CHAPTER 4

Individual Differences in Mental Ability

Arthur R. Jensen

One of the most obvious "facts of life" to all teachers, at every level of education, is the phenomenon of individual differences—in mental abilities, special talents, and traits of personality. Especially salient are those characteristics of pupils that are the most clearly related to the success of teachers' efforts to impart knowledge and intellectual skills. The most prominent of such characteristics is general mental ability, or intelligence. Consequently, the study of individual differences, especially differences in intelligence, has been one of four major themes of educational psychology (along with development, learning, and measurement) ever since this field was formally recognized as a branch of psychology. The ideal of universal education, which first gained impetus and implementation in America, literally forced educators' practical and humane concern with the problem of making formal schooling a successful and rewarding experience for the whole school-age population, which ranges widely in mental abilities and other characteristics that are importantly related to scholastic performance.

This chapter centers its focus on the history of attempts to understand only one of these differential variables—intelligence. The concept of intelligence has a longer, more complex, and much more controversial history than is found for any other theme within the whole purview of educational psychology. The history of the concept of intelligence therefore merits a whole chapter in its own right. Indeed, a large book could well be devoted to the topic. Other dimensions of individual differences are relatively latecomers to educational research, and their importance, in terms of their relative contribution to variance in scholastic performance, is minor in comparison with the role of individual differences in intelligence. Moreover, the basic concepts and methodology of measurement and research developed in connection with the study of intelligence have considerable generality, because they have been applied as well to the investigation of other educationally relevant traits, particularly in the domains of personality and motivation.

Few psychological phenomena, however, are as highly relevant to education as individual differences in mental ability. Probably because of the practical consequences of individual differences for scholastic performance and all of its occupational, economic, and social correlates, this subject has had perhaps the most tumultuously controversial history of any topic in psychology and education.

There is really no argument about the prominence or importance of the topic itself. The argu-

Arthur R. Jensen • School of Education, University of California, Berkeley, CA 94720.

ments today involve quite different issues. In the past half-century, millions of school children in America and the Western world have been given tests called "IQ" tests, "intelligence" tests, "scholastic aptitude" tests, and the like. (Quotation marks seem advisable early in this discussion, first, to indicate loosely defined popular terms, as contrasted with precisely defined technical terms, and second, to warn against the risk of improper reification of terms that represent abstract concepts.)

Whatever these tests "measure," which we will let remain an open question for the time being, two things are now definitely known beyond dispute: (a) The majority of such tests (labeled "IQ," "intelligence," or "general aptitude") all measure pretty much the same source of variance as indicated by high correlations among scores on such tests; correlations typically fall in the range of .70 to .90, averaging close to .80. (b) No other single item of information that we can obtain about children is as highly correlated with assessments of scholastic performance as the children's scores on these tests. No other kind of information concerning children's background is as highly predictive—not the socioeconomic status of the children's parents, or the parents' education, or occupation, or race, or the national origin of children's ancestry, or their gender. Children's scores on "IQ" tests account for more of the total variance (i.e., individual differences) in overall scholastic achievement than all of these background variables combined, independent of IQ. This appears to be true in every country, for every type of educational system, and for every method of instruction yet devised. No attempts, by means of varied instructional techniques, to completely overcome the correlation between individual differences in scholastic performance and scores on "IQ" tests, when a fully representative sample of the school-age population is considered, have come anywhere near success. The fact that this is so is scarcely disputed today. But *why* this is so and what it means have long been, and still are, questions of intensive inquiry and heated debate in educational psychology.

Through it all, the use of numerous tests of "mental abilities" has become widely entrenched in education, in connection with "streaming" or "tracking" pupils, for placement in special classes, for individual diagnosis of learning problems, for vocational counseling, and for selection for higher education. The lives of countless persons have undoubtedly been affected to some degree by "mental tests." Just what do such tests actually "measure" that would seem to justify such widespread use?

Similar tests, often called "aptitude" tests, are also now commonly used with adults outside the school setting, in screening job applicants for industry, and for selection and allocation to various training programs in the armed services. The tests commonly used for these purposes have also been shown, through correlation analysis, to measure much the same individual differences as are measured by the IQ tests administered in schools. There is no longer any question that such tests possess some practical validity for predicting job performance and success in training programs. The persisting question is why such tests have predictive validity for so many practical, real-life criteria.

The fundamental question implied here, we know, has existed long before mental tests were ever invented. Stated bluntly in laymen's terms, it is the simple question: Why are some people smarter than others? Many other questions that need to be answered naturally spring from this single question, which many persons have viewed as the Pandora's box of psychology. Yet for more than a century, it has remained, and continues to remain, a central question in that branch of psychology now known as differential psychology, or the scientific study of individual and group differences in psychological traits. The current status of research, theories, and controversies on this topic is highly complex and perhaps even perplexing to newcomers to this field. It seems likely that the present scene can be more clearly understood when viewed in historical perspective. The history of thought about the nature of individual differences in human abilities should essentially enlighten the question, how did we arrive at our present state of knowledge and theory on this topic? A historical overview might also suggest the most promising avenues for future research. It is the writer's belief that the modern era of research in this field has been evincing lively progress toward addressing, with advanced statistical and laboratory methods, a number of the key questions that have come down from the past. It seems unlikely that a historical survey of the thinkers and their theories and researches that have led up to the present state of the field could justify the wiseacre's definition of history as "a chronology of events that never should have happened."

The Prescientific Era

The concept of mental ability, as we conceive of it today, is of surprisingly recent origin in the history of human thought. There is little evidence of association between the concept of *mind* and the concept of *ability* in the literature of theology and philosophy prior to the latter half of the 19th century. It is the ability aspect of mental ability that was so delayed in making its appearance. The notion of individual differences in mental ability is even more scarce in philosophical thought prior to the nineteenth century. The leading theologians, philosophers, and political and social thinkers before that time apparently did not concern themselves with the subject of individual differences in mental abilities.

Yet it seems almost impossible to imagine that since the dawn of history people have not noticed differences among their fellows in characteristics that today we would think of as constituting mental ability. Indeed, the concept of individual differences, although not of concern to early philosophers, is evident in literature throughout history. Characters have been described in literature by a variety of adjectives, such as clever, keen-witted, and discerning, or dull-witted, addled, and stupid; also, geniuses and feebleminded persons have figured in literature for centuries. There seems little doubt that individual differences in mental traits have always been recognized. Why then, we must wonder, did it take so long for such an evidently well recognized human phenomenon as individual differences in mental traits to become a subject for systematic thought by the leading thinkers in history before about 1850?

Even after psychology became a formal discipline, with its own textbooks and dictionaries of specialized terminology, the ideas of mental ability and individual differences were slow to enter. The first prominent American psychologist, William James (1842–1910), at Harvard University, published his famous textbook *The Principles of Psychology* in 1890, yet it makes only three brief and scattered mentions of "intelligence," but only in the philosophic sense of "intellect" or "reason," and James never makes any reference to individual differences. One will search in vain for any mention of intelligence or individual differences of any kind in William James's later *Talks to Teachers* (1899). James wrote extensively on such topics as perception, association, emotion, will, habit, and the "stream-of-thought," but there is no evidence that he ever entertained any notion of individual differences in abilities. At that time, the subject of individual differences was evidently not considered within the purview of formal psychology. Another comprehensive text of that period, *Handbook of Psychology* (1890) by James Mark Baldwin (1861–1934) contains two pages on "intellect" and nothing at all about individual differences. Baldwin's encyclopedic *Dictionary of Philosophy and Psychology* (1901) does not accord the word *intelligence* a separate entry, but refers to it merely as a synonym of *intellect*. To understand this surprisingly late entry of the concepts of mental ability and individual differences into psychology, we must look back to the earliest recorded beginnings of psychological thought.[1]

Origins of Psychology

The great philosopher Plato (427–347 B.C.) is credited as the first thinker to distinguish (in *The Republic*) three parts or aspects of the human soul, corresponding, in modern terms, to intellect, emotion, and will, or the cognitive, affective, and conative aspects of the human psyche. Dualism, or the distinct separation of mind and body, as a formal philosophic doctrine in Western thought, probably originated with Plato. Intellect, or reason, was regarded as an attribute of the perfect or divine soul, not of the physical person or the person's observable behavior. Therefore, the soul was thought to remain untouched by the existence of individual differences that were manifested in man's overt behavior. Mind, reason, thought, and intellect—all more or less synonymous concepts in Plato's thinking—were seen as part of the immaterial soul, or *nous*, as Plato called it. The soul, according to Plato, transcends mundane activity and distinguishes man from the lower animals. Thus it was viewed as a universal quality incompatible with the notion of individual differences. In Plato's day, philosophers were mainly concerend with the essences that distinguish humans from animals, rather than distinctions between individual humans. Physical distinctions were recognized, of course, as were differences in moral character. In *The Republic*, Plato clearly recognized psychological differences in classifying people into three

[1]Besides the sources specifically cited, material on the early history of the concepts of mind and intellect were obtained mainly from the following: Boring (1950), Burt (1955), Guilford (1967), Matarazzo (1974), Peterson (1925), Stoddard (1943), Watson (1963).

types. Plato likened these types, in terms of their rarity, to gold, silver, and brass, and held that the ideal society would assign people to occupations on the basis of this classification. The three main divisions were first the philosophers, who would govern; then the warriors; and lastly, the artisans. But the basis for such a classification of people was not made clear, nor were the means of achieving it. But Plato's idea is probably the first major expression of opinion regarding the recognition of individual differences as being related to a society's general welfare.

Plato is also credited as the first thinker to suggest a hierarchical structure of mental functions—an idea that comes down to the present day. He regarded reason, or intellect, as the highest aspect of the soul, which ideally dominated the lower functions of emotion and drive. In *Phaedrus,* he depicts intellect as the charioteer who holds the reins, the emotion and drive are likened to the team of horses that draw the vehicle. The charioteer is the *cybernetic* element, the horses the *dynamic* element. Here already we can see some of the basic ingredients of modern psychology.

Plato's illustrious student, Aristotle (384–323 B.C.), was really the first formal psychologist, in that he wrote the first books on the subject, *De Anima, De Sensu et Sensili, De Memoria et Reminiscentia,* and *On Psyche*. Aristotle clearly distinguished various psychological functions, such as sensation, reaction, desire, memory (recognition and recall), knowing, and thinking. Unlike Plato, Aristotle recognized thinking as directly dependent upon what he regarded as the lower processes of sensation and memory. Thought was viewed as deliberation preceding action. Aristotle might also be regarded as the first cognitive theorist. He constrasted actual activity with the hypothetical capacity or mental activity on which it depends; this is the first introduction of the concept of ability as a latent trait, distinct from its behavioral expression.

Aristotle reduced Plato's threefold classification of the soul to only two broad divisions, which he termed *dianoetic* (cognitive functions) and *oerectic* (emotional and moral functions). It was the Roman author, orator, and statesman, Cicero (106–43 B.C.), who, in translating Aristotle's Greek terminology, coined the almost exact equivalent of "dianoetic" in Latin as *intelligentia*—hence the origin of the word *intelligence.* But neither Aristotle nor other ancient Greek philosophers said anything about individual differences in the various psychological qualities that they propounded. Besides the fact that these qualities were thought of largely as qualities of the soul and hence were exempt from human frailty, the social systems of the ancient and medieval world, consisting of aristocracies and serfdoms, probably afforded little scope for the salience of individual differences in abilities. A person's occupation and station in society were determined by the circumstances of his birth. Formal education was the privilege of only an elect few, and the great inequality of opportunities for education and vocational choice could largely obscure the perception of human differences as representing characteristics that are intrinsic to individuals.

