers who published factor analytic results without reporting their underpinnings. His virtually exhaustive search turned up 461 data sets that could meet the statistical and methodological requirements for a proper factor analysis. First of all, he had to apply a single set of strict criteria for adequacy of the data sets and a consistent method of factor analysis. The stringent rules for the factoring procedures are spelled out in his 1993 book and can serve as an excellent example for conducting an exploratory factor analysis. But that was only the beginning. The main job was the multiple cross-comparisons of the factors and factor loadings of specific cognitive tests and various types of tests in numerous studies. Of course, the jangle fallacy guarantees much factor redundancy among the many hundreds of tests involved. So it was a matter of finding those factors that are true latent variables in the sense that they appear with reliable consistency across a number of diverse data sets, and discarding supposed factors that are really just specifics that fail to reflect a latent variable common to any other data sets. The problem was to discover all of the nonredundant, or independent, latent traits, or orthogonal dimensions, that could account for the most variance in all of the many tests and their intercorrelations, an outcome generally described as representing the correlational *structure* of individual differences in mental abilities in terms of an empirically determined number of orthogonal (independent or uncorrelated) factors.

A most critical decision for the whole project was the choice of a single-factor model by which to analyze all of the selected test batteries, as there are many possibilities in current use. Studies have shown that the various appropriate methods of factor analysis actually make very little difference to the identification of the general factor, or Spearman's *g*. But Carroll also wished to reliably identify in his data sets all of the true subordinate group factors independent of *g*. With this purpose in mind he made a wise choice in selecting the Schmid–Leiman orthogonalized hierarchical factor model. It insures perfect orthogonality among all the factors; it is less affected than most other methods by unequal numbers of tests of a certain type contributing more than their share to the higher-order factors; and it is a more severe barrier to the contamination of high-order group factors by lower-order specifics.

Jack referred to the final result of his analysis as the *Three-Stratum Theory of Cognitive Abilities*. Each stratum represents factors with different levels of generality in terms of the number and diversity of the particular cognitive tests they dominate. At the lowest level of generality is the *first stratum*, represented by some 40 narrow first-order factors. The factor analysis of these first-order factors residualizes their common factors up to the *second stratum*, which is represented by eight second-order factors. The factor analysis and residualization of their common variance constitutes the *third stratum*, the single, most general factor, *g*, at the apex of the factor hierarchy. Thus, Carroll's analysis identifies some 50 independent factors of cognitive abilities at different levels of generality.

It should be noted that this is an open-ended empirical theory to which future tests of as yet unmeasured or unknown abilities could possibly result in additional factors at one or more levels in Carroll's hierarchy. In fact, in what is probably his last article (published in July 2003), we see that Carroll was still working on his three-stratum model, incorporating new data in his analysis to deal with a disputed aspect of his 1993 discussion of Cattell's concept of fluid intelligence, *Gf*, particularly the claimed disappearance of *Gf* as a second-order factor, when it is residualized into the third-order *g* factor—in other words, the claim that Cattell's *Gf* and Spearman's *g* are both just one and the same factor. Carroll's final analysis identifies a very tenuous residualized *Gf* even in a test battery (Woodcock–Johnson III) expressly constructed to measure *Gf* in addition to *Gc* (crystallized intelligence) and several other second-order factors. Carroll concluded “. . . more and better tests of factor *Gf* are needed to establish this factor as linearly independent of factor *g*, if indeed this is possible. . . .” On a more general note, Carroll reminds us that factors are latent traits and do not necessarily reflect the observed phenomenal properties of the tests that are loaded on them. A fundamental principle on which factor analysis is based, he points out, is that “the nature of a single factor discovered to account for a table of intercorrelations does not necessarily relate to special characteristics of the variables involved in the correlation matrix: it relates only to characteristics or underlying measurements (latent variables) that are common to those variables.”

Carroll's magnum opus thus distills and synthesizes the results of a century of factor analyses of mental tests. It is virtually the grand finale of the era of psychometric *description and taxonomy* of human cognitive abilities. It is unlikely that his monumental feat will ever be attempted again by anyone, or that it could be much improved on. It will long be the key reference point and a solid foundation for the *explanatory* era of differential psychology that we now see burgeoning in genetics and the brain sciences.

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