Indeed, the first clear statement concerning individual differences in mental abilities came some years following the heyday of Greek philosophy, from the Roman philosopher, Quintillian (A.D. 35–95), who might well be called the first real educational psychologist. He wrote the following advice to teachers, which would not look out of place in a modern textbook of educational psychology.

> It is generally, and not without reason, regarded as an excellent quality in a master to observe accurately differences of ability in those whom he has undertaken to instruct, and to ascertain in what direction the nature of each particularly inclines him; for there is in talent an incredible variety, and the forms of mind are not less varied than those of bodies. (As quoted in Stoddard, 1943, p. 79)

It would be a long time, however, before anyone else systematically considered the subject of individual differences in mental abilities. (*Mental* means simply that individual differences are not mainly due to differences in sensory or motor capabilities *per se.*) The mind–body dualism propounded by the early Greek philosophers, and the idea of mind as a spiritual essence or soul independent of physical or organic cause, was elevated and perpetuated by the Christian scholastics. Most prominent among them was the Catholic theologian Thomas Aquinas (1225–1274), who followed Aristotle in subdividing the functions of mind. The first division was between the intellectual and the appetitive functions. The intellectual function was further subdivided into sensation, perception, memory and reproductive imagination, and reasoning and creative imagination. This structure of the mind, with minor variations, persisted in philosophical writings down to the 19th century. But throughout this period, these categories of mind remained philosophic abstractions without being viewed in relation to human differences in their individual manifestations. That conceptual leap would have to await a major revolution in human thought, namely, a fully biological conception of the human species, and of human behavior, as fundamentally continuous with the rest of the animal kingdom, as a product of organic evolution rather than of special creation.

Among early philosophers, John Locke (1632–1704) has had a lasting influence on this field through his most famous work, the *Essay Concerning Human Understanding* (1690). Essentially, Locke brought mind closer to naturalistic explanation. He opposed the notion of innate ideas and viewed the human mind at birth as a blank tablet, or *tabula rasa,* which is gradually filled with impressions through the avenues of the special senses. All knowledge, Locke claimed, comes from only two sources, *sensation* and *reflection,* or "the association of ideas." He wrote,

> Let us suppose the mind to be, as we say, white paper, void of all characters, without any ideas; How comes it to be furnished? Whence comes it by that vast store, which the busy and boundless fancy of man has painted on it with an almost endless variety? Whence has it all the materials of reason and knowledge? To this I answer, in one word, from *experience.* In that all our knowledge is founded, and from that it ultimately derives itself. (Quoted by Boring, 1950, p. 172)

Thus the line was clearly drawn between *nativism,* or the idea that the mind comes equipped with certain built-in qualities, and *empiricism,* according to which the properties of the mind are wholly attributable to individual experience. Although there is nothing explicit in this empiricist philosophy concerning intelligence and individual differences, the implications of Locke's *tabula rasa* conception were that both intelligence and human differences therein must arise entirely from differences in people's experiences—an idea that has come down to the present day in the research and controversy concerning the relative effects of "nature" and "nurture" (or heredity and environment) on mental abilities and other psychological characteristics.

The British philosopher Herbert Spencer (1820–1903) was the immediate precursor of the scientific era in the study of intelligence and individual differences. He was a Lamarkian evolutionist, who propounded his own pre-Darwinian ideas about evolution. After the publication of Darwin's *Origin of Species* (1858), Spencer was converted from Lamarkism to the theory of natural selection, and he became the leading philosopher of the Darwinian revolution. Because Spencer was never himself an empirical scientist, we must assign him to the prescientific era as regards his contributions to psychology. However, his textbook, *The Principles of Psychology* (1855), was the first psychology book to resurrect the term *intelligence* and to pay specific attention to individual differences. Spencer viewed human intelligence as a unitary trait that emerged through the differentiation of adaptive functions in the course of biological evolution. Later, with the publication of Darwin's theory of natural selection as the explanation of evolution and the "survival of the fittest" as its principal mechanism of evolution, Spencer perceived the biological significance of individual differences as the essential raw material on which evolution depends. Spencer's extension of this line of thought to the human social conditions of his time has been termed "Social Darwinism," often in a pejorative context. However, Spencer's idea of intelligence as a biologically adaptive function for achieving the "adjustment of internal to external relations" is a progenitor of the detailed modern efforts to understand both animal and human intelligence in an evolutionary perspective, as seen, for example, in Harry Jerison's chapter, "The Evolution of Biological Intelligence" in the recent *Handbook of Human Intelligence* (Sternberg, 1982). The concept of the *phylogeny* of intelligence, the idea that intelligence increases progressively throughout the phylogenic scale of the animal kingdom, is also attributable to Spencer. His view of the *ontogeny,* or individual development, of intelligence in humans, from birth to maturity, is that it has three main aspects, (a) an increase in the accuracy of inner adjustments to outer demands, (b) an increase in the number of items of simple knowledge, and (c) an increase in the complexity of consciousness of the external environment. The idea of accuracy of perceptions was likely a precursor of Francis Galton's (1822–1911) emphasis on sensory discrimination as a measure of intelligence, and the ideas of number and complexity were much later relabeled and empirically researched by Edward L. Thorndike (1874–1949) as breadth and altitude of intellect (Thorndike, Bregman, Cobb, & Woodyard, 1927). But it was actually Spencer, rather than Galton, who is so often credited (or blamed) for the concept of intelligence as a unitary or general ability. As Guilford (1954) has put it, "The conception of intelligence as a unitary entity was a gift to psychology from biology through the instrumentality of Herbert Spencer'' (p. 471). This unitary conception of intelligence was destined for a turbulent history. It is still a pivotal theoretical issue in contemporary psychology.

The Scientific Era

The scientific era in the study of individual differences is marked by the advent of objective measurement and the quantitative treatment of data. Systematic, objective observation and some form of measurement are partly what distinguish empirical psychology from speculative philosophy. Although measurement does not guarantee the advancement of a science, without measurement a science seldom advances beyond a rudimentary or purely descriptive and taxonomic stage. The idea of the measurement of mental attributes was particularly crucial for the development of the psychology of individual differences.

The first actual measurement of any kind of psychological individual differences was performed not by a philosopher or a psychologist, but by a German astronomer, F. W. Bessel (1784–1846), in 1822. He was fascinated by the discovery, made in 1795 at the Greenwich Observatory, that individual astronomers differed systematically in the exact time at which they recorded the transit of a star across a hairline in the field of a telescope. Telescopic observers could not voluntarily correct their errors of observation in order to bring their time measurements into perfect agreement. Bessel systematically investigated this phenomenon, estimating differences in visual reaction times between individuals in milliseconds. He discovered reliable individual differences in reaction time, to which he gave the name *personal equation,* which could be used to correct the astronomical observations of different individuals, thereby improving the accuracy of measurement. Bessel discovered not only that individuals differed reliably in reaction time, but that there was considerable variability among a number of reactions by the same individual, hence the distinction between *inter*individual and *intra*individual variability. The temporal constancy or accuracy of the personal equation (i.e., interindividual differences in reaction time) was seriously limited by the fact that an individual's reaction time varies from one occasion to another. To read through this intraindividual variability and discern consistent differences between individuals required averaging a large number of reaction time measurements obtained from each individual. Students of psychometrics will immediately recognize that the basic concepts of classical test theory, such as true score and error components, are latent, if not actually explicit, in this early research on reaction time.

The chronographs and chronoscopes invented by astronomers for the precise measurement of reaction time were soon adopted by physiologists, and shortly thereafter, in the 1880s, they became standard apparatus in the first psychological laboratory, established in 1879 in Leipzig by Wilhelm Wundt (1832–1920). In adopting the reaction time technique that astronomers specifically developed for studying individual differences, however, experimental psychologists failed to adopt also the astronomers' primary interest in individual differences. The primary aim of experimental psychology was to discover general laws of mental functioning; individual differences were regarded merely as error, noise, or nuisance variance in this endeavor, to be minimized as much as possible through experimental control, careful selection of subjects, and the refinement of procedures. Reaction time became an important technique for the objective measurement and analysis of reflexes, attention, sensory discrimination, choice decision making, association, and recall memory. This line of research has come down through a spotty history to modern times, where, known as mental chronometry, it has taken on new life as the chief methodology of experimental cognitive psychology (e.g., Posner, 1978).

Reaction time has also figured in the study of individual differences in mental abilities, but through a quite different tradition of scientific psychology, instigated mainly by Sir Francis Galton in the 1860s. The work of Galton marks the real beginning of scientific research on individual differences, that is, the fields of differential psychology and psychometrics.[2]

In what is probably the most frequently cited presidential address by any president of the American Psychological Association, Lee Cronbach (1957) in ''The Two Disciplines of Scientific Psychology,'' deplored the theoretical and methodological gulf that, throughout the history of psychology, has separated experimental psychology, on the one hand, and differential psychology and psychometrics, on the other. The founding fathers of these two branches were Wundt, in Germany,

[2]Burt (1962) provides the most useful source on Galton's contributions to psychology.

and Galton, in England. Until recent years, these two lines have shown only occasional and casual interaction. The one subject on which the "two disciplines of scientific psychology" have finally become focused in a fruitful merger, only within the last decade, is the study of human intelligence. But the threads of this development really go back to Galton in the latter half of the 19th century.

Sir Francis Galton

Galton was born the same year as Gregor Mendel (1822–1884), the father of modern genetics, and he died the same year as Alfred Binet (1857–1911), the inventor of the first practical test of intelligence. Interestingly, Galton was the first investigator of the genetics of intelligence and the first to attempt the objective measurement of abilities.

Galton was born into a wealthy English family. A half-cousin of Charles Darwin (1809–1882), they both were grandsons of the philosopher, physiologist, and poet, Erasmus Darwin (1731–1802). Galton was a prodigy who could read and write by the age of three. After attending medical school and earning a degree in mathematics at Cambridge University at 21, he fell heir to a family fortune that allowed him freely to pursue his extremely wide and varied scientific interests for the rest of his long life, without need to earn a living. He used his fortune to travel, to finance his research, to found journals (*Biometrika* and *Annals of Human Genetics,* which are still in existence today), to endow a chair in genetics (occupied by such luminaries as Karl Pearson and Sir Ronald Fisher) and the famous Galton Laboratory at the University of London. He also founded the Eugenics Society, which still exists.

Galton was one of the greatest scientific dilettantes of all time. Because he was also a genius, he made original contributions to a variety of fields: exploration and geography (of Africa), meteorology, photography, fingerprint classification, genetics, statistics, anthropometry, and psychometry. His prolific achievements and publications brought him worldwide recognition and many honors, including knighthood, Fellow of the Royal Society, and several gold medals awarded by various scientific societies in England and Europe.[3]

[3]The chief sources on the life of Galton are Galton's *Memoirs* (1908), Pearson's (1914–1930) three-volume biography, and a modern biography, containing also a complete bibliography of Galton's publications, by Forrest (1974).

What is Galton's legacy to the psychology of individual differences? Above all, he vigorously promoted the idea of objective measurement and quantitative analysis of data, whether by mere counting, or by ranking, or by true measurement. His favorite motto was, "When you can, count." He acted accordingly, some would say, to an almost eccentric extreme. He applied this predilection for quantification mainly to the study of human variation in just about every physical and mental characteristic that was within his power to count, rank, or measure. Unlike Wundt, the father of experimental psychology, who saw individual differences as a nuisance to be overcome in the search for general laws, Galton regarded human variation as of paramount importance and as perhaps the most interesting of all phenomena for scientific study in its own right. Hence the "two disciplines of scientific psychology," stemming respectively from Wundt and Galton.

As a result of Galton's pursuit, he was led to invent a number of the statistical and psychometric concepts and methods familiar to all present-day researchers, including the bivariate scatter diagram, regression and correlation, multiple correlation, percentile ranks, standardized or scale-free scores, rating scales, the use of the normal, or Gaussian, distribution as a basis for the interval scaling of traits, and the use of the median and geometric mean as measures of central tendency. But the details of these contributions more properly belong in the history of measurement and statistics *per se.*

Galton's main substantive contributions, which depended heavily on his quantitative inventions, are found essentially in two works: *Hereditary Genius: An Inquiry into Its Laws and Consequences* (1869), his most famous and most influential work, and *Inquiries into Human Faculty and Its Development* (1883). The second work is of interest from our standpoint for its descriptions of the odd assortment of "tests" Galton invented for measuring human capacities. Successful or not, they were the very first objective "mental" tests. Like every scientific innovator, Galton was also a product of his time. This is reflected in his choice of "tests." The prevailing doctrine at the time was *faculty psychology,* which traces back to the ancient Greek philosophers, who conceived of the mind as consisting of a number of distinct and separate powers or faculties, such as sensation, discrimination, perception, memory, and reason. And the chief techniques of experimental psychology at the time were the so-called brass instrument apparatuses of Wundt's laboratory, gadgets for measuring various types of sensory discrimination and speed of reactions. In keeping with the psychology of his time, Galton believed that because all the contents of intellect must come through the sense organs, the capacity for fineness of sensory discrimination was one of the two main aspects of mental ability; the other, because of its supposed adaptive evolutionary significance, was sheer speed of reaction to an external stimulus. In *Human Faculty* (1883), he argued,

> The only information that reaches us concerning outward events appears to pass through the avenue of our senses; and the more perceptive the senses are of difference, the larger is the field upon which our judgment and intelligence can act. (p. 19)

Hence, Galton's battery of tests consisted mostly of devices for measuring auditory, visual, and kinesthetic discrimination, short-term memory span, as well as simple reaction time to visual and auditory stimuli. These various tests, along with a number of physical measurements, were obtained during the brief period between about 1884 and 1890, on more than 9000 individuals, who paid threepence apiece to be run through all the tests in Galton's "Anthropometric Laboratory" in the South Kensington Science Museum. Galton expressed his notion of the aim of such tests as follows:

> One of the most important objects of measurement . . . is to obtain a general knowledge of the capacities of a man by sinking shafts, as it were, at a few critical points. In order to ascertain the best points for the purpose, the sets of measures should be compared with an independent estimate of the man's powers. We thus may learn which of the measures are the most instructive. (Quoted in Anastasi, 1965, p. 25)

Galton's idea was quite sound, and presages the modern psychometric concept of external validity.

Unfortunately, however, Galton's particular collection of tests of sensory discrimination and reaction time did not prove to be very fruitful in his own day. Such simple tests could often distinguish the mentally deficient, but differences among persons of normal and superior intelligence, as judged by educational and occupational attainments, were generally so slight and seemingly unreliable as to afford scarcely any evidence for the claim that they measured intelligence. At least so it seemed at the time. Mere visual inspection of the data yields an unpromising picture. Reliability theory had not yet been conceived, and modern analyses of Galton's data reveal exceedingly low reliability of many of his tests. The reaction time tests, for example, were based on only a few trials and therefore yielded measurements with an average reliability of only 0.18 in the total sample. Tests with such low reliability could hardly show impressive correlations with any criterion, and mean differences between different age groups and occupational categories look unimpressive to casual inspection. Unfortunately, multiple regression analysis and statistical tests of significance had not yet been invented. When, in recent years, modern statistical analyses have been applied to Galton's old data, there were found to be highly significant mean differences by age group and by five occupational categories (ranging from professional to unskilled) on many of Galton's measurements.[4] Still, Galton's simple tests, at least in their original primitive form, proved to be practically useless for individual assessment. The first practically useful test for mental ability was still waiting to be invented by Alfred Binet, some 15 years later.

It was not until almost a century after Galton's failed attempt that psychologists have looked with renewed interest at Galton's ideas in search of more refined techniques for fathoming the nature of individual differences in mental abilities. One of the leading modern cognitive theorists, Earl Hunt, has stated, "We believe that Galton, not Binet, had the right approach. Measurement in science should be dictated by theory. What is needed is a better theory" (Hunt, Frost, & Lunneborg, 1973, p. 195). The statement is somewhat reminiscent of John Dalton's comment to the effect that the most important thing for a scientist is not necessarily to be right, but to have the right idea. And Galton had the right idea. But he lacked the necessary technical and statistical apparatus to make it work.

Galton's ideas about the nature of intelligence were not very formalized as a theory in the usual sense. Deeply impressed by Darwin's theory of evolution and the central role of individual variation in natural selection and "fitness for survival," Galton thought of intelligence as having developed in the course of evolution as a general, heritable fitness trait in the Darwinian sense, attaining its highest development in *Homo sapiens,* while still evincing variation between individuals and between various subspecies, or races. (One chapter

[4]Nearly all of Galton's original data had been secured by Professor Gerald McClearn, while at the University of Colorado's Institute of Behavior Genetics. Various specialists in genetics and psychometrics are in the process of analyzing the data with modern statistical techniques. The information reported here was provided by one of those who are reexamining Galton's data, Professor Ronald Johnson of the University of Hawaii.

of Galton's *Hereditary Genius* is given a title that today would surely be viewed as quite unacceptable, "The Comparative Worth of Different Races.") Galton's view of intelligence stemmed much more from his evolutionary philosophy than from the disappointing empirical findings based on his battery of sensory and motor tests. But Galton's view of intelligence was also influenced by his study of "hereditary genius," in which he found that the blood relatives of men who were eminent for their intellectual achievements showed a markedly higher probability of also attaining eminence than would be expected by chance or social advantage, and that the probability decreased in a regular stepwise fashion the remoter the degree of kinship—a pattern that Galton observed as well in the case of various physical characteristics, for example, stature and athletic prowess. From this he concluded that mental ability was inherited in much the same manner and to the same degree as physical traits. The fact that eminent relatives in the same family line were often eminent in quite different fields of endeavor (for example, mathematics, literature, and music) was seen by Galton as supporting his idea that mental ability, or at least its hereditary component, is a *general* ability that can be channelled, by circumstance or interest, into any kind of intellectual endeavor.

Thus, Galton's conception of intelligence can be summarized as innate, general, cognitive ability. The specification *cognitive* is intended to distinguish it from the other two aspects of the Platonic triarchic division of mind—the affective and conative. Because Galton thought the inheritance of general ability followed the same laws as physical inheritance, and because Galton found that individual variation in physical traits, such as stature, was distributed approximately in accord with the Gaussian, or normal, bell-shaped distribution, he assumed that the same type of distribution held also for general ability. He thereby scaled genius and lesser levels of ability on a graded continuum by dividing the baseline of the normal curve into 18 equal intervals. Galton's conception of ability as a perfectly continuous trait, aside from the assumption of a normal distribution, represented a break with the typological thinking of his contemporaries, who viewed genius and mental deficiency as distinct types, separate from the general run, rather than as the upper and lower extremes of the continuous distribution of a single trait. The ideas of the continuity of traits and of the normal curve have had a profound and enduring influence in differential psychology and psychometrics.

Galton also recognized the existence of special abilities, such as linguistic, mathematical, memorial, and artistic, although he regarded them as of secondary importance, believing that general ability was the primary factor in all intellectual achievements, though it is more important in some types of achievement than in others. In *Hereditary Genius* (1869), he stated,

> Numerous instances recorded in this book show in how small a degree eminence can be considered as due to purely special powers. People lay too much stress on apparent specialities, thinking that because a man is devoted to some particular pursuit he would not have succeeded in anything else. They might as well say that, because a youth has fallen in love with a brunette, he could not possibly have fallen in love with a blonde. As likely as not the affair was mainly or wholly due to a general amorousness. (p. 64)

Thus Galton replaced the doctrine of mental faculties by the formulation of mental ability as consisting of a *general ability* and a number of *special abilities*. It is apparent today that virtually none of Galton's theoretical ideas concerning mental ability—the hypothesis of general and special abilities, the normal distribution and inheritance of general ability—were rigorously tested or established scientifically by Galton's own researches, which fall far short of the methodological requirements for attaining that goal. Nevertheless, most of the key research questions that presently occupy contemporary researchers in this field stem directly from Galton. It is doubtful that anyone else has had a greater influence on our theories of intelligence, although Binet unquestionably had the greater influence on the measurement of intelligence for practical purposes.

Galton's methods were introduced to America by James McKeen Cattell (1860–1944). Cattell (who was no relation to the contemporarv psychologist Raymond B. Cattell) was the first American to earn a Ph.D. in psychology under Wundt, in 1886. In 1888, he spent a postdoctoral year in England and worked with Galton, whom Cattell greatly admired, later referring to Galton as "the greatest man whom I have ever known" (Cattell, 1930). Cattell coined the term *mental tests* (in 1890 in the British journal *Mind*) in reference to Galton's battery of techniques for measuring various sensory acuities and reaction times. In 1891, he founded the psychological laboratory at Columbia University and headed the psychology department there for 26 years. He early on emphasized research on individual differences along Galtonian lines. But his own research with "mental tests" of the Galtonian "brass instrument" variety and, in particular, a study published in 1901 by one of his Ph.D. students, Clark Wissler (1870–1947), led to the early demise of Galtonian methods of mental testing in America.

Wissler, working in Cattell's lab, administered to between 90 and 252 Columbia College undergraduates a battery of Galtonian tests measuring various simple sensory and motor capacities, discrimination, short-term memory, color-naming speed, and simple visual and auditory reaction time, as well as several physical measurements. These simple measures were correlated with class standing and grades in classics, foreign language, and mathematics courses, which were assumed to reflect individual differences in general mental ability, or intelligence. Pearsonian correlations were calculated between each of the "mental tests" and the academic criteria. It was the very first use in psychology of the product-moment coefficient of correlation, invented in 1896 by Karl Pearson (1857–1936), protegé of Galton. Few of Wissler's correlations significantly exceeded zero. Unfortunately, Wissler's results, interpretation, and conclusions largely reflected psychometric and statistical naiveté. With the clarity of hindsight, modern students can easily see that the deck had been strongly stacked against finding significant or substantial correlations. Each test score was based on an average of only three to five measurements, which we now know would result in exceedingly low reliability; the "range of talent" was very restricted in this highly selected group of Ivy League students, a fact that greatly attenuates correlations; and the reliability and validity of course grades as a measure of intelligence leave much to be desired. (The best present-day IQ tests generally show correlations of less than .50 with grades in selective colleges.) Wissler's and Cattell's disappointing results, coming from the most prestigious psychological laboratory in America, cast a pall over the whole Galtonian approach to studying individual differences in abilities. Galton's methods might have survived this blow and been developed further, however, had it not been for a momentous development in France, just 4 years later.

Alfred Binet

Binet (1857–1911) was France's greatest psychologist, an investigator of remarkably broad interests, insight, and ingenuity.[5] Trained in experimental and physiological psychology, as well as in medicine, Binet was the first major figure in our field of interest who could be called a clinical psychologist, who thought and acted like a clinician in the best sense of that term. All his predecessors perceived themselves either as philosophers or as natural scientists. Binet was not a strong theorist, and he developed no formal theory of intelligence; but his numerous writings afford a fairly clear impression of his conception of intelligence, and his methods of developing the first practically useful intelligence test have provided many followers, as well as critics, grist for theoretical inference about the nature of intelligence as conceived by Binet.

Binet was already eminent when he was drawn to the study of intelligence. The story is well known, how he and his co-worker, Théodore Simon (1873–1961), a psychiatrist, were commissioned in 1904 by the Minister of Education, to devise a practical, objective means for assessing mental subnormality in primary school children. Contrary to some of the later lore that has grown up about Binet, largely through the interpretations of American followers who wished to sharpen the contrast between Binet and the Galtonian school in Britain, Binet, in fact, greatly admired and was profoundly influenced by the British evolutionists Darwin, Spencer, and above all, Galton. The idea that Galton and Binet were at opposite poles is false, although their disciples have often been at odds. Binet accepted Galton's idea of intelligence as a general ability that enters into "nearly all the phenomena with which the experimental psychologist has previously concerned himself—sensation, perception, memory, as well as reasoning," and Binet also distinguished special abilities, which he termed "partial aptitudes" (Binet & Simon, 1905a). Binet was also a hereditarian regarding the basis of individual differences and claimed that his intelligence scale was expressly devised to reflect innate differences, in contrast to "pedagogical scales" that measure specifically educational attainments (Binet & Simon, 1905b).

It was when Binet actually set about devising a test of intelligence that he became truly innovative, taking a quite different approach from the one suggested by Galton. Binet was well informed of the unimpressive results obtained using the Wundtian and Galtonian "brass instrument" techniques of measuring simple processes as a means for assessing intelligence.

In looking around for more promising measures, Binet was impressed by a new sentence completion test devised by the German psychologist Hermann

[5] The best account of Binet's life and work is the biography of Binet by Theta H. Wolf (1973).

Ebbinghaus (1850–1909), who is best remembered for his experimental studies of verbal learning and memory. The completion test consisted of sentences with missing words that the subject had to fill in with words selected so as to make good sense of the incomplete sentence. This was probably the first successful test of higher mental abilities; it quite clearly discriminated between primary school pupils when they were classified by their teachers as being good, average, or poor in scholastic standing. (A sentence completion test is still in use today, for example, as part of the well known Lorge-Thorndike Intelligence Test; and it generally shows a higher correlation with the total IQ than any other type of subtest.) Ebbinghaus emphasized the importance of complexity of a task's cognitive demands as being essential for the assessment of the higher mental functions thought of as intelligence. Complexity thus became a key idea in Binet's effort. He abandoned Galton's and Cattell's simple sensorimotor tests (except Galton's test for discriminating weights) and devised instead a large number of single-item "tests" based, not on laboratory apparatus, but on brief tasks children could perform with such commonplace things as pencil, paper, coins, blocks, pictures of familiar objects, and the like. Each task posed a problem involving attention, adaptability, memory, judgment, reasoning, or some common item of information.

Binet's most original contribution was the concept of mental age as a device for selecting and scaling items so as to permit a meaningful interpretation of the child's performance. As it was obvious to Binet that children's mental capability increases with age, he used age as a criterion for selecting and grading his test items. By calibrating items in terms of the percentage of each normative group of children sampled at one-year age intervals from age 3 to 15 years who passed the item, it was possible to express a child's raw score (i.e., number right) on the whole battery of items in terms of mental age. A 6-year-old who got as many items right as the average 8-year-old, for example, would be said to have a mental age of 8 years. It was the German psychologist, William Stern (1871–1938), who suggested dividing the child's mental age (MA) by his chronological age (CA) in order to express his *relative* standing, in comparison with other children, in rate of mental development. The ratio of MA/CA (× 100, to remove the decimal), was termed the "mental quotient" by Stern, and was later translated by Lewis M. Terman (1877–1956) as "intelligence quotient," or IQ. The Binet-Simon intelligence scale, consisting of a graded series of heterogeneous items, was the prototype of virtually all subsequent tests of intelligence down to the present time.

Binet never attempted to develop a consistent or unified theory, or even a formal definition, of intelligence, but from his voluminous writings one can discern Binet's implicit conception of intelligence. This effort, however, may be a bit like describing a Rorschach inkblot, with different writers emphasizing different aspects of Binet's rather unsystematic views. Those aspects of Binet's ideas about intelligence that show the least similarity to the Galtonian and British lines of thought have been the most emphasized by Binet's followers in America. Although at times Binet writes of intelligence as a general ability, at other times he emphasizes its heterogeneity, which seemingly (but mistakenly) justifies the heterogeneous item content of his test. General intelligence, in Binet's thinking, is not a single function, but the resultant of the combined effects of many more limited functions, such as attention, discrimination, and retention. In his later writings, he put greater emphasis on the more complex mental functions—logical processes, comprehension, judgment, and reasoning—as the *sine qua non* of intelligence. He argued that intelligence could be measured efficiently only by using a great variety of items that "sample" these higher processes. As Tuddenham (1962) has aptly put it: "Regarding intelligence as a product of many abilities, Binet sought in his tests to measure not an entity or single dimension—'general intelligence'—but rather an average level—'intelligence in general'" (p. 489).

Tuddenham's characterization of Binet's view probably represents the prevailing conception of intelligence among the majority of American psychologists and especially among clinical psychologists. But there are also serious theoretical and psychometric problems with this Binetian view, as first pointed out by the first really important theoretical successor to Galton, Charles Edward Spearman (1863–1945). The question of whether intelligence is a unitary process or is a resultant of the complex interaction of a great many different, more specialized processes is one of the chief issues of contention by contemporary theorists. But before bringing in Spearman, who begins a whole new line of investigation, this would seem the right place to mention Binet's main intellectual heirs in America. There is not much that needs to be said about them in the present context, however, because, like Binet, they were mainly applied psychologists and test developers, rather than major theorists of intelligence.

The Binet-Simon Intelligence Scale was translated into English and introduced to American psychology by Henry H. Goddard (1866–1957), a leading researcher on mental retardation. Ironically, although Goddard was impressed by the usefulness of Binet's test in his research with retarded children, he was actually a follower of Galton and was an ardent evolutionist and hereditarian, imbued with enthusiasm for Galton's idea of eugenics, or the improvement of the human species through genetic means. He was also the most energetic early promoter of the use of mental tests in clinics and schools in America. His contributions to theory and measurement, however, were nil.

Lewis Madison Terman (1877–1956) was the most important representative of the Binet tradition in America. As a professor at Stanford University, he translated and reworked the Binet-Simon scales, adapting, extending, and norming them for the American population, to produce the Stanford-Binet Intelligence Scale. It was first published in 1916, with revised editions appearing in 1937, 1960, and 1972.

Terman was not a very explicit or original theorist in this field; he largely echoed Binet's notions about the nature of intelligence, although he attached greater importance than did Binet to the capacity for abstract thinking as a necessary attribute of intelligence. Terman was mainly preoccupied with investigating the validity of the IQ, not only for predicting scholastic performance, but for predicting occupational and personal success in adult life as well. His truly monumental study of gifted children, published in five volumes under the general title *Genetic Studies of Genius,* had this purpose. This famous longitudinal study of more than 1,500 children selected on the basis of Stanford-Binet IQs of 140 and above (i.e., the top 1% of the school-age population) is still in progress, now under the supervision of Robert Sears and Lee Cronbach at Stanford University, both of whom, interestingly, were themselves subjects in Terman's study. Terman's intellectually gifted subjects are now in their late 60s and early 70s. The group as a whole shows much higher levels of occupational and intellectual achievements than a random sample of the general population, or even when randomly selected subjects are matched with the parental socioeconomic and educational background of the gifted group.

David Wechsler (1896–1981) followed in essentially the same tradition as Binet and Terman, mainly as an applied psychometrician and constructor of tests, rather than as a theorist or researcher on the nature of intelligence (Matarazzo, 1974; Wechsler, 1958, 1975). Wechsler is best known for the intelligence scales that bear his name: The Wechsler Preschool and Primary Scale of Intelligence (WPPSI), the Wechsler Intelligence Scale for Children (WISC), and the Wechsler Adult Intelligence Scale (WAIS). They are now the most widely used individual tests of intelligence. Wechsler was the first to abandon Binet's mental age scale, which not only seemed indefensible for the measurement of adult intelligence, but has other psychometric defects as well. (The Wechsler IQ scales are all based on standardized scores within narrow age groups of the normative population.) Wechsler conceived of intelligence perhaps more broadly than any of the formal theorists, as an aggregate or global capacity for purposeful action, rational thought, and effective interaction with the environment, a view that broadens the concept of intelligence beyond the strictly cognitive sphere into the realm of affect, motivation, and personality. Wechsler's conception was probably too all-inclusive to attract serious theoretical or scientific interest and, although it has been the favored view of clinical psychologists for half a century, it has been virtually a cipher in the theoretical development of differential psychology.

The Factor Analysts

Charles Edward Spearman

Spearman (1863–1945) was the first really major theorist of human ability. His interest was in founding an empirically based scientific theory of mental ability. Although test development and other aspects of applied psychometrics were, for Spearman, necessary for the realization of his aim, they were quite incidental adjuncts, never holding the center stage in his thinking and research. Yet he was the first important theoretical psychometrician. He presented the first clear conception of what today is referred to as "classical test theory"; he developed the modern concept of reliability, invented the correction of the correlation coefficient for attenuation, formulated precisely the relationship between the length of a test and its reliability (i.e., the Spearman-Brown prophesy formula), and derived the formula for the nonparametric rank-order correlation coefficient. But his greatest methodological contribution was the invention of factor analysis, a methodology that has developed and dominated the study of human abilities ever since it was first introduced by Spearman in 1904.

Spearman came to psychology relatively late in life. After a career as a British Army officer, from which he retired, at age 34, with the rank of major, he began a new career by earning a Ph.D. degree in psychology at the University of Leipzig, under Wundt. He then joined the psychology faculty at the University of London, and soon thereafter he was appointed successor to William McDougall as professor and head of the psychology department, a chair he held for 25 years. In terms of the importance of the topics he researched, his great originality, and his enduring influence, Spearman was unquestionably Britain's greatest psychologist. Besides his intellectual brilliance and mathematical talent, the traits that characterized his career were his clear, no-nonsense, scientific style of thinking about psychological problems and his unalloyed impatience with armchair philosophizing and speculation. This hard-nosed attitude led Spearman into conflict with much of the psychological thought of his day. In his autobiography, Spearman (1930a, p. 330) described his career as "one long fight." For the present purpose, unfortunately, it is impossible to do more than summarize Spearman's contributions rather too briefly and hence inevitably with considerable simplification. Spearman's major works, however, are still worth reading, as many of the issues he raised are still very much alive in contemporary research on intelligence (Spearman, 1904, 1923, 1927, 1930b; Spearman & Jones, 1950). Spearman's most famous book, in which he most completely explicates his main contributions, is *The Abilities of Man* (1927). It still ranks near the top of the list of "must" reading for students of individual differences. Virtually all the basic questions that continue to occupy contemporary researchers and theorists of human ability were first clearly posed by Spearman.

When Spearman began his career in psychology, the doctrine of formal faculties was the generally accepted view of individual differences in abilities. Persons differ in the powers of the many distinct "faculties" that constitute the mind, such as perception, discrimination, memory, recollection, attention, reason, common sense, language, imagination, invention, comprehension, motor control, kinesthetic sense, visualization, and so on. One theorist even listed as many as 48 distinct mental faculties, including "sense of the ridiculous."

Spearman questioned whether the numerous listed faculties were truly distinct components of the mind. Are "memory" and "recollection" really different abilities, or "imagination" and "invention," or "reason" and "comprehension"? If so, mental ability could be objectively measured only by devising special tests for each of the many faculties. But there were endless armchair debates among psychologists concerning the number and names of the faculties. Spearman saw an objective solution to this problem by the use of correlation. If two (or more) nominal faculties were claimed to be distinct, it should be possible to devise tests of each one, to administer the tests to a group of persons who show individual differences in the power of the faculties in question, and show that the measurements of the different faculties are uncorrelated.

Spearman performed this type of study with school children, using tests, examination marks, and teacher ratings on a variety of variables, including classics, French, history, geography, mathematics, "common sense," musical talent, and measures of auditory, visual, and kinesthetic (weight) discrimination. The matrix of correlations among all of these tests revealed all positive intercorrelations, suggesting to Spearman that all of the measures reflect a common factor, that is, a common or unitary source of the covariance among the variables. Individuals who scored exceptionally high on any one variable tended to score above average on all the others as well. Moreover, the correlation matrix displayed a quite regular variation among the sizes of the correlation coefficients, such that by arranging the variables in the matrix in the order of their average correlation with every other variable, the correlations displayed what Spearman referred to as a hierarchy, that is, the correlations in the matrix decreased regularly in both the horizontal and vertical directions from the diagonal, going from the upper left to the lower right corner of the matrix. It especially impressed Spearman that in this hierarchical pattern of correlations there was no clear discontinuity between the scholastic measures (classics, etc.) and the measures of musical ability and of sensory discrimination. This observation seemed to confirm Galton's notion that discrimination ability is a basic aspect of general intelligence. Spearman showed mathematically that such a hierarchical correlation matrix could be "explained" in terms of a single *factor* (i.e., source of variance) that every test in the matrix has in common. He later assigned the label *g* to this *general factor,* which he identified with general intelligence. Spearman hypothesized that every type of cognitive test measured *g* in addition to one other source of variance (besides error), labeled *s* (for *specific*). The *s* is entirely specific to a particular test (or a very narrow class of highly similar tests). This hypothesis became known as Spearman's "two-factor theory" of ability, according to which the total true-score variance (σ_t^2) on any test is expressed as the sum of two components, *g* variance (σ_g^2) and *s* variance (σ_s^2), hence $\sigma_t^2 = \sigma_g^2 + \sigma_s^2$.

Spearman invented a method, now known as *factor analysis,* but actually a rather simple forerunner of the modern techniques under this name, that made it possible to determine precisely the proportion of *g* variance in each of the variables that are entered into a correlation matrix. The square root of this proportion can be interpreted as the test's correlation with the hypothetical ability represented by *g;* this correlation between a test and a factor is commonly termed the *loading* of the test on a given factor (in this case *g*).

Much of Spearman's subsequent research consisted of determining the *g* factor loadings of numerous diverse tests. As many as 94 various tests were factor analyzed in one study (Spearman & Jones, 1950, Chap. 8). Various tests differed widely in their *g* loadings, even when the loadings were corrected for attenuation, ranging from slightly greater than zero up to .80 and above. Spearman regarded the differences in tests' *g* loadings as a basis for discovering the essential nature of *g*. He attempted to do this by comparing high and low *g*-loaded tests for their similarities and differences. The types of tests with the highest *g* loadings, he found, were those that require inductive or deductive reasoning and have a quality of abstractness. In general, the *g* loadings of tests were found to increase, going from tests of simple sensorimotor abilities, to tests of rote and associative memory, to tests involving the grasping of conceptual or abstract relationships, as typically found in verbal and figural analogies tests. Hence, Spearman characterized *g,* or general intelligence, as the "eduction of relations and correlates," that is to say, inductive and deductive reasoning. But this is merely a description of the types of tests that best measure *g;* these are tests requiring fairly complex mental manipulations in order to arrive at the correct answer. But this empirical observation can hardly be called a theory of *g*. It does not tell us what *g* is, independently of the very mathematical operations of factor analysis, by means of which we have determined the "existence" of *g* and the extent of its loading in various tests. Nor does the description of *g* in terms that characterize the most highly *g*-loaded tests tell us why even tests that involve no reasoning or conceptual content, such as pitch discrimination and choice reaction time, also have some moderate *g* loading. Spearman fully admitted that factor analysis does not, and logically cannot, permit a declaration of the nature of *g,* but can only point to those tests that measure it best. This "defining of *g* by site rather than by nature," he wrote, is a "way of indicating what *g* means . . . just as definite as when one indicates a card by staking on the back of it without looking at its face" (1927, p. 76).

Spearman (1927, Chap. 7) considered many different speculative hypotheses of the nature of *g*. He settled on the hypothesis of a unitary mental energy. This "energy" was deployed to whatever specific "engines" or brain processes were involved in different mental tasks, some tasks requiring more energy, and some less, and hence their different *g* loadings. In Spearman's view, this unitary source of energy enters into every kind of mental task, and the observed positive correlation between all tests is a result of individual differences in the amount of mental energy that people brought to bear on the tests. The specificity peculiar to different tests was attributed to localized or specific energies. "Successful action would always depend partly on the potential energy developed in the whole cortex and partly on the efficiency of the specific group of neurons involved" (1923, p. 6).

The main problem with Spearman's theory of *g* as "mental energy" is not that it is necessarily wrong, but that no means have been found to test it empirically. Theories are scientifically useful only when opposing theories can be pitted against one another in an empirical test. Thus, without an empirical means of being tested, Spearman's theory of *g* remains only speculative and problematic to this day. The *g* factor itself, however, remains secure as an established empirical phenomenon, summarizing the observation that virtually all mental tests that are scorable according to an objective standard of performance are positively intercorrelated in an unrestricted sample of the general population.

The application of Spearman's method of factor

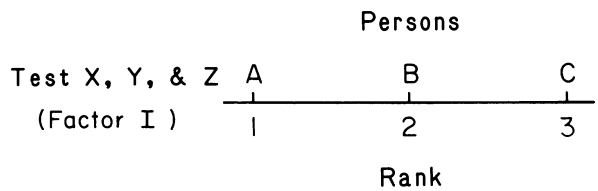

Figure 1. Representation of the rank order (i.e., 1,2,3) of three persons (A,B,and C) on three tests (X, Y, and Z) in a hypothetical one-dimensional (i.e., one factor) test correlation matrix.

analysis to a variety of test batteries by other pioneers of factor analysis, such as Sir Cyril Burt (1883–1971), as well as by Spearman and his students, soon made it apparent that the two-factor theory of ability was too simple to account for the data.[6] Spearman had proven that if only one factor, say *g*, accounted for all of the intercorrelations among a collection of tests, the correlation, r_{xy}, between any two tests, *x* and *y*, would be equal to the product of their *g* factor loadings, g_x and g_y (i.e., $r_{xy} = g_x \times g_y$). Hence, if *g* were partialled out of the correlations between tests, the resulting residual correlations should be reduced to zero. But often, this outcome would not be found; after *g* was partialled out, the residual matrix, although markedly reduced in total variance, would reveal a number of significant correlations, usually among tests of similar content, such as verbal tests, or numerical and mathematical tests, or spatial visualization tests, or tests of memory. This meant that there were actually other factors in addition to *g*, a fact that Spearman reluctantly conceded. He termed these additional factors *group factors*, because, unlike the general factor, *g*, which is loaded on every test, the other factors showed substantial loadings on only certain groups of tests. The so-called group factors could be easily named in terms of the similar features of the tests with the largest loadings on a given factor. Among the main group factors identified by Spearman were verbal, mechanical (or spatial), mathematical, and memory factors. When these group factors were viewed as residual sources of test variance, that is, the remaining reliable variance after *g* is partialled out, they usually accounted for a relatively small proportion of the total variance in test scores, as compared with the amount of variance accounted for by *g*. Thus we have a *hierarchical* factor model, in the sense that *g*, at the pinnacle, is correlated with every test, whereas each group factor is correlated with only a limited domain of tests that are quite similar to one another. In this system, *g* and each of the group factors are said to be *orthogonal* (i.e., uncorrelated) dimensions.

[6]A detailed critique of Spearman's two-factor theory and of later developments and results of factor analysis can be found in two articles by Burt (1949a, b).

To those who are not familiar with the mathematical operations of factor analysis, the idea of factors can be made less mysterious if they are thought of as *dimensions*. The question, then, is how many dimensions are needed to represent the covariation (or correlation) among a number of tests. The conceptually simplest example can be illustrated by assuming three tests, labeled X, Y, Z, given to three persons, named A, B, C. Rather than using scores, for simplicity we can simply rank these persons' performance on the tests, giving ranks 1, 2, 3. Consider the following data matrix; the correlation matrix is below.

		Person		
		A	B	C
Test	X	1	2	3
	Y	1	2	3
	Z	1	2	3

Test	X	Y	Z
X		1.0	1.0
Y	1.0		1.0
Z	1.0	1.0	

Only one dimension (or factor) is needed to describe these results; the persons show the same rank order on every test. One dimension can be represented by a straight line (see Figure 1).

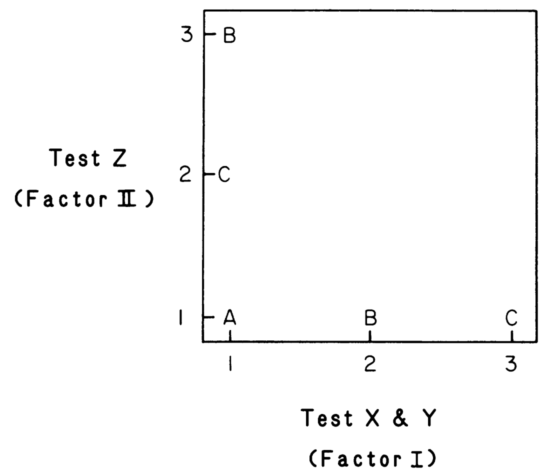

Figure 2. Representation of the rank order of three persons on three tests in a hypothetical two-dimensional (i.e., two factors) test correlation matrix.

A two-factor (2-dimensional) case:

		Person		
		A	B	C
Test	X	1	2	3
	Y	1	2	3
	Z	1	3	2

Test	X	Y	Z
X		1.0	0.5
Y	1.0		0.5
Z	0.5	0.5	

A 2-dimension space is needed to represent these data (see Figure 2).

A three-factor (3-dimensional) case:

		Person		
		A	B	C
Test	X	1	2	3
	Y	1	3	2
	Z	2	3	1

Test	X	Y	Z
X		0.5	−0.5
Y	0.5		0.5
Z	−0.5	0.5	

And a 3-dimension space is needed to represent these data (see Figure 3).

One can go on adding dimensions, although it becomes impossible to depict more than three dimensions graphically, and the geometry of *n*-dimensional space can be treated only in purely mathematical terms. The scientifically desirable economy of factor analysis as a means of describing the "structure" of a correlation matrix results from the fact that most of the covariance among a large number of tests can be accounted for in terms of a relatively much smaller number of factors, because many different tests share some of the same factors in varying degrees.

It is important to recognize just what factor analysis does and does not tell us. It tells us which tests "go together," that is, it parsimoniously describes the correlations among a number of diverse tests in terms of a limited number of uncorrelated common sources of individual differences variance, called factors, that are shared by all mental tests (in the case of *g*) or by particular groups of tests (in the case of group factors). Thus factor analysis is es-

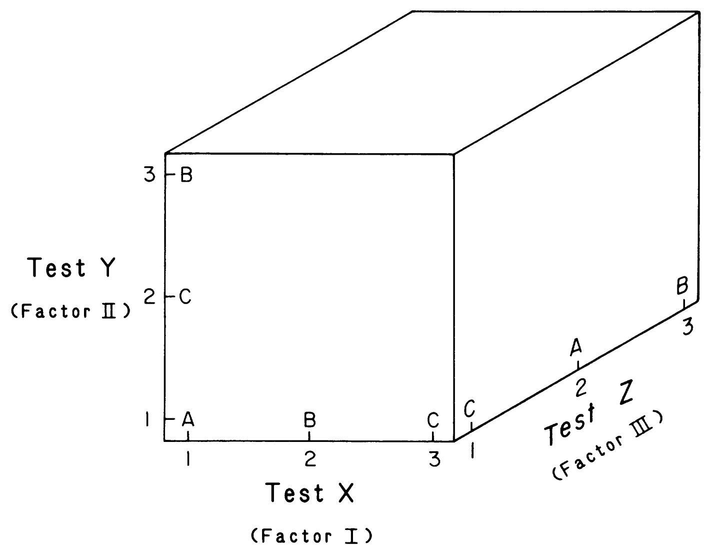

Figure 3. Representation of the rank-order of three persons in a hypothetical three-dimensional (i.e., three factors) test correlation matrix.

sentially descriptive. It is said to describe the structure of abilities. It is not an explanatory theory. It does not explain why various tests are correlated as they are, or why various tests show quite different average correlations with all the other diverse tests in a battery. Factors merely afford a systematic description of phenomena with unknown causes. Factors themselves are not the causes of anything; they are simply descriptive abstractions. The basic empirical phenomena from which factors are derived are individual differences in test scores and their intercorrelations among diverse tests. It is these phenomena, and consequently the factors to which they give rise, that are in need of scientific explanation in causal terms.

If we accept *g*, the largest common factor, as a working definition of intelligence, then a major aim of a theory of intelligence is the explanation of *g*. This boils down to an explanation of why different tests are correlated with one another and why some tests are correlated more highly than others. As already noted, Spearman put forth a unitary or monistic explanation of *g* in terms of a hypothetical "mental energy." He hoped that future neurophysiological research would discover individual differences in some form of general neural energy in the cerebral cortex. Spearman's monistic theory of *g* as mental energy was soon challenged by rival theories.

Edward Lee Thorndike. The leading American educational psychologist, Thorndike (1874–1949) was best known for his studies of learning. But he also played a major role in the development of intelligence tests and was the first American to espouse a theory of intelligence, the elements of which were borrowed directly from his theory of learning as the formation of new stimulus–response (S–R) bonds under the influence of reward, or positive reinforcement. For Thorndike, learning was a process of "selecting and connecting"; hence his term *connectionist theory*. An individual's behavioral and intellectual repertoire was made up, basically, of innumerable S–R connections in the nervous system, the specific connections being acquired through experience in the environment. Thorndike's theory of intelligence was set forth in his major contribution to this field, *The Measurement of Intelligence* (Thorndike *et al.*, 1927), which is also one of the major classics of this field that is still rewarding to read. According to Thorndike, individual differences in intelligence reflect the number of S–R bonds that persons acquire by a given age. He hypothesized that persons differ innately in the number of potential neural connections that they possess, so that even given the same environment and experience, two individuals may differ markedly in the number of S–R bonds they can acquire, and hence they will differ accordingly in intellect.

In Thorndike's theory, the ubiquitous positive correlations between tests, and the *g* factor that can be extracted from all their intercorrelations, result from two hypothetical conditions: (a) various tests draw on different numbers and combinations of neural bonds, and (b) there is overlapping of the bonds "sampled" by different tests. Thus, according to Thorndike, there is no unitary factor, such as Spearman's "mental energy," that underlies *g*. The *g* factor, and all other factors as well, are artifacts resulting from different tests sampling common bonds. The elemental bonds themselves could be entirely uncorrelated, differing only in their quantity from one individual to another. A person's score on an intelligence test represents an average of all the particular connections tapped by the test items.

Spearman (1927, Chap. 5) termed this kind of theory "anarchic." He argued that it was a scientifically inadmissable basis for the measurement of intelligence. Taking an average of what he termed a "hotchpot" of test items, which was the method of the Binet tests, for example, did not meet essential criteria of scientific measurement. How could one claim that any given item or class of items measured intelligence? What rational basis is there for giving all types of items equal weight in the composite average? Should memory items and reasoning items be weighted equally? Questions such as these could be debated endlessly or decided arbitrarily. Factor analysis provided an objective means for dealing with them. The fact that "hotchpot" tests such as the Binet and Wechsler scales actually turn out to be quite good measures of intelligence, or *g*, and show substantial correlations with real-life, commonsense criteria of intelligence is explained by Spearman's principle of "the indifference of the indicator" of *g*. Because every kind of mental task involves *g* to some extent (in addition to any other more specific factors), the larger and more diverse that the collection of tasks is, the greater is the cumulative proportion of *g* variance relative to the variance attributable to the many task-specific factors, which, being uncorrelated across diverse tasks, cancel each other out, so to speak. Hence the summed scores over a wide variety of tasks may represent a rough approximation to the measurement of *g*.

In the early days of factor analysis, a great deal of argument was wasted on the question of whether *g* did or did not "exist." The answer now is clear: certainly *g* exists as a product of the factor analysis of any sizable collection of diverse mental tests.[7] The fact that a very substantial *g*, in the sense of proportion of total variance accounted for, is found in virtually any sizable collection of diverse tests, and that the *g* is highly similar for different collections of tests, provided each collection is reasonably diverse in form and content, is a fundamental and important empirical discovery.

The crucial issue that remains worth considering is the question, What causes *g?* That is to say, what are the mechanisms or processes, entirely independent of factor analysis, that could explain the positive intercorrelations among individual differences in performance on virtually all mental tasks and hence make possible the extraction of a predominant *g* factor from any large collection of mental tasks? To argue, as do some psychologists, that because *g* is a mathematical abstraction, it cannot be thought of as having a cause, is fallacious, in that it fails to take account of the fact that a *g* factor need not be found at all. If all mental tasks involved only specific abilities, no *g* factor could emerge by any method of factor analysis, and persons' scores on tests would vary solely as a function of the particular collection of tasks (or items) included in the test, plus errors of measurement. All the correlational evidence, however, completely contradicts this possibility. But this fact alone cannot prove that the *g* factor has a single or unitary cause. The *g* factor could be explained, as did Thorndike, by hypothesizing a multitude of independent components (S–R bonds, neural elements, or whatever) of ability, a number of which are necessarily sampled by any task, and a larger number being sampled by the more complex tasks. Indeed, it is observed that complex tasks are more highly correlated with one another than simple tasks are correlated with one another. This is just what one would predict from the hypothesis that complex tasks sample more elements than do simple tasks, and therefore increase the proportion of overlapping elements between the tasks. It could also be argued equally well that more complex tasks are more *g* loaded because

[7]By far the most profound and sophisticated discussion of the logical and metaphysical status of the mental factors yielded by factor analysis that I have found is in *The Factors of the Mind* by Burt (1940).

they require more mental energy. From the viewpoint of sampling theory, however, the factors revealed by factor analysis really describe the characteristics of tests rather than factors of the mind. Although "sampling theory," as it later came to be known, originated with E. L. Thorndike, it was formalized mathematically by the British psychometrician and educational psychologist, Sir Godfrey H. Thomson (1881–1955), who had spent a year (1923–24) at Columbia University working with Thorndike. Thomson's (1951) "sampling theory" of *g* was seen as a challenge to Spearman's "mental energy" theory. It has gained considerable popularity among psychometricians, especially in the United States. Although the "sampling theory" has been around since at least 1914, when first introduced by Thorndike, it has never given rise to any empirical research that could put it to a significant test. Its appeal is entirely intuitive. The typical criticism of Thorndike's and Thomson's sampling theory has been cogently expressed by Jane Loevinger (1951):

> The sampling theory hardly qualifies as a true theory, for it does not make any assertion to which evidence is relevant. Perhaps the large number of adherents to this view is due to the fact that no one has offered evidence against it. But until the view is defined more sharply, one cannot even conceive of the possibility of contrary evidence, nor, for that matter, confirmatory evidence. A statement about the human mind which can be neither supported nor refuted by any facts, known or conceivable, is certainly useless. Bridgman and other philosophers of science would probably declare the sampling theory to be meaningless. (p. 595)

Louis L. Thurstone. The leading American psychometrician and factor analyst, Thurstone (1887–1955) developed a method of "multiple factor analysis" (Thurstone, 1947) that facilitated the extraction of a number of factors from a correlation matrix of numerous diverse tests, and along with it he proposed an objective criterion for the "rotation" of the factor axes that he called *simple structure,* intended to yield psychologically interpretable factors. Rotation of the factor axes to the simple structure criterion maximized the loadings of certain tests on particular factors and minimized the tests' loadings on other factors, making it relatively easy to describe the various uncorrelated factors in terms of the particular tests on which they had the largest loadings. Ideally, each factor would load only on certain tests and each test would be loaded on only one factor, in which case it could be called a "factor pure" test.

Applying his method of multiple factor analysis to large batteries of tests, Thurstone (1938) extracted a number of factors that he termed *primary mental abilities:* verbal fluency, verbal comprehension, numerical, spatial, reasoning, perceptual speed, and associative memory. There was no *g* factor in this structural model of abilities, for the simple reason that the criterion of simple structure mathematically precludes the extraction of a general factor. This limitation of Thurstone's method became a point of considerable contention between British and American psychometricians. The appropriateness of the simple structure criterion in the domain of human abilities was soon challenged. It was noted that a good simple structure could not be achieved with orthogonal (uncorrelated) factor rotation; allowing oblique rotation of the factor axes, so that the axes were at less than right angles and were thus oblique, or correlated, factors, permitted a much closer approximation to the ideal simple structure. Thurstone himself resolved the conflict with Spearman. By factor analyzing the intercorrelated primary factors, Thurstone showed that the *g* factor emerged as a second-order factor, or superfactor. Thurstone's method of multiple factor analysis with orthogonal rotation to simple structure had merely scattered the large *g* factor among the so-called primary factors. When Eysenck (1939) reanalyzed Thurstone's correlation matrix of more than 50 diverse tests, using a method of factor analysis that allows the appearance of a general factor and various group factors, he found that the *g* factor accounted for more of the total variance in all the tests than the variance accounted for by all of the remaining group factors combined. In fact, it has proved impossible to construct factor-pure tests of Thurstone's primary mental abilities that do not also measure Spearman's *g,* and usually each test is more highly loaded on *g* than on the primary factor it was specially devised to measure. At best, so-called factor-pure tests measure *g* plus the one primary factor they were devised to measure.

Contemporary Theorists

The two leading contemporary factor analysts of the abilities domain are Joy Paul Guilford (b. 1897) and Raymond Bernard Cattell (b. 1905).

Guilford (1959, 1966, 1967, 1977) has proposed a complex scheme, or "facet" model, for the classification of abilities that he has called the Structure of Intellect (SOI) model. The hypothetical abilities of the SOI model represent the intersections of 5 different mental *operations* (cognition, memory, divergent production, convergent production, and evaluation) × 5 different types of *contents* (visual, auditory, symbolic, semantic, and behavioral) × 6 different types of *products* (units, classes, relations, systems, transformations, and implications), making for 5 × 5 × 6 = 150 abilities in all. Guilford regards each of the SOI abilities as unique, or factorially distinct from all the others. The SOI model thus suggests a possible 150 types of tests, and from year-to-year new tests are reported as having been devised to measure still a few more of the abilities suggested by this model. The number of such tests must now exceed 100. If all these tests were subjected to a type of factor analysis that does not mathematically prohibit the extraction of a general factor, it seems virtually certain that a large *g* would emerge. Yet the SOI does not admit a *g* factor. A model with 150 hypothesized unique abilities, however, is actually beyond the reach of factor analysis for all practical purposes, and so the 150 abilities have not come anywhere near being substantiated by factor analysis. The testability of the SOI model poses such staggering problems that it seems unlikely that it will ever be able to face the challenge of empirical verification (Undheim & Horn, 1977). Scientifically, the SOI model has not really advanced beyond a purely formal system (one of many possible rational systems) for the generation and classification of mental tests. Although Guilford's SOI is apparently a quite comprehensive and fine-grained system of categories into which an extremely great variety of tests may be classified, it is highly arguable whether it actually tells us anything about the nature of intelligence. It completely evades the central question: Why are all tests correlated with one another, thereby giving rise to *g?*

Cattell (1963, 1971) has distinguished two aspects of *g*, which he has termed fluid (g_f) and crystallized (g_c). Tests based on specific knowledge and cognitive strategies acquired prior to taking the test, such as general information, vocabulary, arithmetic, scholastic knowledge and skills, and the like, are most heavily loaded on the g_c factor. Tests with little or no knowledge content but that depend on short-term memory for novel material presented in the test situation (e.g., digit span memory) and novel problem solving involving reasoning about figural materials (e.g., figure analogies, matrices, series completion) are the most heavily loaded on the g_f factor. People reach their peak power on g_f in their late teens or early twenties, whereas g_c gradually increases until old age, provided persons are not entirely cut off from experiences that afford opportunities for new learning. The g_c factor can be interpreted as reflecting the knowledge and skills acquired through the individual's investment of g_f in specific forms of learning and experience. Consequently, individual differences in g_f and g_c will be more or less highly correlated depending on the degree of similarity in people's educational experience and in the cultural values that influence the types of experience in which g_f will be invested. The correlation between g_f and g_c again yields the superfactor *g*. Recent studies (Gustafsson, 1984; Undheim, 1981) based on a hierarchical type of factor analysis of collections of tests well representative of fluid and crystallized abilities suggest that g_f is "absorbed" into the *g* (a "neo-Spearmanian" *g*) at the top of the factor hierarchy; that is, when *g* is partialled out of g_f, the residualized g_f is reduced to zero, and hence it is concluded that g_f is the same factor as Spearman's *g* (or vice versa). The g_c factor remains as one of two or three second-order factors in the hierarchy.

In contrast to the factor analytic school, a quite different approach, clinical and qualitative, to the study of intelligence was taken by the noted Swiss child psychologist Jean Piaget (1896–1980). In his major work on this subject, Piaget (1950) viewed intelligence as a biological process of adjustment between the conscious organism and its physical and social environment. The term *intelligence* indicates the forms of organization or equilibrium by which the organism cognitively structures its sensory and motor experiences. The complexity of the cognitive structures increases and changes qualitatively through different stages of the child's mental growth. Piaget's descriptions of the stages of mental growth developed from his observations of children when confronted by various problems cleverly devised by Piaget to reveal the "logic" of children's thinking at different stages of their mental development. Briefly, Piaget viewed the mental development of the child as going through four main stages, which are invariant in sequence for all children: (a) the *sensorimotor* stage (onset from birth to about 1 year) is the first phase of intellectual development, in which knowledge and thought are intimately tied to the content of specific sensory input or motoric activity of the child; it includes conditioning, stimulus–response learning, reward learning, perceptual recognition, and associative or rote learning and memory. (b) The *preoperational* stage (onset ages 1 to 2 years) is a transitional period between the sensorimotor stage and the next stage and is mainly characterized by symbolic play and cognitive egocentrism, that is, the child in this stage can view objects and relationships only in terms of his own relation to them. (c) *Concrete operations* (onset 6 to 7 years) is the first stage of what Piaget called operational thinking, which characterizes his view of intelligence. It involves the capacity for performing mental operations on concrete objects, such as numeration, seriation, and classification or other forms of grouping, and the ability to conceive the invariant structure of classes, relations, and numbers. (d) *Formal operations* (onset 11 to 13 years) is the final level of operational thinking, manifested in logical reasoning (not dependent on the manipulation of concrete objects), propositional thinking, combinatorial and inferential thinking that involve using hypothetical possibilites, abstractions, and imaginary conditions, as well as the mental manipulations of symbols for real or experiential knowledge. The main stages are claimed to be invariant in sequence for all children, but there are individual differences in the rate of progress from one developmental stage to the next, attributable to both innate factors and environmental influences. In the light of numerous empirical studies by other experimental child psychologists, Piaget's theory of qualitatively distinct stages of mental growth has come under increasingly severe criticism and doubts in recent years (e.g., Brainerd, 1978).

Piaget's *méthode clinique,* consisting of various tasks administered individually with careful inquiry to elicit the child's thought processes, has been psychometrized, in the fashion of the Binet scale, by Tuddenham (1970), Vernon (1965), and others. When the Piagetian tasks have been factor analyzed along with a large number of conventional psychometric tests, they show quite large loadings exclusively on the *g* factor; there is no group factor that is unique to the Piagetian tasks. Thus even Piaget's quite different approach to the study of intelligence, in the final analysis, reveals essentially the same *g* factor as originally discovered by Spearman. (For a review of the relevant research, see Jensen, 1980, pp. 669–677). The behavioral manifestations of *g* are almost infinitely multifarious, and much has been written, and will no doubt continue to be written, by way of describing the many behavioral aspects of *g* throughout the course of development from infancy to old age. An understanding of the essential nature of *g,* however, would depend on approaching the problem from a different level of analysis than that afforded either by Piaget's *méthode clinique* or by the application of factor analysis to conventional psychometric tests.

Information Processing Theories

By the mid-1940s, the factor analysis of abilities had about run its course in its potential conceptual contribution to the study of human intelligence. From the viewpoint of theoretical development, the whole field went into the doldrums for nearly a quarter of a century. Strictly methodological and statistical developments and refinements in factor analysis and test theory came to occupy the center stage, whereas the substantive issues of differential psychology remained virtually at an impasse. It became increasingly clear that the factor analysis of psychometric tests alone could serve only a descriptive function and could not compel any particular structural model. Such basic questions as whether intelligence is singular or plural could not be settled by any methodology available in traditional psychometrics. The explanation of the descriptive factors yielded by the factor analysts would have to be explained by means that are entirely independent of factor analysis itself. It is important to recognize that the results of factor analysis describe individual differences in abilities rather than the abilities themselves. Abilities can show up as factors only to the extent that there is individual variation in the abilities. If there are abilities, even very crucial abilities, which everyone possesses to much the same degree, they will not be revealed as important abilities by factor analysis. Hence, not all of the operating features of the mind—call them *cognitive processes*—are necessarily revealed by factor analysis. Theoretically, all mental processes could not be revealed by factor analysis as it is traditionally used, unless it were assumed that there are substantial individual differences in all of the processes.

In the 1960s, psychologists whose chief interests were not individual differences or psychometrics, but the experimental psychology of learning, memory, and problem solving, turned to the newly developed information processing theory as a model for the intervening variables, or hypothetical constructs, needed to explain the complex types of behavior that strictly behavioristic S–R theories seemed inadequate to cope with. Information processing theory, or cognitive theory, is a "black box" approach, in which the processing of information, from sensory reception to motor response, is explained in terms of the operations of a number of hypothetical constructs termed "elementary information processes," which act in sequence (or, on occasion, in parallel) to mediate problem solving (Newell & Simon, 1972).

Because tests involving problem solving are among the most highly *g* loaded, it is not surprising that the information processing approach to problem solving was soon perceived as a promising new paradigm for the study of intelligence. Information processing research on human abilities sprang up like mushrooms in the 1970s and has since become one of the liveliest fields in contemporary psychology. Among the leading pioneers in this relatively new field that brings the information processing paradigm to bear on the problems of differential psychology on which traditional psychometric approaches had run out of steam are J. B. Carroll (1976, 1980), E. B. Hunt (Hunt, 1976; Hunt *et al.,* 1973), and R. J. Sternberg (1977, 1979). An introduction to the major developments in this approach can be found in several multi-authored books edited by Resnick (1976), R. J. Sternberg (1982a, 1982b, 1984), and Eysenck (1982a).[8]

Processing theory attempts to analyze various cognitive tasks in terms of a limited number of "information processes" (or "components" in Sternberg's theory) having the status of intervening variables or theoretical constructs that are hypothesized to execute different cognitive functions termed elementary information processes. Among the more prominently invoked processes are visual search, stimulus encoding, discrimination-comparison, scanning short-term memory, storing information in intermediate and long-term memory, and memory search and retrieval of information. Metaprocesses are those executive functions that deploy and integrate the elementary processes, direct and monitor performance, and invoke acquired learned strategies for more efficient information processing, such as chunking or grouping stimuli, use of S–R mediators and verbal mnemonics, rehearsal of associations, and the like. These hypothesized elementary information processes are operationally definable, and individual differences in them can be measured, at least indirectly, by various chronometric techniques that measure reaction times in the performance of simple tasks that are contrived to elicit certain information processes. Because the experimental tasks are usually so very simple that error rates are extremely small, individual differences must be measured in terms of reaction time (RT) or response latency, usually in milliseconds. For example, the speed of scanning for an item in short-term memory has been measured by displaying a set of anywhere from 1 to 5 digits, which the subject studies for 2 seconds. The series then disappears from the screen, and immediately a single probe digit appears. The subject responds as quickly as possible by pressing one of two keys labeled "yes" or "no," as to whether the probe digit was or was not a member of the previously presented set (S. Sternberg, 1966).

According to the information processing view, there are individual differences in the speed or efficiency of the various elementary processes and in the presence or absence of certain metaprocesses, and these differences account for the differences in performance on psychometric tests and the kinds of educational and occupational performance criteria predicted by conventional test scores. The as yet unrealized task of information processing research is to show that individual differences in the same limited number of elementary cognitive processes are indeed involved in a wide variety of superficially different kinds of test items and can thereby afford an adequate explanation of the sources of variation in, and correlations between, standard psychometric tests. The *g* yielded by factor analysis of psychometric tests, according to information processing theory, results from there being certain elementary information processes and perhaps also certain metaprocesses that are required for successful performance on virtually all test items (Sternberg & Gardner, 1982). But it turns out that measures of the elementary cognitive processes are themselves intercorrelated, and when factor analyzed they yield a *g* factor that is correlated with the *g* of psychometric tests. If the elementary processes are themselves *g* loaded, the explanation of *g* is merely passed on to another level of analysis. At the end of this reductionistic regress of *g* to more and more elemental levels of analysis, presumably, is some physiological substrate, the precise nature of which is still highly speculative. Research on the electrical potentials of the brain evoked by simple auditory stimuli

[8]A comprehensive discussion of the educational implications of information processing conceptions of intelligence, as contrasted with the psychometric and Piagetian views, is presented by Wagner and Sternberg (1984).

("clicks") while the conscious subject does nothing overtly has shown remarkably high correlations between psychometric *g* and certain indexes derived from the average evoked potential. Both Eysenck (1982b) and Schafer (1985), in independent studies, have found that the degree to which indexes of the average evoked potential are correlated with each of the 11 diverse subtests of the Wechsler Adult Intelligence Scale is directly related (with correlations of +0.90 and +0.95) to the size of the *g* loadings of each of the subscales. In other words, the Wechsler subtests with the highest *g* loadings also show the largest correlations with the average evoked potential. The specific neural mechanisms that mediate this impressive relationship between evoked potentials and psychometric *g* are not yet known and the field is wide open for theoretical speculation and empirical investigation. It is entirely possible, some would even say likely, that the basis of *g* at the level of brain physiology could be much simpler than the multifarious manifestations of *g* that we can observe at the psychological or behavioral level of analysis.

The Inheritance of Mental Ability

The correlation of *g* with measures of the brain's electrophysiological response to sensory input is surely consistent with Galton's view of intelligence as a biological phenomenon and is therefore influenced by hereditary factors. Although the belief that mental traits are inherited much as are physical characteristics can be traced at least as far back as the philosophers of ancient Greece, it was Galton who first tried to put this idea on an empirical, scientific footing. He can therefore be claimed as the founder of behavioral genetics, which is now recognized as the application of the principles and methodology of quantitative genetics to the study of individual differences in behavioral traits. The essential features of quantitative genetic analysis are seen in their present form in Galton's own work in *Hereditary Genius* (1869). Inferences concerning the relative effects of genetic and environmental factors on individual variation are based on quantitative estimates of the varying degrees of resemblance, or correlation, between relatives of different degrees of genetic kinship. Galton was also the first scientist to recognize the value of monozygotic (MZ) and dizygotic (DZ) twins for genetical analysis.

With the advent of psychometric tests and the development of quantitative genetics by Sir Ronald A. Fisher (1890–1962) and others, it became possible, using various kinship and twin correlations, to analyze the variance in any given metric trait into its genetic and environmental components. The second quarter of this century brought forth a number of now classic studies in this vein, most of them showing that a substantial proportion of the population variance in IQ, at least half and perhaps as much as three quarters, is attributable to polygenic inheritance. Consider such findings with respect to IQ as the following: the pattern of various kinship correlations rather closely approximates the pattern of correlations predicted by a simple ploygenic model; MZ twins reared apart are much more similar in IQ than DZ twins or full siblings reared together; the IQs of genetically unrelated children reared together show a much lower correlation than the correlation of full siblings reared together; the IQs of adopted children are more highly correlated with the IQs of their biological parents than with the IQs of their adoptive parents; inbred children born to genetically related parents (e.g., incestuous matings and cousin matings) show lower IQs, on average, than children born to genetically unrelated parents—a genetically predictable phenomenon known as "inbreeding depression" (Jensen, 1978, 1983). Such findings virtually defy explanation in strictly environmental terms; yet rather simple polygenic models fit these data remarkably well. The methodology and typical findings of quantitative genetic research on human abilities have been explicated in a nontechnical fashion by Jensen (1981), Plomin, DeFries, and McClearn (1980), and Vernon (1979). A more technical and comprehensive review of the evidence is provided by Scarr and Carter-Saltzman (1982).

At the same time that the early classic studies of the inheritance of intelligence were taking place, a new development, radical behaviorism, under the leadership of John Broadus Watson (1878–1958), was on the ascendance in American psychology. Watson hoped to explain all behavior, including individual differences, in terms of Pavlovian conditioning and learning. Watson's bold challenge, in *Behaviorism* (1925), to the Galtonian idea of inherited mental capacity has been often quoted:

> Give me a dozen healthy infants, well-formed, and my own specified world to bring them up in and I'll guarantee to take any one at random and train him to become any type of specialist I might select—doctor, lawyer, artist, merchant-chief, and yes, even beggar-man and thief, regardless of his talents,

penchants, tendencies, abilities, vocations, and race of his ancestors. (p. 82)

Watson's view, although usually expressed in less brash tones, became the dominant sentiment in American psychology, sociology, and cultural anthropology. The heated polemics of opposition and conflict between the hereditarian and environmental positions in all their aspects regarding the explanation of individual differences, as well as of social class and racial differences, in mental test scores and scholastic achievement have long been known as the nature–nurture controversy. The controversy, with roots going back at least to Locke's *tabula rasa* theory of the mind and the egalitarian philosophy of 19th century liberalism, has actually been fueled more by philosophical, political, and ideological values than by the intrinsic scientific problems of behavior-genetic analysis. An excellent account of the history of the nature–nurture controversy is provided by Loehlin (1984). Researchers in behavioral genetics are confronted with a quite different order of theoretical and methodological issues than those that are paraded under the popular banner of the nature–nurture controversy. The real scientific questions now are not whether genetic factors are importantly involved in human variability in mental abilities, but concern the details of the genetic architecture and its evolutionary basis, the specific nature of the pathways from genes to behavior, and the forms of interaction and covariance of genetic and environmental factors. The controversies engendered in this endeavor are of a highly technical nature intrinsic to the scientific issues, and bear little resemblance to popular hereditarian or environmentalist ideologies.

Along with the decline of interest in the theory of intelligence following World War I, there was a corresponding waning of genetic studies of intelligence. Interest in this field almost completely disappeared from the psychological scene. However, in the late 1950s and early 1960s, the increasing national concern over the quality of public education and the increasingly conspicuous inequalities in scholastic performance among different segments of the population stimulated a renewed interest in the improvability of intelligence, educability, and scholastic achievement by means of environmental interventions, especially during the crucial developmental period in early childhood. Research and action programs in this vein, made possible under the War on Poverty and the Great Society programs of Presidents Kennedy and Johnson, received a level of federal support previously unknown in the behavioral and social sciences.

Probably the single most influential publication of the 1960s, with respect to the thinking of the psychologists and educators who were concerned with bringing about greater equality of educational performance, was *Intelligence and Experience* (1961) by J. McVicker Hunt (b. 1906). A scholarly and persuasively argued work, it greatly minimized the role of genetics and strongly emphasized the effects of early environmental stimulation on intellectual development. Hunt's thesis was perceived by many as the needed theoretical rationale for innovative programs in early childhood education and compensatory education.

By the late 1960s, after such educational programs had already been in effect for several years, the evidence from various large-scale compensatory education programs and Head Start had not shown the theoretically predicted effects of markedly raising the IQs or scholastic achievements of the children these programs were specifically intended to benefit. Intellectual development and its manifestation in scholastic performance, it appeared, were not as easily alterable as the then prevailing theory led many psychologists and educators to believe. In 1969, the present writer, at the request of the editors of the *Harvard Educational Review,* prepared a lengthy critique (Jensen, 1969) of the overly extreme environmentalist theory that had engendered unrealistic expectations regarding the susceptibility of human differences in ability to psychological and educational manipulation.[9] This article, entitled "How Much Can We Boost IQ and Scholastic Achievement?" included a fairly comprehensive review of the then available research on the heritability of intelligence. Largely because the article not only revived what, since the 1930s, had become an unpopular view—that IQ differences have a genetic basis—but also because it conjectured that genetic as well as environmental factors were probably involved in the observed statistical differences between social class and racial groups, the article became widely cited and stirred up a storm of protests and criticisms and debates. Some of these events have been detailed in the Preface of *Genetics and Education* (Jensen, 1972), a volume that also contains the original article that set off all the commotion. These events also coin-

[9]A recent review of the evidence on attempts to raise IQ is provided by Spitz (1986).

cide with the beginning of what appears as a new era of scientific interest, research, and publication concerned with the theory of intelligence and the behavior-genetic analysis of individual differences. Besides many dozens of books and hundreds of articles published on these topics since 1970, and numerous research programs addressed to fundamental issues, there also now are two quarterly journals that publish research exclusively in these areas: *Intelligence* and *Behavior Genetics*. By the mid-1980s, the era of vehement controversy on these topics seemed a thing of the past. The arguments that we can expect in the future of this thriving branch of science will most likely be more the kind of intrinsic controversy that is seen as a normal and necessary aspect of every lively and developing science.

Intelligence and Education

Theories of education, of its proper aims and the means for achieving them, have been strongly influenced, implicitly or explicitly, by theories of the nature of intelligence. Throughout the history of education, theories of intelligence and of the nature of individual differences therein have ranged between polar opposites: the notion of individual differences as completely innate and immutable, and the notion of almost unlimited plasticity. The idea that individual differences in intelligence are predominantly a product of differences in the opportunities for learning and in cultural privileges afforded by the environment and, by the same token, can be markedly shaped by educational means has been a dominant theme in American educational philosophy. Yet scholastic achievement, and, by inference, scholastic aptitude, or intelligence, persistently vary over a wide range. Quite large differences are often seen even between full siblings reared together in the same family, the *average* IQ difference between siblings being 11 to 12 IQ points (after correction for errors of measurement). And these IQ differences are highly correlated with scholastic performance. IQ differences are manifested in different rates of learning scholastic subject matter, in the level of cognitive or conceptual complexity of the material that can be mastered at a given age, and probably, for all practical purposes, in the level of complexity of the material that can ever be mastered with any amount of training. Obviously, not everyone can become a Shakespeare, a Beethoven, or an Einstein, however excellent their training and plentiful their opportunities.

The ubiquity of large individual differences in pupils' performance in every type of instructional program that has ever been tried inevitably raises the question whether education should attempt to overcome or minimize individual differences so as to shape all children to similar educational goals and attainments or should itself be shaped to meet the needs of children varying widely in abilities. The preponderance of the research evidence to date inescapably supports the view that schooling, by every method of instruction yet tried, is capable of inculcating knowledge and skills, interests and attitudes, but has relatively negligible effects on the wide spread of differences in the rates of acquisition of knowledge and skill and in the levels of subject-matter complexity that can be comprehended at any given age. The problem of individual differences may well be one of those many aspects of reality that have no universally satisfactory solution from the standpoint of individual aspirations.

To the best of our present knowledge, it appears that some substantial part of the variance in IQ and scholastic achievement—probably somewhere between 50% and 70%, according to the best evidence on the heritability of IQ—is probably not subject to manipulation by strictly psychological or educational treatment. The reason for this, presumably, is that the main locus of control of that apparently unyielding variance is more biological than psychological or behavioral. At an even more fundamental level, we might ask why variance in intelligence should be so suprisingly resistant to experimental manipulation. This apparent resistance to manipulation seems less surprising if we view human intelligence as an outcome of biological evolution. Genetic variation is the one absolutely essential ingredient to enable evolution to occur. If intelligence has evolved as a fitness characteristic in the Darwinian sense—that is, as an instrumentality for the survival of humankind—it is conceivable that the biological basis of intelligence has a built-in stabilizing mechanism, rather like a gyroscope, that safeguards the individual's behavioral capacity for coping with the exigencies of survival. If that were the case, mental development would not be wholly at the mercy of often erratic environmental happenstance. A too malleable fitness trait would afford an organism too little protection against the vagaries of its environment. Thus, as humanity evolved, processes may also have evolved to buffer human intelligence from being pushed too far in one direction or another, whether by adventitiously harmful or by intentionally benevolent environmental forces.

What many contemporary educational psychologists would consider a realistic position regarding the broad implications for education of our present knowledge of intelligence can be summarized as follows. Individual differences in measured intelligence are reflected in the child's performance in school in a variety of ways: in the age at which he reaches optimal readiness for beginning classroom instruction in certain school subjects (especially reading and arithmetic), in the ease and speed with which he learns scholastic subjects under ordinary conditions of instruction, in his generalization and transfer of learning from one lesson to the next and from one subject to another, and in his ability to apply principles learned in one context to somewhat novel situations. Given other necessary conditions of learning, such as good motivation and good study habits, differences in intelligence are also reflected not only in the rate of attainment but also in the levels of mastery and complexity that are generally reached. The learning of addition and subtraction, for example, will not reflect IQ differences to as great an extent as the more complex operations of multiplication and long division, which in turn are not as discriminating as the still more complex and abstract concepts of algebra, geometry, and calculus. Similarly, penmanship and spelling ability are much less differentiated along the lines of IQ than is ability in written composition.

Despite real differences in ability, however, a diversity of appropriate instructional programs and flexibility in the age grading of school subjects can make it possible for the vast majority of children to attain at least the basic scholastic skills during their years in school.

Because mental abilities are distributed over a wide range and are reflected in differences in educability, and because most of this variability is related to both genetic and environmental factors that are not directly under the school's control, it seems a reasonable conclusion that schools and society must provide a range and diversity of educational methods, programs, and goals, and of occupational opportunities, just as wide as the range of human abilities. Equality of educational opportunity accordingly is not to be interpreted as uniformity of instructional facilities and techniques for all children. Diversity rather than uniformity of approaches holds greater promise for making education rewarding for children over the full range of abilities. The reality of individual differences should not mean educational rewards for some children and frustration and defeat for others. If the ideal of universal education is to be successfully pursued, the extent to which all children can be beneficiaries of the educational system will depend in large part on the proper recognition of individual differences.

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